The Potential of Emissions Trading to Mitigate Socio-Economic Inequality across China

A Participatory Systems Study of the Residential Electricity Sector

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Abstract

In Western academic research China is usually viewed as a homogenous entity. However, it is a vast country with significant regional differences in environmental conditions, economic development and the population's standard of living. The energy system is a reflection of the socio-economic and environmental disparities that exist between different regions. Large amounts of electricity are generated in pollution intensive coal-based power plants in the poorer inner provinces to support rising consumption in the more affluent urban centres on the East coast.

The main objective of the thesis is to examine the effect of a national carbon market on these regional differences through a qualitative and quantitative case study of the residential electricity sector. The study also aims to provide methodological insights on how to identify and evaluate alternative energy futures in a complex world. In order to cope with the uncertainty of future developments and the plethora of partly contradictory social preferences, a participatory approach is combined with the application of a system analytical toolset that considers complex system interlinkages. The empirical analysis consists of three stages: First an exploratory stage with stakeholder engagement, second a systems modelling stage simulating different carbon market scenarios and third an evaluation stage ranking of these scenarios based on public opinion.

The main empirical insight is that a price on carbon is relatively ineffective in limiting electricity demand of affluent households in the East. This is significant as increasing residential electricity usage could jeopardise the sustainability reform of the electricity sector. Another key finding from the empirical study is that the carbon market scenario ranked highest by study participants would lead to a widening gap between the inner and the Eastern regions. In such a scenario, where the energy generators shoulder most of the cost burden, the advanced economies of the coastal provinces would grow at a faster pace than the mining dominated inner regions. Scenario simulation also demonstrates that supplementary equity enhancing interventions could mitigate regional socio-economic and environmental disparities by supporting the establishment of innovative industries in China's centre.

In general, the thesis contributes to the discussion on the significance of China's current political, institutional and cultural setting for its market-led sustainability transition. By illustrating the constraints to achieve the sustainability targets anchored in the 13th Five Year Plan (2016-2020), implications are drawn from the research that are relevant for the current political process. Furthermore, the thesis highlights the importance of identifying dependencies and interactions between and within different levels of analysis to aid the understanding of a multifarious problem. To this end, it develops a bespoke methodological framework that supports the appraisal of complex situations involving divergent preferences for the solution outcome.

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List of Abbreviations

AHP	Analytical Hierarchy Processing
CCER	Certified Emission Reduction Credit
CCP	Chinese Communist Party
CCS	Carbon Capture Storage
CDM	Clean Development Mechanism
CEER	Intergovernmental Panel on Climate Change
CLD	Causal Loop Diagram
CO_2	Carbon Dioxide
COP	Conference of Parties
CP	Carbon Price
CPR	Cost Pass Through Rate
EPA	Environmental Protection Agency
ETS	Emission Trading Scheme
EU	European Union
EU ETS	European Union Emission Trading Scheme
EUA	European Emission Allowance
FiP	Scheme and Feed in Premiums
FiT	Feed in Tariff
FYP	Five Year Plan
GHG	Greenhouse Gases
HSM	Hard Systems Methodology
IBT	Increasing Block Tariff

IEA	International Energy Agency
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
JI	Joint Implementation
MCDA	Multi-Criteria Decision Analysis
MRV	Monitoring, Reporting, Verification
NAP	National Adaptation Programme
NBSC	National Statistics Bureau of China
NDRC	China Development and Reform Commission
NGO	Non-Governmental Organisation
NO_x	Nitrogen Oxide
OECD	Organization for Economic Cooperation and
PM	Particulate Matter
SSM	Soft Systems Methodology
SO_2	Sulphur Dioxide
UN	United Nations
UNFCCC	United Nations Framework Convention of Climate Change
WHO	World Health Organisation

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1 Introduction

At the beginning of the post-Mao reform in the early 1980s, China's per capita income was only one-third of that of sub-Sahara Africa. Rapid development from an agrarian society to an economy based on industry has seen double digit annual GDP growth. Hundreds of millions have been lifted out of poverty (Lin, 2017). Today, China is the world's largest manufacturer: It produces nearly half of the world's major industrial goods. Most of the global supply of steel, cement and coal originate from China. The country is also the world's largest producer of ships, high-speed trains, IT equipment and mobile phones (Kroeber, 2016).

China has recently found itself at a 'crossroads'. The main elements of the reform program launched over 35 years ago are no longer applicable for guaranteeing the country's continued growth over the next decades. The country has reached a series of critical junctures in its economic, social, political, environmental development. The economy is slowing. Traditional growth industries are in decline. Social inequality is undermining the Chinese ideal of a 'harmonious society' and environmental pollution is reaching record highs (Shambaugh, 2014).

China is facing the challenge of finding solutions to adequately address these issues without compromising its economic development and impacting people's standard of living. The central leadership has been increasingly looking to create market-based incentive systems to harness the forces of supply and demand and to channel these towards a more sustainable model for economic growth (Lacey, 2012; Woetzel et al., 2009). The introduction of market -based elements has not just been limited to the financial sector, there is also a new emphasis on using markets to facilitate China's wider economic reform to a more sustainable development model. In a move away from past command-and-control measures, market-based environmental policy instruments have been chosen by the government as one pillar of a greener and more innovative economic model (Zhang, 2016; Mol and Carter, 2006). One of the major initiatives to achieve environmental as well as economic targets will be China's carbon trading program, which is expected to expand from eight pilot market to nationwide coverage by 2018. The scheme will encompass large polluters within six emission intensive industrial sectors[1] including energy generation (Dong et al., 2016).

[1] The sectors expected to be covered by the national emissions trading scheme are (Carbon Pulse 2016):
1. Petrochemicals (Crude oil processing, ethylene)
2. Chemicals (Calcium carbide, ammonia synthesis, methanol)
3. Building materials (Clinker, plate glass)
4. Iron and steel (Crude steel)
5. Non-ferrous metals (Electrolytic aluminium, copper smelting)
6. Paper production (Pulp manufacturing, machine made paper, cardboard)
7. Electricity generation (Power, heat-power cogeneration, power grid)
8. Aviation (Civil aviation, passenger transportation, air cargo transport, airports)

Given that China is faced with enormous challenges in all three dimensions of sustainable development, economic, social and environmental, the newly adopted market-based approach to regulate carbon emissions will produce a profound impact not only on the domestic development path but also on overall sustainability at a global scale. To better understand the challenges the national emissions trading scheme (ETS) will be confronted with, China's sustainability issues and their origins are briefly explored and presented.

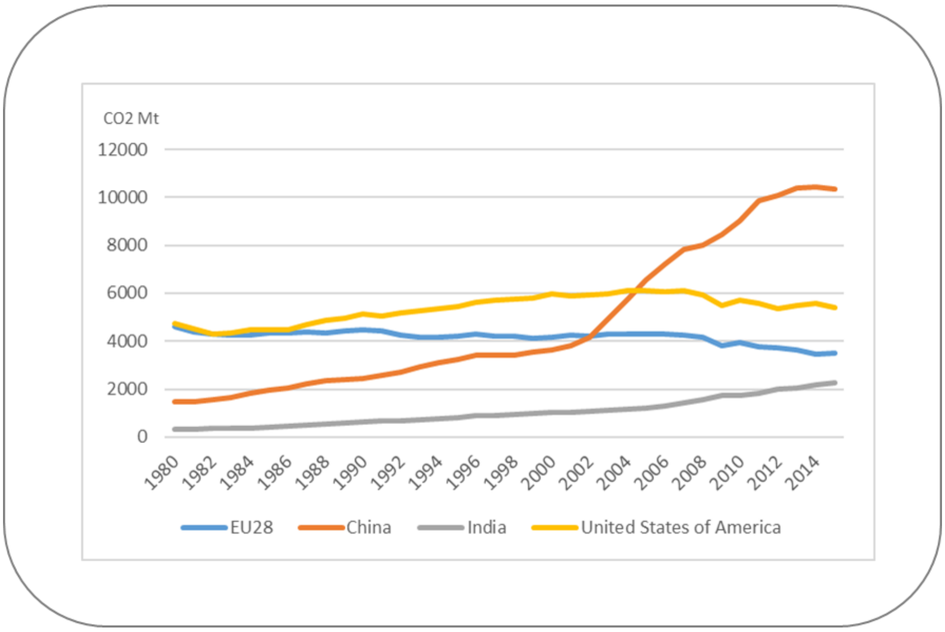
1.1 Problem Statement

The following presents the research problem in more detail. The problem statement provides an in-depth description of the issues that this research intends to investigate. It also gives contextual detail and defines the scope and purpose of this study.

1.1.1 The Status Quo - Exploring Current Sustainability Problems

People's material standard of living has improved significantly within a short order, but economic development has come at the expense of the country's environment and people's well-being. Under the Chinese government's unyielding backing of economic growth, measures dealing with the side effects of the country's rapid industrialisation, have *de facto* been secondary in the political agenda. China's environmental problems are one of the most serious challenges emerging from the country's unprecedented economic rise. China is the world's biggest polluter. As illustrated in Diagram 1.1, China has overtaken the United States as the world's largest emitter of carbon dioxide (CO_2).

Diagram 1.1 Territorial CO_2 Emissions of China, U.S., India and the EU 28 from 1980 to 2015 (Carbon Project, 2017)



China is also one of the world's regions most vulnerable to climate change impacts such as flooding and droughts (Pew Environment Group, 2011). The country's air, soil and water have been polluted to an alarming degree. Sixteen of the world's twenty most polluted cities are in China. Air pollution alone contributes to an estimated 1.1 million premature deaths annually (Dockery and Evans 2017). Life expectancy in the Northern part of the country, China's industrial heartland, is five and a half years lower than the national average because of poor air quality (Chen et al., 2013). It has been estimated that environmental degradation has cost China between three and nine percent of its annual GDP (Rhode and Muller, 2015).

The Cultural Revolution left China with a legacy of severe and pervasive poverty by the late-1970s. Since the beginning of the post-Mao reform the country has made notable progress in many areas such as eliminating hunger, achieving universal primary education and improving healthcare (Ministry of Foreign Affairs China and UNU, 2017). The poverty rate declined from 64 percent at the beginning of reform to under ten percent in 2004 (Dollar, 2007). Improved social indicators such as per capita income illustrate increased prosperity. The average per capita income has increased from US $154 in 1980 to US $6,098 in 2015 (World Bank, 2017c).

While society as a whole has become more affluent, wealth among the richest tier is growing more rapidly than in any other group (Hsu, 2016; Hoeller et al., 2014). Communist China has one of the world's highest levels of income inequality. The richest 1% of households own a third of the country's wealth. The poorest 25% of Chinese households own just 1%. China's National Bureau of Statistics documented a declining Gini coefficient[2]: from 0.49 in 2010 to 0.46 in 2015. Academic studies examining existing levels of inequality paint a different picture. Xie and Zhou (2014) calculate China's Gini co-efficient at 0.55 and Gan et al. (2013) report a value of 0.61 for 2012. According to the World Bank a coefficient above 0.40 indicates severe income inequality.

The rise in income inequality is significant. In the early reform years, around 1980, the Gini coefficient was significantly lower at about 0.3 (UN_WIDER, 2015; Gao and Riskin, 2009*)*. Among the world's 25 largest countries by population only South Africa (Gini coefficient of 0.63) and Brazil (0.53) have similar levels of inequality as China (Das and Das, 2013). Wealth inequality, which considers the total amount of assets of an individual or household, is thought to provide a more accurate picture of economic inequality[3]. Li and Wan (2015)

[2] Inequality is a normative concept that is difficult to define and quantify. The Gini coefficient provides an index to measure inequality in terms of income or wealth distribution. This allows comparison over time and between economies. The Gini coefficient provides an indication of economic inequality prevailing in a society. Income levels are an approximation of impoverishment which is typically the result of unemployment or low wage employment. Income inequality may also be caused by a failure of a government to provide a welfare safety-net for the destitute. Inequality on the Gini scale is measured between 0, where everybody is equal, and 1, where all the country's income is earned by a single person (Lamb, 2012).

[3] Income data is often considered to have too many flaws to be the primary measure of inequality. Income inequality does not account for the impact of taxes and transfer, which act to reduce inequality, as well as assets and capital gains from assets, which increase inequality (Desilva, 2015).

find that wealth inequality reached a Gini coefficient of 0.739 in 2010. They believe that increasing price of real estate and housing have been the main contributor to rising wealth inequality in recent years.

Rural-urban inequality has been well documented (Appelton et al., 2014; Whyte, 2010; Sicular et al., 2006, Kanbur and Zhang, 1999). A number of studies found that the gap between city dwellers and the population in the countryside has been narrowing in recent years as the average net income in rural areas has witnessed faster growth than that in urban areas (Zhang, 2016; Yang, 2015). One factor increasingly contributing to inequality at national level is the widening gap between regions (Xie and Zhou, 2014; Fan et al., 2011; Kanbur and Zhang, 2005). In particular inequality between coastal and inner provinces has continuously been increasing (Liao and Wei, 2016). Economic data shows that China's gross domestic product (GDP) increased nearly 17 times, and GDP per capita rose 12-fold between 1978 and 2016. Most of this growth, however, was generated by a handful of Eastern and Southern provinces (NSBC, 1980-2016; Huang et al., 2010).

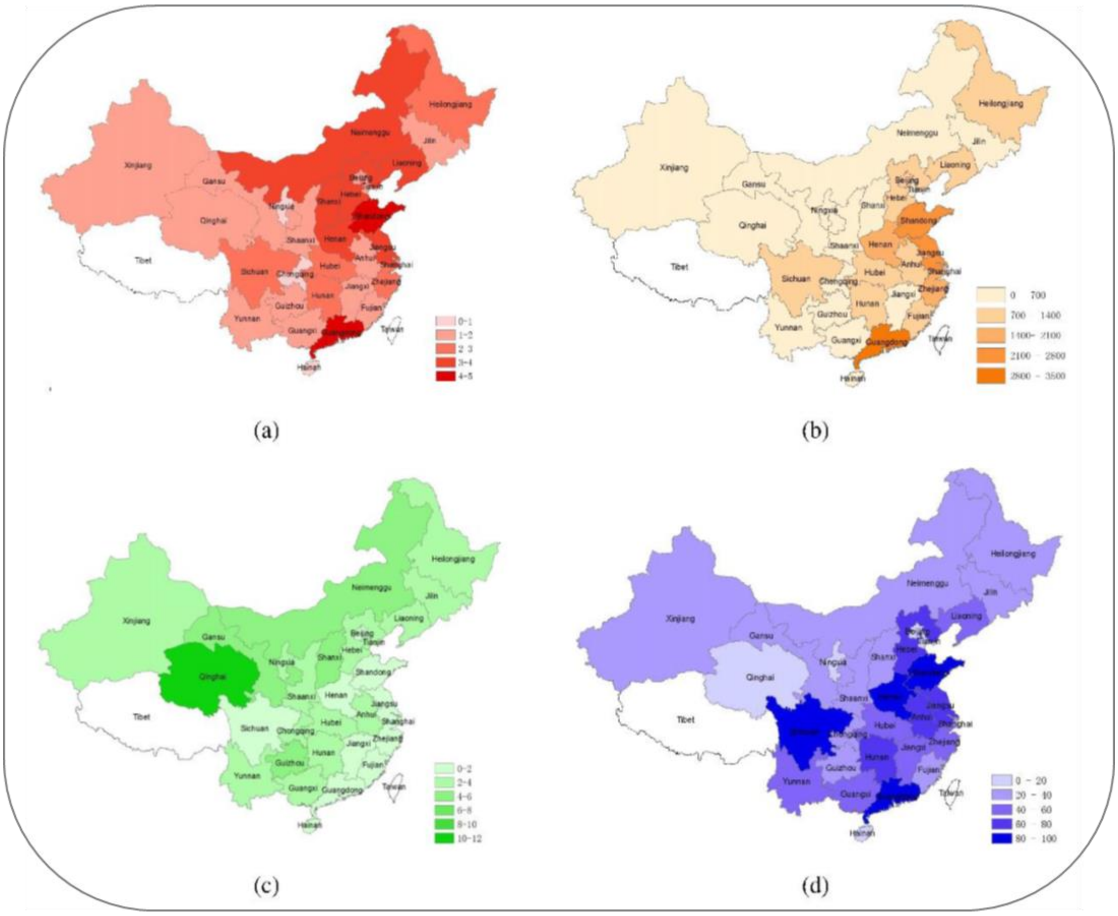
A number of studies found that regional economic inequality has become more severe compared to that at the end of the Mao era (Chen and Groenewold, 2010; Hao and Wei, 2009; Pedroni and Yao, 2006; Westerlund, 2013; Zhang and Zou, 2012). Disparities between provinces are so significant that today China resembles a collection of disparate economies at different stages of development rather than an entity (Lindner et al., 2013). According to the World Bank's classification of economic development in terms of Gross National Income (GNI)[4] per capita the provinces of Tibet, Yunnan, Gansu, and Guizhou classified as lower-middle income regions. The city states of Tianjin, Beijing, and Shanghai fall within the high income group (World Bank, 2017b).

Closely linked to economic development is the emergence of interregional carbon flows. Diagram 1.2 below illustrates the relationship between regional CO_2 emission levels and economic development at provincial level. The Eastern coastal provinces have higher per-capita GDP and higher total emissions rates but lower emission intensities than the central and Western provinces. The high standard of living enjoyed by the majority of the population on China's East coast comes at the expense of carbon intensive emissions generated with inefficient technologies in the less affluent inner regions.

Feng et al. (2012) offer an analysis of emission drivers at a disaggregated level, which reveals an imbalance in economic growth and energy consumption among different regions in China. They find that 57% of emissions are related to goods that are consumed outside of the province where they are produced and up to 80% of the emissions are embodied in goods exported to the affluent East from the less developed provinces in central and western China where many low value but carbon intensive goods are produced (see also: Meng et al., 2011; Liu et al., 2013).

[4] GNI and GDP both reflect the national output and income of an economy. The main difference is that GNI accounts for the flows in and out of the country (OECD, 2017a).

Diagram 1.2 Regional Distribution of (a) CO_2 Emission (100 MtCO2e), (b) GDP (billion RMB), (c) CO_2 Emission Intensity (MtCO2e /10,000 RMB), and (d) Population (million) across China's Provinces (Zhang et al., 2014)



To reduce disparities between different regions, the central government has launched a number of development programmes to address these imbalances. Initiatives such as the 'Great Western Development', 'Rejuvenating Northeast Old Industrial Bases', 'The Rise of Central China'[5] and most recently the 'One Belt One Road' programme have been aiming to

[5] The Western Development Strategy was the first central government-directed development program for China's western region. It passed in 1999 and implementation began in 2000. The focus of the programme was the development of infrastructure (transport, hydropower plants, energy, and telecommunications). Other programme elements included environmental protection (such as reforestation) and improved education. By 2006, a total of 1 trillion RMB was spent (Huang et al., 2010; Ma and Summers, 2009).

The Northeast China Revitalization Plan includes a number of socio-economic and environmental targets and measures, which run from 2013 to 2020. Main objective is to support traditional industrial centres to upgrade to a high technology base. The target is that by 2017 high technology industries account for 17.8% of the total production, while services contribute 45% of total output. In 2016, it was announced that a budget of 1.6 trillion RMB is allocated to revitalize the economy of the north east (CSC, 2016; Li, 2007).

The Rise of Central China Programme was announced in 2004. The goal was to transform six provinces in central China into a production base for: Grain, energy and raw materials, equipment manufacturing, and high technology. The plan also aims to develop the region into a major transport hub and supports urbanisation (Huang et al., 2010; Zheng and Cheng, 2007).

The One Belt One Road Initiative was launched in 2013, when the Chinese leadership proposed establishing a modern equivalent of the Silk Road, a network of railways, roads, pipelines, and utility grids linking China initially with Central Asia, West Asia and later with South Asia and Europe. The objective of the economic plan is to mitigate the promote deep structural changes of the economic sector in the inner and Western provinces.

Massive investment has boosted the inner region's output. From 2000 to 2015, the Western region's GDP grew by an average of 10 percent annually. The support programmes, however, have had varying effects. Significant growth in Western China was mainly limited to four major cities: Chengdu, Sichuan, Chongqing and Xi'an (Huang et al., 2010). Overall, the programmes failed to achieve their goal of eliminating the economic gap between China's East and West. Evidence from the China Statistical Yearbook confirms the widening economic gap between China's regions. The East-to-west GDP ratio increased from 2.98 in 1980 to 6.39 in 2015. Average annual incomes in the Western region remain below the national average. The economic growth rate of China's coastal provinces continues to exceed that of the West, causing the Western share of the domestic product to continue to fall. The West's contribution to the national GDP decreased from 20.88% in 1990 to 15.76% in 2016[6]. Relative levels of GDP per capita in the West decreased from 73.30% in 1990 to 60.87%. The Western region covered by the 'Great Western Development Plan' contains 71.4% of mainland China's area, but only 28.8% of its population and 19.9% of its total economic output, as of 2015 (NBSC, 2016).

The coastal provinces have thrived on an economic model based on an expanding service sector and advanced industries at the higher end, while traditional industries, mining and agriculture remain the mainstay of the economy of the inner provinces (Fu, 2008). According to studies by Fu and Zhang (2011); Crescenzi et al. (2012) and Qu et al. (2017), regional inequalities in the industrial structure and economic development are the outcome of an unbalanced innovation strategy in terms of financial and institutional support. Unless effectively addressed these disparities are set to become self-perpetuating leading to persistent disparities between provinces.

The gap between rich and poor provinces was already identified by the 17th Chinese Communist Party National Congress in 2007 as a serious issue and a potential source of political instability. Ten years on, regional disparities have become even greater challenges to social stability. The recent economic downturn has disproportionately affected China's industrial heartland and key coal regions as demand for steel and cement wanes. Protests and strikes are becoming more frequent as wage cuts and unemployment threaten people's livelihoods. The China Labour Movement (2016) recorded almost 600 incidents in 2015, three quarters of which were in manufacturing, mining and construction, the three sectors most affected by changing drivers for growth.

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impact of the economic downturn on traditional economic sector in the west by creating new markets for Chinese manufacturing industry and to help export excess cement and steel capacity. The initiative is also to boost the economies of less developed border regions such as Xinjiang by linking them with neighbouring countries (Phillips, 2017; Tian, 2016).

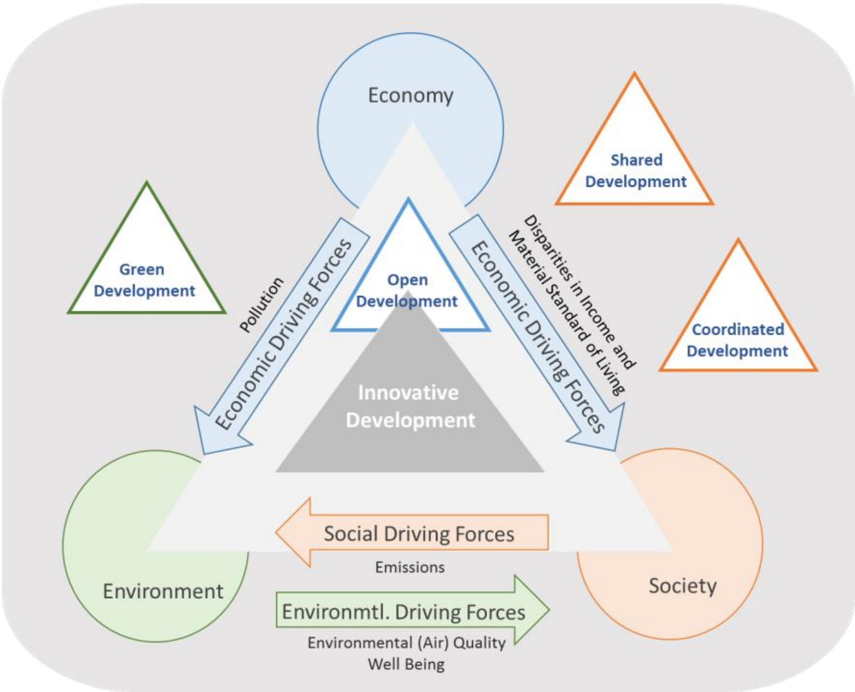
[6] According to official regional categorisation, the western region covers the city Chongqing and the provinces of Gansu, Guangxi, Guizhou, Ningxia, Qinghai, Shaanxi, Sichuan, Xinjiang and Yunnan.

As the environment deteriorates, economic growth stagnates and inequality grows, the government recognises that China could face social upheaval unless fundamental changes to the current development model are undertaken. In a departure from the traditional 'growth at all cost' model, the current Five Year Plan promotes a cleaner and greener economy, with strong commitments to environmental protection, clean energy, the development of innovative industries and the creation of an equitable society (Lyn and Wu, 2016; Rushton, 2016).

1.1.2 Understanding the Policy Response to the Sustainability Challenge

The recent Five Year Plans are a reflection of the Chinese government's intention to address pressing environmental and social issues. A Five Year Plan (FYP) is a blueprint outlining the key economic and development targets for the country over the next five years. The 13th Five Year Plan (2016-2020) includes concrete environmental and socio-economic targets (NDRC, 2016a). It emphasises the importance of economic development to reach an average GDP growth rate of 6.5-7% (down from 12% in 2012), consistent with the goal of a 'moderately prosperous society'. The current FYP is guided by the five key principles of 'innovative development', 'coordinated development', 'green development', 'open development' and 'shared development' (Zhao, 2016). Innovation as facilitator of the reform is given centre stage in China's development plan as the concept is explicitly named as the main goal as depicted in Diagram 1.3. It appears alongside the familiar objectives of green growth, shared development, coordinated development between regions and the country's opening up to foreign investment and co-operations (Lyn and Wu, 2016; Rushton, 2016).

Diagram 1.3 The 13th Five Year Plan's Vision of Sustainable Development



In line with its ‘green development’ goals China aims to achieve ‘acceptable air quality levels’ in major cities for 80% of days by the end of 2020. To meet its Nationally Determined Contribution to CO_2 reduction communicated at the 2015 Conference of Parties (COP 21) in Paris, China intends to reduce carbon dioxide emissions by 18% from 2015 levels by 2020. Total carbon emissions per unit of GDP are to fall by 60 – 65% from 2005 levels by 2030 (Kuhn, 2016). The FYP further highlights the importance of sustainable production and consumption, as well as changes to China’s pollution intensive energy mix, which has been identified as limiting economic growth (NDRC, 2016a).

To facilitate its ‘green development’ objective, the government prioritises the research and development of technological solutions to lower emissions, save energy and improve efficiency. This 13th Five-Year Plan is the first major policy document which lists innovation first in the ordering of development goals. ‘Innovative development’ is to expedite the transition of the country’s industrial base in line with the deployment of innovative and smart technologies. Internet technology is to improve the daily lives of people (NDRC, 2016a; Rushton, 2016).

The advancement of technological innovation is supported by the goal of ‘open development’. China’s commitment to opening up the country’s economy for foreign investment and for international companies to enter the market place is to support the upgrade of the economy through the deployment of foreign technology and the transfer of know-how (NDRC, 2016a).

With a major focus on ‘shared development’ the guidelines for this FYP expand the previous FYPs’ policies to create a ‘harmonious society’ and pursue ‘inclusive growth’ for all Chinese citizens by alleviating poverty, raising people’s standard of living, improving accessibility to and affordability of healthcare services, and promoting education. As part of its efforts to promote ‘coordinated development’ the differences in industrial production and consumption between the coastal and inner regions are being addressed. The FYP specially mentions the provision of support for the accelerated development of poor regions through infrastructure projects, poverty alleviation programmes as well as collaboration between the advanced and less developed regions (NDRC, 2016a; Kolesky, 2017). ‘Shared development’ also means changing China's growth drivers making the economy more consumption-led and more environment-friendly. To stimulate consumption and spending the government intends to strengthen the social-safety net (Bertoldi and Melander, 2015).

The term ‘New Normal’ is often used to describe the outcome of rebalancing the Chinese economy in the direction of sustainable growth (Hu, 2015). It entails structural changes of the current development model from the ‘Old Two’ to the ‘New Two’: From the ‘old’ economy built on domestic investment, primarily into infrastructure, and exports to the ‘new’ economy founded on innovation and knowledge, domestic consumption and an expanded service sector (Mingjie, 2016; Shambaugh, 2014; Green and Stern, 2014).

1.1.3 The 'New Normal': Source of New Unsustainability?

China's 'New Normal stage of economic development' is characterised by features never seen before. Boosting innovation and technological advancement, increasing consumption and expanding the service sector were identified as pillars of the new development model. Analyses on China's new development model suggest that economic restructuring appears to be regarded by the Chinese leadership as panacea to simultaneously address environmental and social drivers of current unsustainability.

The positive effect of an innovation and consumption based economy on environmental conditions lies at hand. Firstly, the substitution of heavy manufacturing as a source of growth with less pollution intensive knowledge based industries, services and consumption has an immediate positive effect on local environmental conditions and longer term positive effects on global warming. Secondly, the adoption of innovative solutions developed in China is expected to contribute to further lowering the pollution intensity of the economy through efficiency improvements, the installation of end of end-of- pipe technology and similar equipment as well as the replacement of coal through renewables in the energy generation fuel mix.

Technological advancement is widely associated with the accelerated growth in living standards through the increase of average household incomes. Through the so-called 'multiplier effect' rising incomes act as a driver of economic growth. This is because an injection of extra income leads to more spending, which stimulates the economy and creates more income, and so on[7]. Moretti (2010) estimates that the multiplier for employment in innovative sectors is 5 versus 1.5 in non-innovative sectors.

A closer look at China's sustainable development strategy reveals that drivers of unsustainability occurring between society and the environment appear not be addressed as efforts focus on restructuring the economy (see Diagram 1.3). The next section explores whether in the presence of this policy vacuum the achievement of the green, shared and coordinated development goals themselves could turn a consumption and innovation based economy into a driver of unsustainability jeopardising China's transition to the 'New Normal'.

[7] The multiplier effect is a key element of Keynesian macroeconomics. Keynes argued that a fiscal stimulus is more effective in stimulating growth than monetary measures. The relevance of the concept for development has been hotly debated. Empirical study suggests that a relationship between income levels and economic expansion exists (Goos et al, 2015; Marchand, 2012; Moretti 2010).

The size of the effect is determined by consumers' propensity to save. For example, if consumers spend \$0.8 and save \$0.2 of every \$1 of extra income, the multiplier will be: 1/0.2=5. A multiplier of 5 means that every \$1 of new income generates \$5 of extra income (Rittenberg and Tregarthen, 2009).

1.1.3.1 Restructuring the Economy towards the 'New Normal': Innovative Development and Green Development

The first pillar of the new development model is the expansion of the innovation sector. The overarching objective is to shift the main source of economic growth away from heavy manufacturing to industries at the higher end of the value chain. The country has felt the pressure of diminishing returns in its traditional industries due to over-investment leading to surplus capacity. A shrinking work force and rising wages are driving production costs gradually eroding China's export competitiveness (Zhu and Kotz, 2011). China's leadership agreed that deeply rooted change to transition the economy is required to avoid a further slow-down of the economy (Hilton and Kerr, 2017). Policy makers have formulated plans to promote industrial upgrading and indigenous innovations. This way, the establishment of a (skills and labour intensive) 'green innovation system' could provide China with a stepping stone to 'leap frog' onto a sustainable development path (Tourk and Marsh, 2016). The country could so escape the 'middle income trap'[8] (Cai, 2012) and become a high income and less pollution intensive developed economy.

It has been wildly acknowledged that innovation drives productivity growth (Aghion et al., 2015). Whilst being a driver for economic expansion, the effect of innovation on society in China seems to be ambiguous. While some industries such as the technology sector may benefit from the transition towards a low-carbon economy, other industries are likely to experience a decline. Economic data suggests that traditional sectors such as coal, cement, and steel are expected to further contract. Most affected are the people whose livelihoods are depended on employment in these industries. The work force will inevitably face further job losses in the future, should the government press ahead with the transition of China's economy (Fan, 2016; Prasad, 2015).

To better understand potential consequences of pursuing an economic strategy relying on an expanding innovation sector for growth, research on the topic was consulted for guidance. Some studies link innovative economies to high levels of income inequality (Acemoglu et al., 2012). Other research finds that a growth model based on innovation has a mitigating effect on inequality (Hopkin et al., 2014). A closer and more differentiated look at these studies reveals that the time frame of the research and the development stage of the region under investigation appear to influence the effect on society. High levels of income inequality are common in emergent innovative economies. During the early stages of transitioning from an economy typically based on manufacturing to one based on creativity and innovation financial benefits are captured by those who generate them. Benefits of innovation are shared broadly across society over time as they diffuse through the economy (Aghion et al., 2015).

[8] The term middle income trap usually refers to countries that have experienced rapid growth typically through the competitive advantage of low labour costs. These countries quickly reach middle-income status, but then fail to catch up to developed countries. Their economies stagnate as the original advantage breaks away, i.e. when average income levels rise (Glawe and Wagner, 2016).

Through the process of new industries replacing old industries innovation fosters upward social mobility as a result of 'creative destruction', a concept conceived by Schumpeter (1934). By forcing existing industries out of the market space (Scherer, 1986; Fankhauser et al. 2013; Kivimaa and Kern, 2016) the process of 'creative destruction' creates opportunities for new innovative businesses. Creative destruction may so facilitate economic transition and growth at a national level over time. Nonetheless, it is important to understand, how individual workers are affected. The creation of highly paid employment opportunities provide a better standard of living for those with a specialised skill set. The effects of the process on those who are being displaced and made redundant in the traditional sectors, however, may be detrimental. Real life experience of economies that have completed the transition suggests that technological change per se is not democratic. Income is being redistributed to entrepreneurs and those who possess the skills that are required by an expanding innovative sector (Komlos, 2016).

The so-called 'rising tide hypothesis' or 'trickle -down effect' (Stiglitz, 2015) captures the notion that inequality at the early stage of economic development is a necessity for growth. The strategy of deliberately widening the gap between the coastal and central regions was adopted by the Deng Xiaoping leadership in the early reform years. In 1988, Deng Xiaoping announced that "The coastal areas, which comprise a vast region with a population of 200 million, should accelerate their opening to the outside world, and we should help them develop rapidly first; afterward they can promote the development of the interior" (Deng, 1988). However, the spill-over effect from the coastal provinces to inland areas has not happened as anticipated. As explained above, regional disparities persist to this day. Past government programmes were not effective in restructuring the economies of the inner provinces (Zheng and Chen, 2007; Sun et al., 2015).

The long term effect of an economic transition on livelihoods varies with a society's inclination to redistribute wealth from the rich to the poor, from those in highly salaried employment to those who are poorly paid or have no employment at all. The majority of studies conducted in the United States found that earning and employment losses of displaced workers have remained large and persistent since the decline of the traditional manufacturing industry (Acemoglu et al., 2012; Komlos, 2016). The failure to redistribute wealth could explain the high levels of income and wealth inequality in the U.S. relative to other Western economies. In European countries with well-developed social welfare systems such as the Scandinavian nations, the effect of industrial restructuring on the work force is mitigated through the provision of benefits and the availability of supplementary programmes such as retraining initiatives (Drechsler et al., 2006).

In sum, literature studying the experience of economies that have completed the transition to a model based on knowledge intensive innovation industries suggest that trade-offs could exist between the Chinese government's sustainability targets of equitable (i.e. shared and coordinated) development and innovative development. The simultaneous achievement of both objectives requires additional effort. Unless adequate measures are taken to balance the growth stimulus of an innovation led economy and the contraction of traditional sectors, inequality, in particular between region is likely to exacerbate with detrimental effects on the country's social stability.

1.1.3.2 Restructuring the Economy towards the 'New Normal': Consumption Led Economic Development

The government's continued policy to encourage urbanisation is a deliberate move to expand the middle class[9] and to drive household consumption, the second pillar of the new growth model. In 2015, China's rate of urbanisation was 56.1% (KPMG, 2016). By 2020 urbanisation is estimated to reach 60% and an additional 100 million households will have relocated from the rural areas to the metropolitan centres of the country. The growth of China's urban middle class is expected to bring sweeping economic change supporting China's transformation from a production to a consumption based economy. By 2022, research suggests that more than three quarters of urban consumers in China will earn above 106,000 RMB a year. In 2012 only 17% of the urban population fell into this income band. In line with the rise in household affluence consumption is anticipated to increase by 10.6% annually over the next five years to 2022 (Barton et al, 2013).

The motivation of establishing urban centres has not been purely economic. Relocating parts of the deprived rural population to cities has been a social development instrument to alleviate poverty. In the presence of rising average income levels in the metropolitan areas with an advanced industrial base, the current FYP emphasises the important role of urbanisation to achieve the goals of 'shared and coordinated development' (NDRC, 2016a).

China's economic policy shift towards a consumption based model seems to have borne fruit. In 2016 growth in consumption by households outpaced overall economic growth in terms of GDP. On the demand side, the share of consumption in overall growth rose to about two thirds in 2015 (Bertoldi et al., 2016). Total retail sales of consumer goods reached over 30 trillion RMB in 2015. This is an annual growth of 10.6 percent after deducting price factors. Expenditure for household appliances and information and communication technology equipment rose by 11.4 percent over the same period despite the overall economy growing officially at 6.9% in 2015. Higher incomes and people enjoying an improved standard of living are per se positive. A central problem of urbanisation and increased household affluence is that consumption causes environmental problems. Demand for energy and water as well as the disposal of waste are just a few examples illustrating the pressures of household consumption on the environment (Kennedy et al., 2016; Interviews 8, 15, 33).

As incomes increase and households own more goods and use more services, environmental degradation stemming from consumption is likely to rise. The rise in consumption based pollution is jeopardising to at least partially off-set future environmental improvements made by the reform of the industrial sector. The emergence of a new driver of unsustainability, consumption by affluent households, appears to be the unintended consequence of the current FYP. By attempting to control current drivers of environmental degradation and socio-economic instability, the government in its quest for

[9] Households are typically considered middle class, when they spend less than 50% of their income on necessities and display distinctive behaviour of consumers (Barton et al., 2013).

the ’New Normal’ faces the additional challenge of not creating new forms of unsustainability.

The role of the energy sector in China’s sustainability transition will be explored in the next section. The energy sector is to a large extent responsible for the cumulative consequences of almost four decades of unbridled economic expansion with little attention paid to mounting ecological and social costs. It is accountable for a large part of China’s pollution. An essential part of China’s sustainability challenge lies in the transformation of the coal-based energy sector towards a more sustainable energy system. The key role of the energy sector in China’s reform efforts was marked by the release of the Five Year Plan for Power Sector Development’, 15 years after the last FYP was released on the development of China’s electricity sector in 2001 (Gosens et al., 2017; Shen and Geall, 2016). The Energy FYP is the breakdown of the energy related targets in the main FYP. The Energy FYP charts a route map to the ‘Energy New Normal’ to better guide policymaking, spending and project planning in the sector (CSNA, 2016).

1.1.4 The Electricity Sector – Case Study of the Sustainability Transition

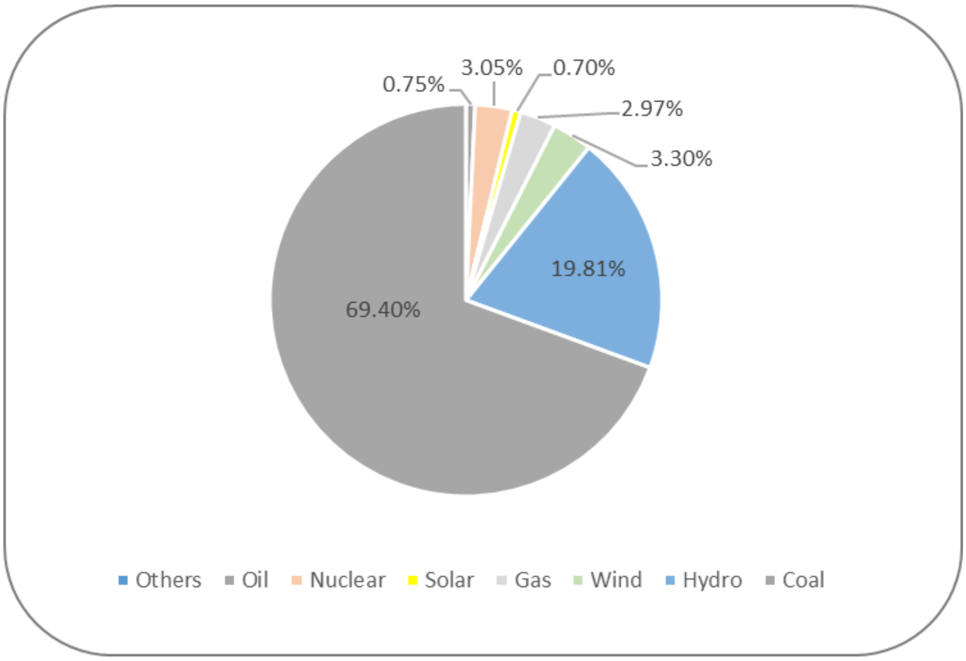
China’s energy sector exemplifies the country’s sustainability challenge. Cheap, reliable and accessible electricity has been the foundation of China’s prosperity. The combustion of abundant coal provided the baseload required for the country’s manufacturing sector that in turn powered the Chinese economic miracle (Wu and Zhang, 2016*;* Yao et al., 2011). Coal also played an important part in bringing affordable electricity to hundreds of millions of households (Bhattacharyya and Ohiare, 2012).

The coal based electricity sector has to a large extent contributed to China’s unsustainable development model. Firstly, it is responsible for a large share of the country’s environmental problems through the combustion of coal (Liu et al., 2017). Secondly, the sector is a reflection of China’s regional inequalities. A significant amount of electricity is generated in obsolete coal fired plants located in the inner part of the country, close to the resource centres. From the coal provinces electricity is then transmitted to the consumption and growth centres in the East, where it is used by affluent households and industries that typically operate at the high end of the value chain (Linder et al., 2010). The achievement of the sustainable development goals of the current FYP will to a great degree depend on the transition of the electricity sector to a cleaner and greener model, where the burden and opportunities of generation and consumption are equitably shared between regions.

1.1.4.1 *The Electricity Sector – Driver of Environmental Sustainability*

Electricity is a secondary form of energy[10]. It is generated from primary energy sources such as coal, natural gas, petroleum and renewable energy sources (for example biomass, hydropower, solar energy and wind energy) (EIA, 2017).

Diagram 1.4 Energy Generation by Type in China in 2016 (NBSC, 2016)



The relationship between energy and human development is very complex. Energy is an essential input to economic activity. Energy directly meets basic human needs and contributes to social development through the provision of food, education and public health. Rising energy use, however, can worsen pollution and harm the environment (Liu et al., 2017)

No country other than China can demonstrate better that energy is deeply implicated in each of the economic, social and environmental dimensions of human development. When the People's Republic was founded in 1949, China had just 1.85 GW of installed electricity generation capacity, which is less than the capacity of a modern coal or nuclear power plant. At the end of the Mao era in the early 1980s, China's installed power generation capacity had reached 50 GW for a population of 1 billion (Jowlett, 1984), about 800 million of whom lived in rural areas with limited or no access to electricity (Peng and Pan, 2006). Within a short order, according to UN data installed generation capacity reached 138 GW

[10] Electric power is the rate at which electrical energy is transferred within an electric circuit. Energy is measured in Joules or Calories. Power is measured in Watts. How much electricity is consumed by an appliance over a specific time period is indicated by the number of kilowatt hours. A 2,000 Watt appliance, for example, would use 1 kWh in just half an hour (Van Valkenburgh, 1992). The terms energy, power and electricity will be used interchangeably for stylistic reasons in this research. Primary energy used for electricity generation will be specifically referred to by source, i.e. coal or wind power.

by 1990, and more than 94 per cent of the population had access to electricity. Today China's energy sector is the largest in the world. In 2016 an estimated 5,920 TWh of electricity was generated in China (Energy Post, 2017). The dominance of coal in the generation fuel mix is illustrated by Diagram 1.4. In 2016 almost three quarters of electricity was generated in coal fired power plants.

The enormous volume of coal burning also generates significant levels of environmental degradation. Coal-fired power generation has significant environmental impacts, which stretch beyond the release of CO_2. In addition to contributing to global climate change, the environment and communities in the proximity to coal fired plants suffer the effects of pollution intensive electricity generation (Liu et al., 2017).

First, power production from coal causes severe local air pollution. Sulphur dioxide (SO_2), nitrogen oxide (NO_x) and other compounds, which form into particulate matter (PM), trigger respiratory disease with serious impacts on human health. In 2014 approximately 30% of SO_2 and 28% of NO_X originated from the Chinese power sector (Xu et al., 2015; Zhao et al., 2008). Second, coal fired power generation requires a large amount of water. High levels of water consumption have led to water shortages and the desertification of vast areas in Northern China (Zhang et al., 2016). Third, SO_2 emissions from coal combustion are the largest contributor to acid rain, and the acidification of soil (Yan and Wu, 2017). Fourth, coal mining itself causes degradation of the environment. Some of the serious environmental problems caused by coal mining include the destruction of farmland and local ecosystems and the damage to underground water and land resources (Hu et al., 2014; Li et al., 2014).

1.1.4.2 The Electricity Sector - Driver of Socio-Economic Sustainability between Regions

Primary energy resources for electricity generation differ across the country. While the North Western region generates about 95% of electricity by coal combustion, provinces such as Sichuan, Yunnan and Hubei, located in South-west China, produce less than 30% of electricity with coal, and instead most of it with hydro power and wind (NSBC, 2016).

In addition to spatial differences in the generation fuel mix, technology disparity in electricity production exists among different provinces. Regions with high emission intensity from the electricity generation sector include provinces in the North Western region where electricity is generated in often inefficient plants with obsolete generation technology. Inner Mongolia, for example, has by far the highest emission intensity which is around two and a half times higher than the national average. On the low end of the emission intensity spectrum are provinces like Beijing or Guangdong. These provinces are typically very rich and rely heavily on electricity imports, or they produce a large fraction of their electricity with renewable energy sources, such as hydropower (Sichuan for example). In the middle spectrum are well developed provinces, such as Jiangsu, that rely on coal for energy but are more likely to have access to modern less pollution intensive technology (Zhang et al., 2016; Liu et al., 2017).

A key characteristic of the Chinese energy sector is the mismatch of electricity demand and supply. The three provinces of Inner Mongolia, Shanxi and Shaanxi share almost half of the nation's total coal output. Yet the economically fast growing Eastern coastal region, consumes more than 50% of the total electric power (NSBC, 2016; Wang and Che, 2010; Lindner et al., 2013). The mismatch between supply and demand results in large parts of electricity to be transferred from economically less developed provinces in the West to economic growth centres in the East.

Energy generation and consumption patterns are a reflection of regional differences in socio-economic development. Major primary energy sources (i.e. coal and hydro) for electricity generation are mostly located in economically less developed regions, whereas the electricity demand is concentrated in fast growing regions along the Eastern coast. Provincial differences in the fuel mix and access to technology as well as supply and demand mismatches between regions have serious implications for the viability of the electricity sector reform. The transmission of electricity between regions over long distances causes a shift of environmental pollution away from the economically advanced and affluent provinces to the resource-rich, and less developed provinces (Fan et al., 2008).

1.1.4.3 The New Energy Normal

The main targets of the current Energy FYP (2016-2020) relate to an overall energy consumption cap and a 15% share of non-fossil-based energy in the country's primary energy mix in 2020. Coal's 2020 share in the energy mix is lowered from currently 70% to 58%. In another landmark document, The State Council signalled the start of the sustainability transition of the energy sector. 'Deepening Reform of the Power Sector (March, 2015)'[11] can be understood as a broad road map for reforming the country's energy system. In essence, it acknowledges the need to orient the transformation of the power sector around China's major goals of reducing emissions, boosting energy efficiency and a low pollution energy supply through the promotion of renewables, enabled by the establishment of an innovative industry (Politt et al., 2017).

By adjusting the economic growth rate, the industrial structure and the primary energy mix the Chinese leadership intends to significantly influence the reduction of energy consumption and the emissions intensity of the economy. China's rapid growth of electricity demand has appeared to moderate recently. Electricity consumption grew by

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[11] *Deepening Reform of the Power Sector* outlines five basic principles governing the reform of the power sector:

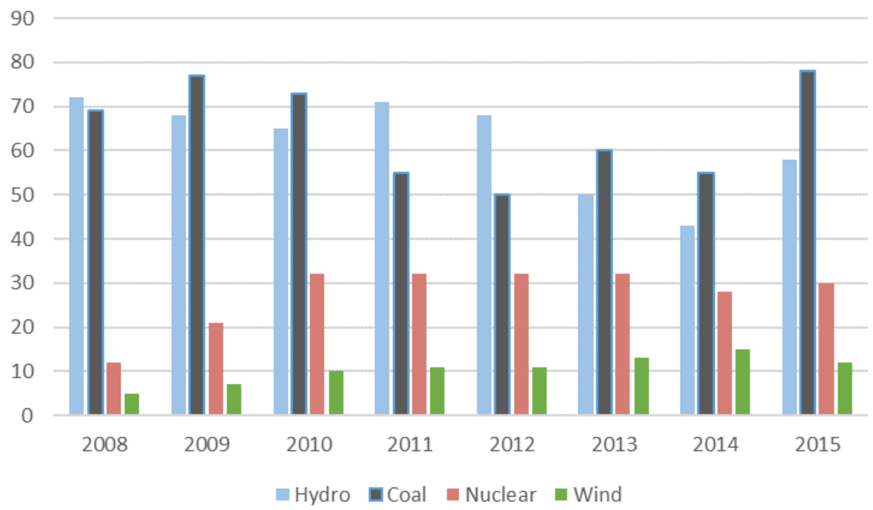
1. The need for reliability;
2. Increased use of market mechanisms;
3. Protection of residential and agricultural consumers;
4. Energy savings, emissions reductions, and increased use of renewable and distributed generation; and
5. Better governance and regulation, including better planning and strengthened capacity in terms of regulatory agencies and approaches.

only 1% over 2015 (down from an average growth rate of 8.6% p.a. from 2008 to 2014). However, demand stabilisation due to a downturn in energy intensive manufacturing appears to be short lived. Economy wide electricity usage has increased by 5% over 2016 to a total of 5920 TWh. The largest growth rates in power consumption can be attributed to the service sector as well as households (Göß, 2017). With rapid urbanisation and rising household incomes, residential electricity consumption in China has increased tremendously from 1990 to now at an annual average growth rate of 12% (Khanna et al. 2016).

Currently the structure of electricity consumption in China is about 70% industrial, 20% commercial and 10% residential. In developed economies, the shares are approximately equal (Eurostat, 2017b). Despite China's electricity generation capacity being the world's largest, Wensley et al. (2013) estimate that China's system is still only half developed. With innovation, services and household consumption being promoted as the new drivers of growth demand from these sectors is expected to grow faster and gradually replace the industrial sector as main user of electricity.

At the moment the average Chinese household only consumes one third of the electricity used by a typical household in Western Europe[12]. The differential in consumption figures between China and countries with a more developed consumer economy, highlights the growth potential of residential demand in China. Estimations based on international per capita consumption data, conservative projections of economic development (in terms of GDP growth) and expected energy efficiency improvements (Wensley et al., 2013) find that considerable investments need to be made to upgrade existing generation capacity and the transmission infrastructure.

Diagram 1.5 Generation Capacity under Construction from 2008 to 2015 (in GW) (Pollitt et al., 2017; CEC, 2017)



[12] The average usage per household in China is around 1,400 kWh p.a. Average household electricity consumption in the UK and Germany are 4,600 kWh p.a. and 3,500 kWh p.a. respectively. U.S. electricity usage per household is almost 12,000kWh per year.

The NDRC (National Democratic Reform Committee) estimates that by 2020 overall Chinese power consumption will reach 6,800 TWh, increasing on average by 3.6-4.8% each year. With China's growing needs for power the 13th Energy Five Year Plan calls for the expansion of the country's generation base. The plan includes targets for the development of renewable forms of energy generation. PV solar capacity is to rise from 70 GW to 110 GW and wind capacity is to increase from around 150 GW today to 210 GW by 2020. As additional renewable capacity is not expected to cover increasing demand, another key target of the new plan is the construction of new coal plants. The country's 2020 target for coal capacity, 1100 GW, an increase from 920 GW in 2016, suggests that 45 GW of coal based power will be added annually (for a summary of energy related targets in 13th FYP, Power Sector FYP and Reform of the Power Sector see Ma, 2017).

The growth of renewables has been impressive in China as can be seen in Diagram 1.5, which also suggests that the expansion of coal generation base, however, continues to be substantial. Unless drastic measures on both the supply and demand side are taken, the reliance of the Chinese power sector on coal will likely to remain significant for years to come (Gößß, 2017).

The declining utilisation of power generators laid bare the overcapacities in the Chinese electricity sector. Despite overcapacities continuing to grow and total power generation from coal decreasing by 4% in the first half of 2016, an additional 25 large coal-fired plants were connected to the grid (Gray, 2016). Significant is the spatial distribution of the new plants. A new policy addressing overcapacity through the retirement of old plants and the suspension of planned projects contains exemptions for certain provinces as well as for projects designed to export power from the West to the East. New 'coal power base' projects in the inner coal provinces of Shaanxi, Shanxi and Inner Mongolia, with over 7,000 MW of capacity, started construction straight after the policy was put into force in May 2016 (Myllyvirta, 2016).

The Energy Five Year Plan and the Power Reform Plan are evidence for the government's resolve to transform the energy sector. Recognising that the energy sector is to a great extent contributing to China's environmental problems, its transformation was made a pillar of new sustainable development model. Two questions, however, remain, firstly, whether the broad principles laid out in the policy documents will be followed by interventions and their workable implementation (Dupuy and Weston, 2015) and secondly, in how far these interventions address the new drivers of electricity demand, residential usage in particular. The current framework does not appear to provide much space for the moderation of residential demand growth. In the context of residential consumption, the reform plans of the State Council (CSC, 2017) are limited to the aspects of access and affordability. The document reassures households of secure and affordable access, in light of the far reaching proposed changes on the supply side. In the context of affordability, the document stresses that the government will continue to subsidise residential tariffs. The protection of livelihoods appears to be a key theme in the power sector reform.

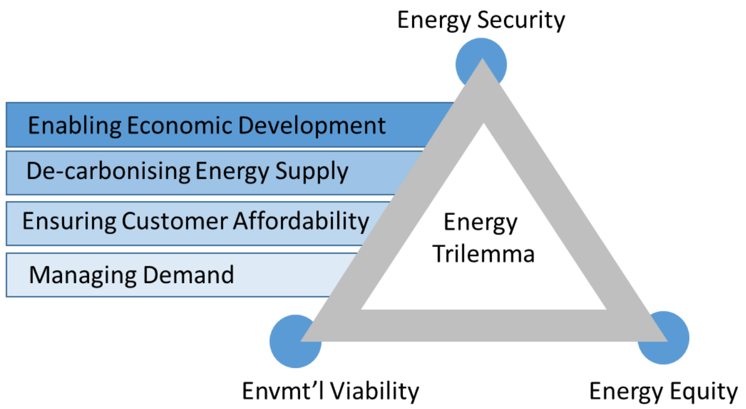
1.2 Implications for Further Study

The sustainability reform of the Chinese energy sector laid out in the 13th FYP exemplifies the challenges at the centre of the energy trilemma (WEC, 2017; Arup, 2017) describing the inter-linked objectives of environmental viability, energy equity in relation to affordability and energy security. Environmental degradation from the combustion of fossil fuels; rising costs as the generation base is de-carbonised; and the gradual depletion of domestic coal reserves due to higher energy demand from rapid economic development, an expanding middle class population and urbanisation cannot be thought of in isolation.

Energy security (Ang et al., 2015) implies that there needs to be sufficient supply in terms of generation capacity, infrastructure and natural resources to meet rising demand. With domestic coal reserves dwindling and oil imports rising China's energy security strategy (Yao and Chang, 2014) involves substantial investment in renewable and low carbon generation technologies. A less carbon intensive fuel mix enhances energy independence as well as environmental sustainability. However, more sustainable sources typically imply a trade-off with affordability as the decarbonisation of the existing generation base requires significant capital expenditure. Energy prices may rise to recoup investment in renewable technology with the consequence of negatively affecting electricity consumers, in particular vulnerable low-income households (Mainali et al., 2018; Lauber and Jacobsson, 2014).

Sustainable energy development requires policies that consider all three of the competing objectives (Poudineh and Tooraj, 2012) and their impact on economic development, the carbon intensity of energy supply, electricity tariffs and household welfare as well as rising demand from an expanding middle class. Policy makers need to decide the desired outcome defined by the position on the axis of each trilemma dimension. Diagram 1.6 illustrates the trade-offs each dimension implies of the other two. When thinking of energy security, environmental viability and equity, interventions are required that address the other two and aim for an integrated understanding of the key challenge at the heart of China's energy problem: Meeting rising household demand with an affordable supply of green electricity.

Diagram 1.6 The Energy Trilemma (adapted from WEC, 2017)



China has announced the introduction of a national CO_2 allowance market as a key instrument to facilitate the sustainability reform of several pollution intensive industries and the energy sector (CSC, 2015). The discussion on past and future problem drivers linked to the 'energy trilemma' highlighted the complex challenge the national carbon market will be confronted with. The main problem of the market-based reform of the power sector is that the system is large and complex and the effect of trading emission allowances on China's sustainable development goals is unpredictable against the backdrop of rapidly increasing residential consumption. In particular, the effects of the market on energy equity, the FYP's objective of 'shared and coordinated sustainability', is difficult to gauge. People will be affected in many different ways by the market-based energy transition. Their location in China appears to a deciding factor how they are affected. Location determines employment opportunities, household affluence and the level of electricity consumption. It also determines exposure to pollution from electricity generation.

The complexity of the situation raises the question of whether China's authoritarian regime is equipped to embark on market-based approach to address current sustainability issues linked to the emergence of the middle class and rising household consumption. In the absence of a liberal political and economic system emissions trading is being tested in an environment unusual for a market-based intervention. To better understand whether a national carbon market is a viable option to transition China towards an innovative, harmonious, green, open and shared model of development, warrants to examine the current debate around the concept of emission markets. A review of literature on China's state-society-market relations may provide further insights that could lay the foundation for this study that has the ultimate goal to provide some empirical insights into whether market mechanisms are effective to complete China's transition to the New Energy Normal.

1.3 Structure of the Study

To present the results of the empirical study on the market-based transition of the residential electricity sector, the rest of the thesis is structured in seven chapters.

To develop the research questions a review of relevant literature is conducted in the next chapter. The review focuses on two sets of previous studies. At the outset literature concerning the main themes around emissions trading and its governance is discussed. Particular attention is paid to studies evaluating the distributional implications of pollution markets. The second part of the review is concerned with studies on the political economy of China. Literature investigating the relationship between the authoritarian regime and an economy based on markets is to provide context for China's unique political situation. The gaps and limitations revealed in previous research guide the development of the research questions that are presented following the literature review.

In Chapter 3 a conceptual framework is designed to better understand the complexity inherent in the market-based sustainability transition. A systems based approach was selected to elucidate the relationships between the many different competing sustainability objectives of the electricity sector reform. Based on the research questions and the conceptual framework, the research methodologies, data collection and analytical tools are introduced in Chapter 4.

The empirical part of the thesis begins with Chapter 5. It recognises that individuals are at the centre of China's endeavour to transition towards a more sustainable development model. Aim of the chapter is to examine the views of stakeholders on the sustainability objectives of the electricity sector reform.

Chapter 6 shifts the analytical focus to constructing a detailed causal model of the Chinese electricity system with an emissions market at its centre. The aim is to develop an understanding of factors inhibiting or supporting the market to achieve the various sustainability objectives. The simulation of different market-based intervention scenarios quantifies the effect of a national carbon market on the objectives. The analysis is carried out at regional level.

Chapter 7 evaluates the simulation results in the light of stakeholder preferences for the reform outcome. Main aim of the analysis is to identify regional differences regarding the priorities people place on the various sustainability objectives. The chapter also seeks to reveal how China's unique political and cultural environment influences the effectiveness of a market-based approach to induce environmentally friendly behaviour of individuals.

Chapter 8 presents a summary of the key findings as well as their theoretical and practical implications. It also highlights limitations of the study and discusses directions for future research.

2 The International Emissions Trading Landscape and its Implications for China

This chapter provides an overview of the literature related to the main themes of this research: China faces a plethora of complex and interdependent problems that the country's government intends to address through a market-based approach. A carbon market is to transform the economy so it becomes less resource and pollution intensive in a way that is equitable for people. The country's past approach of command-and-control has not been effective in addressing current sustainability challenges. Despite far reaching market-oriented reforms, China's government still controls many aspects of the country's economy and society. Most of the experience with emissions trading has been gained in liberal market economies. While the theoretical foundations of pollution allowance trading are widely accepted, opinions regarding its performance in practice diverge widely (Guilli, 2009).

The first part of the literature review considers studies that are related to emissions trading and its governance, with a focus on past and present schemes in the European Union and North America. Studies on the regional Chinese CO_2 pilot markets are also presented. The review adopts an evidence based approach. Insights from evaluation literature appear more relevant for this research than the understanding gained from an in-depth review of economic textbooks and papers explaining the theoretical principles underlying the concept of market-based pollution control. In order to provide an explanation as to how such a scheme could facilitate China's transition to the 'New Normal', the concept is briefly introduced. The lessons learnt from existing schemes appear to be useful in guiding the empirical part of this study. The identification of criteria according to which existing markets are assessed creates awareness of the wider implications of emissions trading that potentially could affect the various objectives of China's sustainability transition.

The second strand of literature is concerned with the distributional implications of emissions trading. The objective of the review is to better understand the on-going debate around pollution markets and equity. More specifically, the aim is to explore the discourse on benefit and burden sharing between consumers and producers. The discussion in Chapter 1 highlighted that consumption and production patterns of emission intensive energy and goods coincide with profound provincial differences in emission intensity and wealth. Lessons from schemes such as the European Union Emissions Trading Scheme (EU ETS) could provide insights into how a carbon market could support the government's goals of coordinated and inclusive development.

The third category of literature is concerned with the unique political and economic circumstances the national emissions market will be embedded in. At the outset of this section, China's political economy in general since the reform era is explored. As a comprehensive assessment of the development of China's political economy would be a research project in itself, only a summary review focusing on the relationship between the government and markets is presented. The rationale for the focus of the review on the evolution of markets is based on the idea a market is embedded in a specific context

(Breslin, 2007). Emission markets have been mostly implemented in Western economies, in which the state plays a far less central role than in China. It is therefore important to understand the country's unique political, social and cultural situation. Particular attention is paid to the extent of public participation in the policy process. This understanding is relevant for the empirical part of this research that is concerned with the investigation of household consumption, an emerging driver of unsustainability.

In combination these three strands of literature provide a foundation for the study to be able to answer the research questions. It also identifies gaps in research, which this study is seeking to fill.

2.1 The Concept of Emissions Trading

The basic principles of emissions trading are straight forward (Tietenberg, 2006; Han et al., 2012). In a cap-and-trade system the overall limit on emissions is based on a national target, the cap, and the trajectory of emission reductions over a set period of time. Emission allowances, which represent the right to emit a specific amount of carbon, are allocated to polluters. If an emitter does not have sufficient allowances to cover its carbon output it can choose to reduce emissions through efficiency improvements or through the adoption of low carbon technology. Alternatively, it could buy additional allowances from other emitters who have excessive allowances. The floating allowance price will determine whether it is more cost efficient to abate or to trade.

The goal of emissions trading is threefold (Stavins, 2001). Firstly, to increase the cost of fossil fuel based energy by putting a price on the environmental and social costs, which are not been counted in the generation and use of fossil fuel based energy. Secondly, to provide polluters with flexibility and least cost solutions to reduce their levels of greenhouse gas emissions in the short run. Thirdly, to pave the way for much deeper emission cuts in the longer term by encouraging investment in research and development of innovative green technologies and their adoption.

2.2 Evaluation of Emissions Trading as an Instrument for Sustainable Development

Real life experience is typically quite different from economic textbook assumptions. Numerous challenges arise in an imperfect world of uncertain political and economic variability. The views on emissions trading as an effective instrument for pollution control encountered in the literature appear ambiguous. Some authors regard emissions trading as superior to any other instrument (Hoel, 1991; Barrett, 1992; Dudek and Tietenberg, 1992; Stern, 2007). Proponents of markets point out the ability of emission allowance trading to deliver abatement in the most cost effective manner whilst others doubt the effectiveness of markets to even control pollution. Critics of market-based solutions to pollution problems believe that markets are nefarious in the ethical sense as they serve certain interests, in particular financial ones (Bachram, 2004; Lohman, 2005).

To better understand why these competing views exist, the performance of three real life examples is explored in the following. The first scheme to be reviewed is the Chinese pilot emissions trading scheme that has been operational as eight separate CO_2 allowance markets since 2013. In contrast to the Chinese markets embedded within a planned economic system, two emissions trading schemes (ETS) operating in a Western context with lower levels of state control are being examined. The plethora of literature published on the U.S. sulphur emissions market and the European Union Emissions Trading Scheme (EU ETS) shed light on the ongoing debate surrounding the controversy of a market-based approach to facilitate a sustainability transition.

2.2.1 The Experience with Emissions Trading in China

The concept of emissions trading was first introduced in China during the 1990s. To date, three phases of emission trading pilots have been implemented. The first test phase was carried out between 1990 and 1994, when emissions trading pilot projects were launched in six cities.[13] The second phase, officially started in 2002 and concluded at the end of 2003, was on a larger scale. The aim was to control SO_2 emissions[14], mainly from the power sector, in four provinces, three municipalities or cities. The scheme also included one trans-regional Chinese power company[15]. These local markets have not been very transparent in their rules. In the absence of information capture systems and disclosure procedures (Lo, 2016; Tao and Mah, 2009) it is difficult to ascertain environmental and other impacts of these schemes. Nevertheless, these schemes provide useful insights into the relation between the state and the market, which will be explored in Section 2.4.

The third phase of China's ETS experiment covers eight separate pilot trading schemes in Chongqing, Shenzhen, Shanghai, Beijing, Guangdong, Hubei, Tianjin and Fujian. The eighth market in Fujian was established in 2016. The planning and implementation phase of the first seven pilots took place in under three years from 2011–2013. In comparison, it took over seven years of preparation time for the EU ETS to be fully operational. The National Development and Reform Commission (NDRC) selected the locations to establish pilot emissions trading systems during the 12th Five-Year Plan (FYP) (NDRC, 2011).

Not much literature on the selection criteria or process was located. According to Zhang et al. (2014) pilot sites were selected based on a region's distinct economic structure and

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[13] The six cities are Baotou, Taiyuan, Guiyang, Liuzhou, Pingdingshan, and Kaiyuan.

[14] SO_2 is a gas, a by-product of burning of fossil fuels such as coal and oil. High concentrations of SO_2 can have serious effects on health as a precursor to the formation of particulates. Particulate matter affects more people's health and causes more economic loss than any other conventional air pollutant (EPA, 2017c). SO_2 and particulate matter cause acute and chronic respiratory disease, heart disease, and premature deaths.
The transport of sulphuric compounds over greater distances leads to the deposition of sulphur in soils and waterways in regions distant from the source of emissions. Sulphur deposition, more commonly known as acid rain, contributes to acidification of forests and lakes.

[15] The provinces, cities, and the power corporation are Shanxi Province, Jiangsu Province, Shangdong Province, Henan Province, Shanghai, Liuzhou, Tianjin, and The China Huangeng Group

emission profile. As can been seen from the map in Diagram 2.1 the pilots cover a relatively large geographic area. However, all are located in relatively developed regions with low emission intensity compared to the national average[16]. Six of the eight pilots are located along the coast or in the South East. Only the province of Hubei and the city of Chongqing in the central region are illustrative of areas with moderate to high pollution intensive industry. Regional carbon inequality appears not to have been a consideration during the conception of the scheme led by the central government. None of the provinces most seriously affected by the environmental impacts of coal burning, such as Inner Mongolia or Shanxi, were chosen as a location for one of the pilot markets.

Diagram 2.1 Current Emissions Trading Pilot Schemes in China

Following instructions from Beijing each of the markets were required to determine overall targets (based on local GHG inventories), establish permit allocation rules, set up a market infrastructure, develop registry and governance systems including the formulation of oversight guidelines (Wang, 2013). As a result of the ETSs being designed at local level, the eight pilots comprise a range of sectors and have different thresholds for inclusion. All markets cover emissions from the power sector and, with the exception of Beijing, the pollution intensive steel and cement industries (Swartz, 2016). The main objective of the eight trial markets is to test the concept of emissions trading prior to the roll-out of a national scheme over the period of the 13th Five Year Plan (2016-2020). Combined the markets cover the equivalent of 1,115 tonnes of CO_2 emissions, which is second only to the European Union Emissions Trading Scheme (EU ETS). Once a national scheme has been

[16] During the planning stage of the ETS pilots the average national emission intensity was calculated as 1.5t CO_2/10k$. Shenzen: 0.6 t$CO_2$/10k$. Beijing: 0.8 tCO_2/10k$, Shanghai: 0.9 t$CO_2$/10k$, Tianjin: 1t CO_2/10k$, Guandong:0.8 t$CO_2$/10k$, Hubei: 1.1 tCO_2/10k$, Chongqing: 1.4 t$CO_2$/10k$. In comparison the average carbon intensity of the EU27 economies was 0.2 tCO_2/10k$ in 2011 (Zhang et al., 2014).

established, China will overtake the European Union to become the biggest carbon market in the world.

A number of studies assess the performance of individual and multiple schemes in order to extract lessons for the national market. Wu et al. (2014) assess the first year of trading carbon allowances on the Shanghai market. They find that a number of issues linked to allowance allocation and the banking of allowances led to market inefficiencies. They also point out regulatory issues related to market oversight and the lack of effective monitoring, review and verification procedures (MRV). Wang et al. (2016a) assessing the Guangdong and Shenzen pilots find similar issues relating to the availability and verification of emission data as well as regulatory shortcomings. In their evaluation of the Beijing pilot Hu et al. (2017) establish that the main problem of the market is the lack of market liquidity and price volatility. Echoing the other studies on the pilot markets the authors point out issues with market oversight and the accuracy of emission data. Cong and Lo (2017) investigate the extent of market volatility present in the Shenzen pilot market. They find that a major source of market instability and market distortions through price volatility has been excessive state intervention into market activities.

Price volatility and market illiquidity, issues in most of the markets, are linked to setting the cap on emissions at an appropriate level, which given the lack of emissions data, is difficult to derive. This is particularly challenging in regions such as Hubei that face a volatile economic situation as they rely on emission intensive traditional industries for growth (Qi et al., 2014). China does not set an absolute emission abatement target for its provinces. The national intensity based target is broken down into provincial targets (Zhang et al., 2012), which then needs to be divided between ETS and non-ETs regulated sectors (Swartz, 2016).

Across all markets the allowance price was found to have been suppressed, mainly due to the over-allocation of emission allowances (i.e. an excessive cap) (Carbon Pulse, 2014-2017). As the experience of more mature markets has demonstrated (see following section on EU ETS evaluation), a low allowance price has resulted in dis-incentivising pollution abatement both through making adjustments to the production process and the adoption of low emission technology. Nevertheless, a number of studies found that the pilot schemes had an effect on ETS regulated emissions and regional economies.

Hu et al. (2017)'s paper concludes that if the Beijing scheme was to develop, its positive effect on the established innovative sector in Beijing could be significant. In contrast to Beijing, Hubei is still heavily reliant on manufacturing industry and coal consumption. A study by Liu et al. (2027) finds that the Hubei Pilot ETS had a negative effect on the economy, but a positive effect on emissions. In 2014 the ETS triggered a 1% (about 6.98 million tons) fall in carbon emissions, while the decline of the province's GDP of 0.06% was attributed to the pilot market. According to Wang (2016), the total emissions volume of major emitting firms in Beijing fell by around 4.5% in the first compliance period as a result of establishing the trading platform. Over the same time the total amount of carbon emission in Shanghai was calculated to have decreased by 5.31 million tons, with a rate of 3.5% in the first compliance period. According to the same study by Wang (2016) in

Shenzhen the total amount of carbon emission decreased by 3.83 million tons during the first year of implementation.

Critically assessing the accuracy of these calculations proves difficult as important information on certain assumptions could not be located. It is not clear how any of these studies isolated the effect of the ETS from external influences such as the general economic climate and parallel regulation. Also, the conditions assumed for the counterfactual scenario (business-as-usual for example) could not be established. As the decrease of carbon emissions coincides with a slowdown of the Chinese economy, the conclusion presents itself that at least part of the decrease can be attributed to a decline in economic activity.

The national scheme will be designed based on best practices and lessons drawn from the ETS pilots. The learning effect of these experimental markets, however, appears to have been limited. Most of the local governments have been attaching more importance to attaining high compliance rates rather than achieving the major objective of developing mechanisms for a transparent and liquid allowance trade. Significant variability of the allowance price across schemes has been observed. Prices have generally been suppressed and markets have shown very little trading activity. It is difficult to ascertain the performance of the pilot markets, their contribution to emission reductions and their effect on local and national economic development, in particular the technology sector (Swartz, 2016).

The majority of evaluation literature on the Chinese pilot markets appears to be concerned with processes involving the monitoring, review and verification of emissions data, cap setting and emissions allowance allocation (Munnnings et al., 2015; Ling et al., 2015; Zhang, 2015; Zhang et al., 2014). One key finding of review of literature on the Chinese experience with carbon trading to date is that little attention appears to have to been paid to the wider environmental, socio-economic and distributional effects of emissions trading in China. It is understood that an in depth analysis of environmental and socio-economic performance appears difficult as the test schemes have only been in operation since 2013 [17]. A lack of accurate data further hinders the in-depth evaluation of the pilot markets.

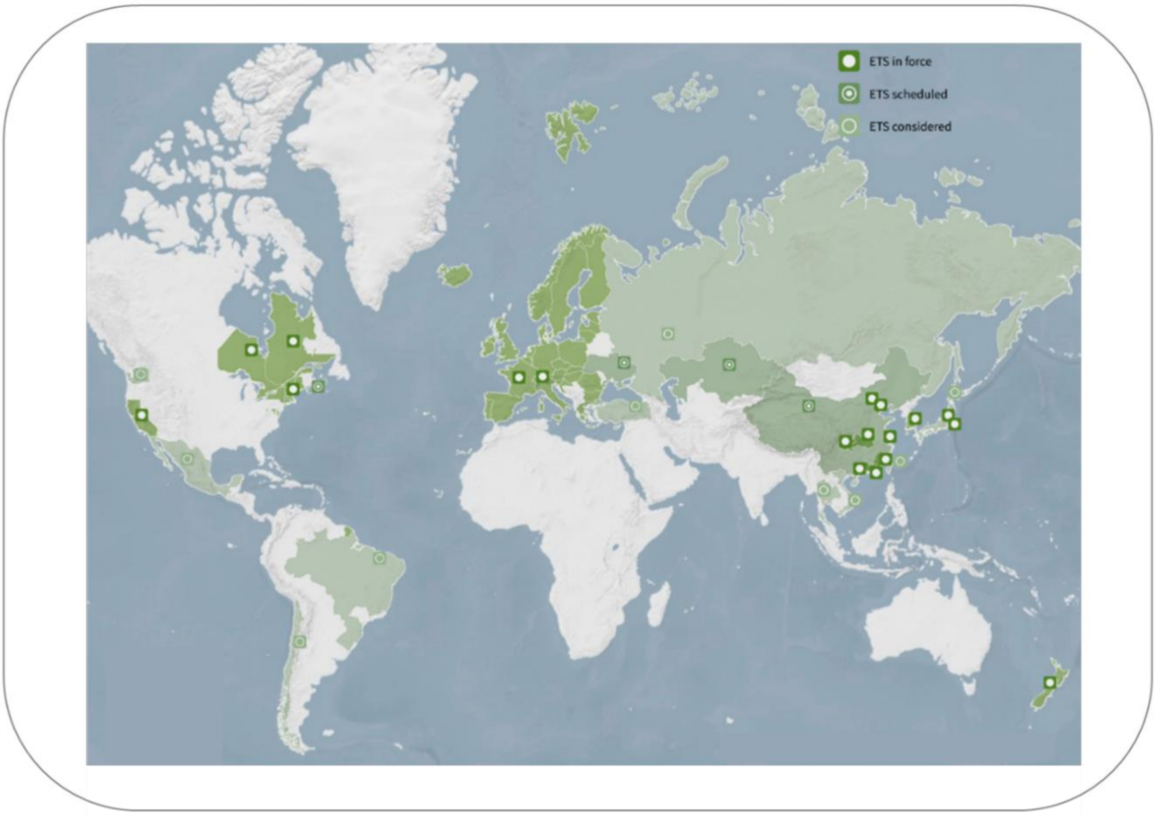
Literature on more mature schemes may be helpful in guiding a structured and comprehensive evaluation of the experience with emission allowance markets to date. The analysis of established pollution markets such as the European Union Emissions Trading Scheme (EU ETS) could provide valuable insights into the effect of emission trading on environmental quality, development based on innovation and an equal society, the key pillars of China's new development model, the 'New Normal'. In addition to understanding the scope and quality of the research carried out in this field, the review of evaluation literature on past and present emission trading schemes could bring to light gaps in the theoretical and practical body of evidence, creating opportunities for further study of emissions trading in China.

[17] Note that the Hubei pilot started in 2014 and the Fujian pilot in 2016 (Icap, 2016 and 2017).

2.2.2 The Experience with Emissions Trading in De-Regulated Market Economies

The interest for market-based approaches to solve environmental problems has been growing globally. Emissions trading schemes are now valued just under $50 billion worldwide and cover about 16% of global greenhouse gas emissions (ICAP, 2016). Currently there are 17 cap-and-trade schemes in operation. As below Diagram 2.2 illustrates, the majority of emissions trading schemes currently in operation are situated in Europe and North America. However, an increasing number of transition economies such as Brazil, Mexico and Vietnam are considering an ETS as an option for implementing their climate policy plans.

Diagram 2.2 Map of Operational and Planned Emission Trading Schemes



A complete review of evaluation of all past and present emissions trading schemes would take up too much space. Studies reflecting on the experience with market-based instruments for pollution control typically highlight several prominent cap-and-trade systems employed in Europe and North America, such as the sulphur dioxide (SO_2) allowance trading established under the U.S. Clean Air Act Amendments of 1990 and the European Union Emissions Trading Scheme (EU ETS) established in 2005.

The SO_2 program that controlled sulphur emissions from power generation in the U.S. from 1994 to 2012, was selected to be included in this review as it was the first practical application of a cap-and trade scheme. By many it is viewed as the only pollution market that was effective in achieving and exceeding its environmental targets (see for example: Harrison et al., 2008; Stavins, 2008; Burtraw and Swift, 1996). The EU ETS is the European Union's flagship instrument to meet its greenhouse gas mitigation objectives. The EU ETS covers approximately 45% of total EU CO_2 emissions from over 11,000 energy intensive installations such as power and industrial plants across 31 countries and airlines operating between the countries (EC, 2017a). The EU ETS launched in 2005 and there is no lack of analyses evaluating the scheme.

Both markets cover emissions from the power sector. One key difference between the SO_2 market and the European carbon trading scheme has been the regulatory environment the two schemes were operating in. Under the U.S. Acid Rain Programme electricity generation was relatively tightly controlled at state level, whereas power companies in the EU are relatively unregulated following a drive for liberalisation of energy markets in the early 2000s (Sokolowski, 2016). The overall aim of deregulating public services, utilities and infrastructure such as power, transport and telecoms is to increase efficiency through the pressure of market competitors. Improved efficiency is assumed to lead to lower costs and tariffs, which benefit end consumers (Jamison, 2011; DTI, 2000; Eberlein, 1999). The preliminary review of literature on equity implications of environmental policies suggests that the regulatory environment, i.e. the degree of market liberalisation, influences the distributional impact of the carbon cost burden (Kaufman and Krause, 2016; Grainger and Kolstad, 2010; Morgenstern, 2002). The exposure of the EU ETS and the SO_2 allowance market to different levels of power sector regulation warrants therefore the investigation of both schemes.

The review of literature examining the two emission trading schemes adopts a multi-criteria evaluation approach. An array of evaluation criteria has been proposed in literature to assess environmental policies (Venmans, 2012; Mundaca and Neij, 2009; Konidari and Mavrakis, 2007**;** Harrington et al., 2004; Mickwitz, 2003). The majority of studies evaluating market-based instruments adopt four core criteria proposed by the IPCC (2007).

Firstly, environmental effectiveness assesses the extent to which an intervention meets its intended environmental objective. In the context of the study of emissions markets, this criterion evaluates the amount of abatement. Secondly, cost-effectiveness captures the extent to which a policy can achieve this objective at a minimum cost to society. This criterion assesses cost savings and other effects of the scheme over alternative interventions (such as command-and-control regulation or business-as-usual). Thirdly, distributional considerations are concerned with equity implications[18] of the policy. These can be linked to wider socio-economic and environmental effects attributable to the emissions trading scheme under study. Fourthly, institutional feasibility considers the

[18] The concept of equity is explained in Section 2.6 following the literature review. This section presents the research questions and the objective of this study.

socio-economic and political environment the policy is embedded in. Ultimately, the first three criteria can only be achieved if the intervention is viewed as legitimate and gains acceptance. The fourth criterion will be discussed in Section 2.3.4., which summarises the lessons drawn from the evaluation literature on the three markets.

2.2.2.1 Evaluation of the U.S. Sulphur Dioxide Allowance Market

The U.S. Clean Air Act of 1990 under the framework of the Acid Rain Program initiated the first large experiment in the application of a market-based instrument to control air pollution . The introduction of a cap-and-trade emissions trading program for sulphur dioxide (SO_2) emissions[19] was later followed by a market for tradable nitrogen oxide (NO_x) emission allowances in 2004 (EPA, 2011). The SO_2 emission market sets a permanent cap on the total amount of SO_2 that may be emitted by power plants in the United States. In the U.S. electricity generation accounts for 65% of SO_2 emissions (EPA, 2012). Because of its significant contribution to pollution, the sector was the prime target of the Acid Rain Program.

The program came into existence mainly in response to concerns about high levels of acid rain in the North Eastern region of the U.S. Phase I (1995–1999) of the trading program required significant emissions reductions from the 263 most polluting coal-fired power plants, almost all of them located in the Eastern part of the country. Phase II (2000-2011) placed an aggregate national emissions cap on approximately 3,200 power stations, nearly the entire fleet of fossil-fuel based plants in the continental United States. The Acid Rain Program put a nationwide cap on SO_2 emissions at 8.95 million tons by 2010, which was 50% below 1980 levels (Ellerman, 2000).

Previous clean air regulation considered the rate of pollution coming from individual plants, but ignored that plants in operation vary in age, generation technology and therefore pollution intensity. Under the cap-and-trade scheme power plants were given the flexibility to decide the most economical and technologically feasible approach to lower emissions based on their own particular circumstances The Environmental Protection Agency (EPA) monitored emissions on a continuous basis and verified allowances submitted for compliance (Schmalensee and Stavins 2012; Burtraw, 1995).

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[19] SO_2 is a gas, a by-product of burning of fossil fuels such as coal and oil. High concentrations of SO_2 can have serious effects on health as a precursor to the formation of particulates. Particulate matter affects more people's health and causes more economic loss than any other conventional air pollutant SO2 and particulate matter (PM) cause acute and chronic respiratory disease, heart disease, and premature deaths.
The transport of sulphuric compounds over greater distances leads to the deposition of sulphur in soils and waterways in regions distant from the source of emissions. Sulphur deposition, more commonly known as acid rain, contributes to acidification of forests and lakes.

NOx also contributes to fine particulates and acidification, but to a lesser extent than SO_2. In addition, NOx contributes to ground-level ozone, which is formed by the atmospheric mixing of NOx and volatile organic compounds (VOCs) and facilitated by warm temperatures and sunlight. Policy to limit NOx emissions has been driven largely by concerns about attainment of air quality standards for ozone and to a lesser extent by concerns about acid rain (U.S. EPA 1998).

2.2.2.2 Environmental Effectiveness

The goal of reducing SO_2 emissions exceeded expectations as they fell quicker than anticipated. By 2004 SO_2 output from electric power plants decreased by 36% since the inception of the allowance trading scheme (EPA, 2011), even though electricity generation in coal-fired plants increased by 25% over the same period. Over the entire program period regulated installations reduced emissions by 12.6 million tons (80%) from 1990 levels (EPA, 2017a).

Indicators of ecosystem recovery have increased significantly from 1990 levels, suggesting the positive impact of the sulphur market on environmental conditions (EPA, 2015). An ex-post evaluation led by the federal government explains that the environmental benefits accrued over the program's life time have been relatively small as it had taken much longer than first assumed to reverse the effects of acidification on ecosystems (National Acid Precipitation Assessment Program, 2005). A number of studies suggest that the monetised benefits for the environment were probably considerably less than the overall program costs.

However, unanticipated benefits, in particular human health benefits, were significant. It has been calculated that 95% of all benefits of the scheme are associated with non-environmental effects. A retrospective report by the Environmental Protection Agency (EPA) estimated that implementation of the Acid Rain Program avoided between 20,000 and 50,000 premature deaths annually due to reductions of ambient particulate matter (PM) concentrations, and between 430 and 2,000 deaths annually due to reductions of ground-level ozone. Estimates of monetised health benefits vary widely. They fall between $50 billion to more than $100 billion per year (Carlson et al., 2000; Burtraw, 1999; Chestnut and Mills, 2005; National Acid Precipitation Assessment Program, 2005; Shadbegian et al., 2005; EPA, 2011, Stavins and Schmalense, 2013; EPA, 2014).

2.2.2.3 Cost Effectiveness of Abatement

There appears to be disagreement among researchers about the economic efficiency of the program. Estimates of cost savings range between 15% and 90% compared to counterfactual policies that specified the means of regulation in various ways (Carlson et al.,2000; Ellerman et al., 2000; Keohane, 2003; Stavins, 1998). Swift (2001) calculates the compliance cost of the SO_2 program from 1995 to 2000. He shows that under a regulatory method where specific technologies such as scrubbers were prescribed, the compliance cost would have been about $7 billion a year, while under a cap-and-trade system compliance costs were only $1.2 billion a year.

The main point of dispute concerns the 'cost-of-service regulation' that was in in place during the Acid Rain Program. The cost-of-service regulation allowed electricity providers to pass on increases in generation costs to consumers. In the presence of cost-pass through it is argued that there is only little incentive to trade emission allowances and to adopt emission lowering technology and processes (Bohi and Burtraw, 1997; Fullerton et al., 1997; Rose, 1997). However, it has been noted that below state level price control limited the ability of power generators to pass on costs to consumers, thus invalidating the argument at least partially.

In sum, the scheme appeared to perform well along a number of relevant environmental and economic criteria. Nevertheless, a number of factors were identified in literature which kept costs above the theoretical minimum (Ellerman et al., 2002; Ellerman et al., 2000; Arimura, 2002; Bohi and Burtraw, 1992). The level of their influence has been debated. State level regulation encouraged the early use of scrubbers instead of switching to low-sulphur coal, which could have resulted in higher emission reductions over a given time frame. Also, regulation at federal level, such as the New Source Performance Standards protecting air quality when power plants were newly built or modified, constrained the scheme's operations (Stavins and Gruenspecht, 2002). Another potential factor undermining the cost effectiveness of the trading scheme was linked to decisions by officials at state level to protect the local (high sulphur) coal industry (Bohi and Burtraw, 1997; Rose, 1995; Rose, 2000). Policy uncertainty regarding future emission targets as well as the lacking awareness of marginal abatement costs on the part of market participants, particularly in the early years of the programme, led to market illiquidity and distorted allowance prices (Schmalensee and Stavins, 2012).

It is difficult to ascertain the cost effectiveness of abatement. Each assessment is based on different assumptions regarding the benchmark against which the trading scheme is compared. Furthermore, it is problematic to attribute to which extent external factors influenced the effectiveness of the scheme to reach emission targets. A number of studies attributed a significant amount of emission reductions to the deregulation of U.S. railways that allowed the less expensive transport of low-sulphur coal from the Powder River Basin in Montana to power plants across the country[20]. Ellerman and Montero (1998) estimate that the switch from high sulphur coal to lower sulphur coal reduced the amount of abatement by about 1.7 million tons of SO_2, half of the required reduction in the first trading phase.

Despite different views on the program's cost effectiveness compared to alternative measures, there is wide agreement that SO_2 allowance trading performed well. It lowered emissions quicker than expected and delivered significant co-benefits, most importantly health benefits for people living in the vicinity of fossil-fuel power plants.

[20] Powder River Basin coal is classified as "sub-bituminous" and contains an average of approximately 8,500 btu/lb, with low sulphur. In contrast, eastern Appalachian bituminous coal contains an average of 12,500 btu/lb and high sulphur. Powder River Basin coal was not in demand until SO_2 emissions from power plants became a concern. A coal-fired plant designed to burn Appalachian coal had to be modified to remove SO_2 at a cost estimated of about $322 per ton of SO_2. If it switched to burning low-sulphur coal, the removal cost dropped to $113 per ton of SO_2. Removal is accomplished by installing scrubbers (CBA, 2017).

2.2.2.4 Socio-Economic and Distributional Impacts

The assessment of wider socio-economic impacts of an intervention with a primarily environmental focus is an increasingly important aspect of evaluation practice. Very limited information was located on the effect of the SO_2 emissions trading scheme on economic growth. Only one study by Chan et al. (2012) appeared to consider the distributional effect on consumers.

One critical question surrounding the distribution impact of pollution markets is how to allocate the allowances, which represent the right to emit a unit of a certain pollutant. There are two main mechanisms, the sale of the allowances (usually through an auction) and the free allocations (usually based on past emissions levels), often referred to as 'grandfathering'. Under grandfathering polluters receive a lump-sum of valuable assets in the form of emission allowances. De-facto the free allocation of emission allowances represents a wealth transfer from consumers to producers. It neither increases nor decreases the incentives for producers to change their activities. A number of studies conclude that actual or perceived cost of the cap-and-trade system passed on to consumers via increased energy prices was the sole effect of the emissions market (Barret, 2009, Hasset et al., 2008; Jensen and Rasmussen, 2000; Smith, 2000)

The case for free allocation of SO_2 allowances rested on three main arguments. Firstly, the main motivation of handing out free allowances was to gain the political support of heavy polluters. Free allocation aims to ensure that the SO_2 trading scheme does not reduce the profitability of regulated power providers (Joskow and Schmalensee, 1998; Sjim et al. 2006; Chan et al, 2012). Prior to the implementation of the sulphur allowance market a number of attempts were made by corporate lobbyists to prevent the Acid Rain Program by insisting it would be damaging for economic growth. However, over time the program increasingly gained in popularity with industry. The cost of compliance was considerably lower than in previous air control programs. According to an assessment by the EPA the economy grew by 64% even though the program cut acid rain pollution by more than half (Schultz, 2009).

Secondly, the free allocation of allowances had political value as it mitigated differential economic impacts across regions. The coal plants that effected the largest share of SO_2 reductions were concentrated in the eastern part of the country (Joskow and Schmalensee, 1998). At first distributional concerns arose with respect to regional impacts. However, compliance costs were kept low so that overall SO_2 allowance-trading did not have significant economic implications on the Eastern states.

Thirdly, the power sector was subject to state-level price regulation. Most electric utilities were regulated and not allowed to hoard windfall profits from the receipt of free emission allowances[21]. The average cost rules applying to electricity providers under the so-called

[21] When a firm can directly influence the level of compensation it receives, e.g. adjustments to regulated electricity prices, it creates opportunities to extract so-called 'rents' at the expense of society (Abito, 2013). A

public utility cost-of-service regulation also prevented the full cost of abatement from being passed on to customers in the form of a tariff increase (Ellerman, 2003).

The adoption of technological innovations and implementation of operational efficiency improvements were another unanticipated outcome, which would have been precluded by conventional control-and-command instruments according to a number of evaluation reports. Power plant operators learned how to burn cost-effective mixtures of different types of coal and how to take the cost of emissions into account when making operating decisions (Ellerman et al., 2000; Popp, 2003; Bellas and Lange, 2011; Frey, 2013).

Even though the SO_2 allowance market functioned well, unintended interaction between federal and state regulation effectively ended its life. The imposition of state-level and source-specific emission standards virtually eliminated the demand for federal SO_2 regulation. Subsequently the trading scheme was closed in 2012.

2.2.3 Evaluation of the European Union Emission Trading System

The European Union Emission Trading System (EU ETS) as the world's most prominent emissions market has attracted much attention from academics and practitioners alike. The exploration of studies on the European scheme is expected to provide further in-depth insights into the functioning of an emissions market complementing the lessons learnt from the U.S. sulphur allowance market.

The program currently covers six types of greenhouse gases including CO_2 emitted by energy intensive installations and airlines operating in the EU. Created in 2005 as a response to meeting the commitments made for the Kyoto Climate Agreement, the ETS has played a key role as an instrument in the EU's long term climate change strategy (EC, 2017a). Over ten years in operation it has offered ample data and has produced a significant number of ex-post ETS evaluation studies. Papers have discussed the scheme's economic performance, its effectiveness to reduce emissions and socio-economic trade-offs. The experience of the EU ETS has informed policy makers not only in the Western world, but also much wider afield. Chinese authorities prior to the implementation of the regional pilots have drawn on lessons and experience from the EU ETS (EEAS, 2016).

As a cap-and-trade scheme the EU ETS functions in principle as the U.S. SO_2 market. During Phase 1 (2005-2007) and Phase 2 (2008-2012) member states proposed a limit ('cap') on total emissions from regulated installations, the so-called National Allocation Plan (NAP). The EU wide cap was converted into allowances, known as EUAs (EU Allowance Unit), where 1 tonne of CO_2 equals 1 EUA. In Phase 3 (2013-2020) a centralised EU-wide cap on emissions is set. The cap will decline by at least 1.74% a year, so that emissions in 2020 will be at least 21% below their level in 2005. In Phase 1 almost all allowances were given to businesses for free. In Phase 2 up to 10% of the allowances could be auctioned instead of

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more detailed discussion on windfall profits in the electricity sector following a market-based intervention is provided in the context of evaluating the EU ETS.

being given for free. The percentage of allowances auctioned was at the discretion of each member state. Over Phase 3 at least 50% of allowances are auctioned. As in any cap-and-trade scheme at the end of a trading period, installations have to surrender sufficient allowances to cover their emissions or sell any surplus (EC, 2017a; EC, 2017b; Climate Policy Info Hub, 2017; Carbon Trust, 2006)

2.2.3.1 Environmental Effectiveness

Depending on the parameters of the evaluation such as the selected counterfactual scenario serving as basing for comparison (BAU or a command-and-control measure) and the mathematical toolset, different studies come to different conclusions regarding the effectiveness of the EU ETS to reduce GHG emissions. Estimations of emission abatement by Ellerman and Buchner (2008) based on an econometric model for the first trading phase (2005-2007) were in the range of 120-300 $MtCO_2$. Anderson and Di Maria (2011) using panel data calculate total abatement equal to 247Mt CO_2.[22] Delarue et al. (2008) calculate that the trading scheme achieved emissions reductions in the power sector of 90 $MtCO_2$ in 2005 and 60 $MtCO_2$ in 2006. Most studies estimate emission abatement between −2.5% and −5% across all sectors for the first phase of the EU ETS.[23]

The lack of reliable emission data meant that Phase 1 caps were determined on the basis of estimates. As a result, the total number of allowances issued exceeded actual emissions. Over the entire trading period the EU ETS had allocated about 5.6% more allowances than needed to cover emissions. With supply significantly exceeding demand, in 2007 the price of allowances progressively fell to zero after peaking at €29.7 per allowance in 2006 (EC, 2006b).

The ex-post evaluation of the second phase (2008-2012) proved even more challenging than the calculation of emission abatement during Phase 1. The global financial crisis affected a slow-down of European production and subsequently emissions. Business-as-usual conditions changed dramatically, making it difficult to calculate emissions reductions directly attributable to the EU ETS. The cap on allowances was reduced in Phase 2. It was based on actual emissions as verified annual emissions data from the first phase was now available (Schleich et al., 2012). Despite the adjustment of the cap a large surplus of allowances depressed the carbon price throughout Phase 2 as the 2008 economic crisis led to emissions reductions that were greater than anticipated (EC, 2017b). A report commissioned by the UK's Climate Change Committee on the impact of the economic downturn on UK GHG emissions (Cambridge Econometrics, 2009) indicates that most of the

[22] In phase 1, trading volumes increased from 321 million allowances in 2005 to 1.1 billion in 2006 and 2.1 billion in 2007 (European Commission, 2017). The quantity of GHG abated over Phase 1 was about 10% of the trading volume at 2007 level.

[23] Note that if the European Commission had not reduced the total of initial NAPs proposed by member states by 4.6%, there would not have been any abatement.

reductions in overall EU emissions that have occurred since the inception of the EU ETS are the result of the economic slow-down rather than the EU ETS itself.

In sum, there is the view that the carbon price signal generated by the EU ETS led to some emission reduction, albeit small in the early years of the scheme (Wrake et al., 2012; Ellerman and Buchner, 2006; Widerberg and Wråke, 2009)[24]. A significant number of authors concur in the opinion that the performance of the EU ETS in terms of emission abatement has been significantly impacted by the over-allocation[25] of allowances (Voorspools, 2006; Clo, 2009; McAllister, 2009). The effectiveness of an ETS to abate emissions depends on the scarcity of allowances in the market. With an oversupply prices typically collapse, making allowances almost valueless and thus greatly limiting the scope of the market to create incentives for polluters to lower emissions.

2.2.3.2 Cost Effectiveness of Abatement

In the absence of tangible emission reductions that can be attributed to the EU ETS, analysing the cost effectiveness of the scheme appears futile. A search for studies on this topic could not locate any relevant literature. A number of policy papers suggest future measures to improve cost effectiveness such as the introduction of an allowance floor price or a mechanism to adjust the cap over the course of a trading period to reduce the number of surplus allowances (Abrell et al.,2016).

2.2.3.3 Socio-Economic Impacts

In addition to reducing emissions, another key objective of an ETS is to facilitate the *transition* to a low-carbon *economy* through fostering the adoption of low-carbon technologies by installations participating in the market.

The multiplicity of policy measures that support Europe's transition to a low-carbon economy make it difficult to establish to which extent the adoption of innovative technology can be attributed to the EU ETS. In the absence of quantifiable information, a number of studies on the topic evaluate the impact of the scheme on investment in innovation through surveys and interviews with managers at firms participating in the EU ETS (Martin et al., 2011; Aghion et al., 2009; Hervé- Mignucci, 2011).

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[24] Over-allocation does not automatically rule out net abatement.378 million allowances were never used for compliance so it is feasible that some abatement can be attributed to the EU ETS (Trotignon and Ellerman, 2009)

[25] An ETS program is considered to be over-allocated if the emission cap is set at a level beyond "business-as-usual" (BAU) emissions. (Ellerman and Buchner,2008).)

The abovementioned studies cover different sectors and regions. Overall they find that a considerable number of companies have been incorporating the allowance price into their decisions to invest in low emission technology and the improvement of processes. Most papers conclude that the EU ETS has emerged as a driver for small-scale investment typically with short pay-back periods. However, it appears that criteria other than a price on carbon drove long term and large scale investment decisions, particularly in the energy sector (Hoffman, 2007; Neuhoff et al., 2011; Lofgren et al. ,2013; Rogge et al., 2010). Most ETS-compliant power generators postponed investing in newer and low-carbon gas technologies, for example, as the collapse of the carbon price provided little or no incentive.

A study by van der Gaast et al. (2016) finds that instruments such as the Feed in Tariff (FiT) Scheme and Feed in Premiums (FiP) have resulted in stronger deployment of renewable energy technologies than the EU ETS. The overachievement of the renewable target in the power sector meant that the demand for ETS allowances by electricity generators decreased, resulting in a lower allowance market price. In terms of economic efficiency, the interaction between the EU ETS and other policy instruments resulted in a loss. Emission abatement delivered by supporting polices such as FiT or FiP have higher costs than those through cap-and-trade systems such as the EU ETS.

In summary, the evidence collected by the surveys and interviews questions the EU ETS' contribution to foster technological innovation on a large scale. The collapse of the allowance price, along with its volatility resulting from an allowance oversupply and global economic fluctuations, seem to have removed incentives for long term investment into low-carbon technology. However, the EU ETS appears to have had a positive role in creating awareness amongst regulated and non-regulated corporations alike of the concept of a cost on carbon (Marcu, 2016).

2.2.3.4 Distributional Impacts

The cost on carbon increases input costs of firms regulated by an emissions trading scheme. Firms have three options: Firstly, they can absorb the cost by reducing profit margins; secondly, they can decrease costs by improving their efficiency; or thirdly, they can pass the additional costs onto the consumers of their products (Laing et al., 2015). Economic theory suggests that cost pass-through is likely for profit-maximising firms (Ritz, 2015; Fabinger and Weyl, 2013).

The review of studies on the extent of cost pass-through made apparent that the quantified cost pass-through rates vary significantly across studies and sectors. They are dependent on the method and data set, i.e. the assumptions made for the carbon price, price elasticity of demand[26], the degree of competition between companies and the region under investigation (European Commission, 2015). The cost pass-through of carbon costs appears especially high for sectors that do not face international competition from outside the EU, such as the power sector because of the limited transmission capacity between EU member states and non-EU countries (Laing et al., 2015).

Closely linked to the pass-through of the carbon cost is the realisation of windfall profits by regulated firms. There is plenty of empirical evidence that companies have generated windfall profits as they have been able to pass through all or part of the carbon costs in product prices (Laing et al., 2014; Venmans, 2012).[27] Windfall profits occur for three reasons. Firstly, windfall profits are created if the polluter is allocated allowances in excess of his emissions (Dimantchev, 2016). Extra allowances generate income when sold. Secondly, windfall profits are generated when allowances are obtained for free (rather than through an auction). Even though the market participant was given the allowances free of charge, the hypothetical costs of these allowances are included in product prices paid by consumers (Sijm et al., 2006). A third source of windfall profits is the so-called Certified Emission Reductions (CERs). In this case companies have used cheaper international off-set credits from the Kyoto Protocol's market mechanisms, the Clean Development Mechanism (CDM) or the Joint Implementation (JI), to meet their emission target instead of their free allowances. The remaining free allowances were sold on the market for a higher price. In some instances the CERs were banked for future use (CE Delft, 2016; Joskow and Ellerman, 2008)

All studies examined, irrespective of their evaluation methods, found a positive and highly significant influence of CO_2 cost on the product prices across sectors. A report by CE Delft (2015) covering the period from 2005 to 2009 finds that pass through in the cement sector is amongst the lowest (20-30%), while steel industry passed on 55-85% of their carbon cost burden. The majority of the literature on cost pass-through appears to be concerned with the electricity sector. In addition to the early study of Sjim et al. (2006), Jouvet and Soulier (2013); Mirza and Bergland (2012) and Zachman and Hirschhausen (2008) find cost-pass-through in the power sector to be significant. There is general agreement that a high rate of cost pass-through results in higher electricity prices for consumers and windfall profits or the power companies (Kara et al., 2008; Oranen, 2006; IPA, 2005 and Linares et al., 2006).

[26] The price elasticity of demand measures the percentage change in the consumption of a good resulting from the percentage change in its price (Varian, 2014). The concept of demand elasticities will be explored in more detail in the empirical part of this study (Chapter 6).

[27] By 2012 the estimated 230 million surplus EUA permits, worth up to 3 billion Euros at a price of €13 per tonne have resulted in significant financial gains for some of the largest polluters (Sandbag, 2013). Across 19 member states windfall profits from over-allocation were calculated as over 8 billion Euro. The usage of CERs for compliance instead of over-allocated allowances yielded an estimated profit of over €630 million. The additional profits from passing through carbon costs was calculated as a minimum of €15 billion between 2008 and 2014 (CE Delft, 2016).

In a frequently cited report to the European Commission Sijm et al. (2006) assess the impact of EU ETS on electricity prices. They find empirical evidence that electricity generators passed through the opportunity value of their freely obtained allowances into the electricity prices in the first two trading periods of the ETS. The study calculates that cost pass-through rates on the forward market in five countries (France, Germany, the Netherlands, Sweden, the UK) were between 38% and 83% in 2005 and 2006. Assuming a carbon price of €20/t CO_2 price and perfect competition between firms, they find power windfall profits of 28 billion Euros across 20 member states. In an oligopolistic scenario, where individual firms have less market power, windfall profits were around €4 billion lower.

Lise et al. (2010) calculate windfall profits of electricity producers from 20 European countries. They found cost pass-through rates between 70% and 90% and mean tariff increases of €10–13 per MWh. Windfall profits for the power sector were estimated to fall within a range of €24 and €35 billion for an assumed allowance price of €20/t of carbon.

A Carbon Trust report (2006) estimated that the UK electricity industry had made approximately €1 billion in wind fall profits in the first year of trading. Studies on other countries such as Germany and Holland also reported significant windfall profits in the power sector (Frontier Economics 2006). According to a retrospective analysis by Sandbag (2011a) in 2011 77% of EU ETS installations held surplus allowances that had been accrued from both previous over-allocation and the financial crisis. The study estimates that 855MtCO2e of excess allowances will have accumulated by the end of Phase 2, of which 672MtCO2e are expected to be banked for use in Phase 3.

2.3 Lessons Learnt from the Application of Emissions Trading

The review of evaluation literature on two prominent emissions trading schemes offered insights into the challenges involved in the design and implementation of such a scheme. The literature was presented through the application of a multi-criteria evaluation framework: Environmental effectiveness, cost effectiveness, wider socio-economic impacts and distributional implications in particular. The fourth evaluation criterion, institutional feasibility, will be considered as part of the following discussion.

The many facets covered by these four criteria highlight the far reaching impacts of a market-based instrument which extend far beyond emission levels and the environment. Impacts are often interconnected, unexpected and unintended as the experience of the EU ETS has shown. Awareness of these interactions could prove useful for the study of China's market-based sustainability transition.

The first key insight gained from the reviewed literature is that unintended consequences of supplementary policies on the ETS are almost inevitable. They can be beneficial as in the case of national energy sector regulation in the EU or the deregulation of the railway in the U.S. Sometimes, however, the effect can be negative for the performance of the scheme.

The introduction of air pollution regulation at state level in effect made the national sulphur market redundant and led to the decision to terminate it. Often these interactions are difficult to predict. The implication is that supplementary measures to a market-based instrument need to be carefully considered. The performance of the EU ETS has been seriously impacted by the interaction with 'parallel instruments' such as FiT and FiP deployed as part of the Renewable Energy Directive. These instruments affected emission levels of ETS regulated installations and subsequently the demand for allowances and the allowance price. Mulder (2016) finds that these interactions alone continue to decrease the allowance price by €5 by 2030 compared to a scenario without the two parallel instruments.

The second lesson learnt from the evaluation literature is that the policy environment has a decisive impact on the performance of an ETS. The degree of deregulation, particular in the power sector, has a significant distributive impact. Freely allocated allowances have a very different effect on electricity prices depending on the degree of regulation (Joskow and Ellerman, 2008). In settings, where electricity tariffs are capped or regulated, generators may not be able to pass through the hypothetical costs of free allowances into retail prices, so that windfall profits may not be fully realised. In the U.S. electricity consumers were shielded from the full price impact of freely obtained SO_2 allowances through state regulation. While the EU ETS was being designed and implemented, the EU was also taking steps to deregulate the wholesale and retail electricity markets (Serena, 2014; Jamas and Pollitt, 2005). In a regulated market power companies are assured of cost recovery in electricity tariffs but only of incurred operating and capital costs. In contrast, in a deregulated system there is no assurance of cost recovery. Power generators receive the market price of electricity regardless of their incurred costs. In a regulated electricity sector generators recover the cost of purchased or auctioned allowances from consumers. The cost of allowances is offset against the revenues generated from the sale of excess allowances. Unlike in a deregulated electricity sector the hypothetical cost of free allowances cannot be passed on to consumers. In such a scenario the generator receives the market price for electricity, which may include the market value of CO_2 allowances, regardless of whether these allowances were obtained for free or purchased.

Even in a policy environment where windfall profits cannot be fully realised, market-based instruments that put a cost on environmental damage have significant distributional effects. As environmental taxes have been in existence longer than pollution markets, ample research has been conducted to assess the distributional effect of taxes. Studies found tax on pollution to be regressive. This means that the tax burden is more than proportionally borne by poorer households (Zhang and Baranzini, 2004; Speck, 1999). This is because heating and electricity are typically overrepresented in the expenditure of low income households (Feng et al., 2010). A carbon tax and auctioned emission allowances have a very similar effect on income distribution as they induce the same price increases. However, when emission allowances are allocated for free carbon markets become more regressive. In a scenario of firms accruing windfall profits from the free allocation of allowances, Dinan and Rogers (2002) find that for a 15% reduction in CO_2 emissions by an ETS, the poorest 20% of households would be worse off by around €500 per year on average, while the top earning households would experience an annual income increase of around €1000. This is because income from emission trading is indirectly distributed to wealthy households through profits for participating industries that are ultimately passed on to shareholders (Parry, 2004)

Windfall profits from the free allocation in the presence of cost pass-through represents the transfer of income from polluting firms such as power plants to consumers. Goulder (1995) put forward the idea of the 'double dividend'. He proposes that revenue from regulation is used to cut distortionary taxes and to mitigate the recursive effect of emission markets. If the allowances are auctioned to regulated generation plants, the auction revenue could be 'recycled' or redistributed to society at large, perhaps to subsidise electricity tariffs for low income households or to support the development and deployment of green generation technology (Venmans, 2012; Callan et al., 2009; Parry, 2004).

The regressive effect was not compensated by the EU ETS (Venmans, 2012). To some extent, the revisions in Phase 3 of the EU ETS have tackled the problems of free allowances and over-allocation, but the pass-through of carbon costs has yet to be addressed (EC, 2017a). There is widespread agreement amongst the studies reviewed that the distributional effects were a major issue of the EU ETS in its present form. A more detailed discussion on transfers between low-income and high-income households caused by the EU ETS is needed to make the discussion about the scheme's equity impact more concrete.

The third insight gained from the review of literature on the two Western emission markets is that politics typically takes precedence over science and economics. Targets, i.e. the cap, and allowance allocation are political decisions rather than the result of careful scientific analysis. In the EU, representatives from industry provided input in the design of the market, which was driven by the consideration of costs and benefits rather than environmental and social motivations. Institutional feasibility through the acceptance of the scheme by regulated firms is paramount. Business support for both the SO_2 programme and the EU ETS was founded on free allowance allocation, making participation in both instances attractive for the majority of participants. The study of evaluation literature made clear that industry has significantly benefitted from the EU ETS, whilst the scheme's effect on emission abatement has been minimal. In case of the sulphur allowance market distributional impacts were less pronounced as the electricity sector was regulated to a higher degree. The scheme also contributed to improving environmental conditions to a larger extent than the European carbon market. The losers in these distributional effects, mainly EU electricity consumers and low-income households, had a relative lower weight in the political balance (Venmans, 2012; Renaud, 2007).

The root cause of the EU ETS' relative ineffectiveness to meet its objectives has been policy makers' reluctance to set ambitious reduction targets and to implement policies to achieve them (Fagan-Watson et al., 2015). Without effective targets, there is no incentive to cut emissions, irrespective of whether a tax, command-and-control regulation or emissions trading is chosen as policy instrument. In this vein Schjolset (2017) concludes that "No policy instrument, be it emissions trading, subsidies or hard regulations, will ever be more effective than policy-makers allow it to be."

The fourth and final lesson derived from past studies is that the allowance price is pivotal. Decisions in a market economy are by large part driven by price. An ETS, by creating an opportunity cost of emissions, harnesses the price signal to induce actions to lower emissions. If the price is too low, behavioural change necessary to bring about a reduction in emissions is unlikely to occur (Frontier in Energy, 2006). The price level is an indication of environmental ambition as it determines the abatement effort. In effect the price level is a political decision, as it policy makers who decide on the 'cap' and other market features such as a price floor (Grubb, 2012). The government also determines who shoulders the cost burden and where abatement occurs. Decisions such as the allocation method (free vs auctioned allowances), the redistribution of revenue (from allowance auctions and compliance penalties) and cost-pass through mechanisms determine who covers the cost of an emissions market. In the EU ETS fictional costs incurred by the power sector were passed through to households. Households inadvertently became stakeholders in the emissions market as they were affected by the ETS, even though they had not been the direct target of the policy instrument.

The evaluation literature on both the U.S. SO_2 allowance market and the EU ETS illustrated that emissions trading is no longer just a subject for academic research. Despite its real life shortcomings, the trade in pollution allowances appears to be a viable option to solve large scale environmental problems. The mistakes of past and present schemes, the EU ETS in particular, provide valuable lessons for future ETS. Evidence for the effectiveness of emission markets, however, will only emerge, if policy makers set ambitious targets and intervene in market proceedings to maintain them. The real test of effectiveness will be in China, where a national carbon market is underway. The implications of a functioning scheme to realise significant emission reductions are significant for the proponents of market-based policy instruments, and even more so for efforts to tackle global and national environmental challenges (Schjolset 2017; Jotzo and Löschel 2014).

2.4 The State and Market Relationship in China

Most literature on environmental policy instruments draws a distinct line between economic instruments and direct regulation of activities by legislation that specifies what is permitted and what is not. On the one side, the use of economic instruments such as emission markets or subsidies to solve large scale environmental problems is justified with the failure of governments to address these issues in an efficient and transparent way (Stern, 2007; Tietenberg, 2006). This view also highlights the 'democracy enforcing' capacity of emission markets, where firms are given the freedom to decide as to how meet a fixed target (Ackerman and Stewart, 1987). Command-and-control measures prescribing how much pollution an individual plant is allowed to emit and/or the types of technology used to meet requirements are frequently seen by proponents of markets as politically motivated and driven by vested interests (Bogojevic, 2013). One the other side, the argument for state intervention is the need to fix market failures and inequalities brought about by economic instruments (Stiglitz, 2010).

The idea that markets are autonomous entities separate from the state does not reflect real world conditions. The state plays a key role in the design, implementation and running of a market-based solution as the evaluation of real world emission trading schemes has demonstrated. The interwoven relationship between state and markets is often overlooked. In case of the EU ETS situated in the context of a liberal market economy, one key reason for the scheme's limited effectiveness to reach environmental and economic goals was found to be a weak state that let regulated firms dictate market rules. At the same time the viability of an emissions market in China has been questioned due to the absence of a liberal economic system (in the Western sense), which is presumed to be a prerequisite for any functioning market (Lo, 2013).

The relationship between state and market in China per se is complex. Prior to the reform the state directly controlled all aspects of production. Free trade and other forms of market economic activities were forbidden. The command economy severely restricted the development of the country and the majority of Chinese people were severely impoverished. The turning point came when the central leadership decided to introduce elements of a market economy. Since the end of the Mao era China transformed from an economy owned and controlled by the state to one supervised and regulated by the state in combination with market mechanisms (Li and Shaw, 2013). The market has been gradually replacing the state in determining investment, production and consumption.

Over the forty years of economic reforms the demarcation between the state and market has remained blurred (Breslin, 2007). As the state has been reasserting itself recently, the trajectory of China's approach to economic governance is in more doubt than ever (Kennedy 2016; Østergaard 2014). The leadership has not followed through announced reform plans with the market playing a 'decisive' role in China's economy. Market liberalisation is now seen as secondary to the leadership's state-centred approach to economic policy (Mitchell, 2017). At the 2017 Communist Party Conference President Xi Jinping reaffirmed the central role of the Party. He announced a 'new era' in Chinese politics where the Party would permeate all aspects of life, from finance to technological innovation (Haas, 2017).

A number of authors attribute China's rapid economic rise to its form of 'state-led capitalism' (Huang, 2008; Lin et al., 2003). The approach of the central government has been to position significant amounts of capital in sectors with high strategic value, such as energy or transport, while regulating no strategic sectors to a lesser degree. State Owned Enterprises (SOE) could so dominate key national and regional markets without facing competition from private and foreign firms (Hsueh, 2011). This growth model has relied on cheap labour. As the country is becoming more affluent and its labour force is shrinking, China's competitive wage advantage is gradually breaking away. Massive amounts of government investment to support projects of questionable value and profitability are the reason for overcapacities in traditional industries such as coal, steel and cement. State led capitalism appears to be reaching its limits to guarantee continued growth (Whyte, 2009; Nee and Opper, 2007).

Emissions trading reflects the deeper and more profound dilemmas of the market transition. The aforementioned SO_2 emission trading experiment was characterized by market illiquidity, government organised transactions and discretionary trading arrangements between the authorities and regulated firms (Tao and Mah, 2009). Local governments were active in taking the part of market players instead of sticking to a role of market designer and limiting interventions to the smooth running of the markets. On most markets local governments were acting as counterparty, either as seller or buyer, in every trade. In effect, the allowance price was mostly fixed, no longer reflecting the balance between supply and demand. In addition, government action undermined market stability as the schemes were designed and overhauled in some cases and in other cases abruptly closed down (Zhang et al., 2016; Lo, 2015). In a way, the SO_2 pilot markets resembled "state-led pseudo-markets instead of autonomous markets" (Liu, 2016), and hence undermining the potential of markets to abate at least cost. Emissions trading in its practical application embodies the delicate balance between state and market. As the experience of the EU ETS has demonstrated, in absence of government intervention markets might fall short of meeting their abatement targets (Felli, 2015; Stephan and Paterson, 2012). On the other side, excessive intervention of the Chinese state was found a major obstacle in regional SO_2 pilots to achieve cost effective abatement. The juxtaposition of the programmes highlights that markets do not exist in a vacuum, but are shaped by norms and political and social relations (Liu, 2016).

One of the most widely discussed questions in the academic literature is whether development and specifically the transition of an economy from one that is centrally controlled by the government to one which is predominantly based on markets inevitably promotes the democratisation of authoritarian regimes (Acemoglu and Robinson, 2006; Przeworski et al., 2000; Wejnert, 2005), and if so whether this can be expected to take place in China. Civil society theory postulates that affluence acts as link between political democracy and a market-based economy (Ersson and Lane, 2008). Seymour Martin Lipset (1959), in his seminal article on the relationship between economic and political development, concluded that the attainment of a certain level of affluence is a prerequisite for political democracy. Milton Friedman (1962) looked at the relationship from a different angle. He thought that a market-based economy encourages political development towards democracy.

Literature on past transitions in East Asia cite South Korea as an example to support the notion that development, the adoption of market mechanisms and the democratisation of society are linked (Dwivedi, 2017; Kim, 2000; Chung-si, 1991). After a tumultuous period of the Second World War the military seized power in 1961. At this point in time South Korea was one of the poorest countries in Asia. Determined to catch up with the more developed North the military leadership carried out radical changes in politics, economy and society. Over two decades of dictatorship rapid industrialisation was prioritised over freedom and democracy. Individual freedom and human rights were considered to hinder economic development (Kim, 2005; Lee, 2000). Between 1962 and 1987 the South Korean economy grew by an average of 9%. Economic expansion was mainly carried by the authoritarian regime's ability to keep labour costs low so that Korean products were competitive in the export market. Development had the effect of shifting the composition of the Korean labour force from almost 80% engaged in the primary sector in the early 1960s to 70% engaged in the secondary and tertiary sectors by the late 1980s (Johnson, 1998). The government-led economy gradually gave way to the private sector in the early 1980s. Early market liberalisation polices are considered as token measures to protect family conglomerates which have been dominating the Korean economy to this day (Yeong, 2015).

Increased affluence and the modernisation of society generated growing demand for political liberalisation and democracy amongst South Korea's younger generation. In the 1980s millions of students and intellectuals took to the streets to protest against human rights abuses and to demand political democratisation. Their demands gradually began to spread to the other parts of society (Dwivedi, 2017). However, very much to the disappointment of the pro-democracy movement, it was a general, handpicked by the former military regime, who won the first free presidential elections in 1987 (Heo et al., 2008; Adesni and Kim, 2008). The democratic transition of 1980s appeared to have been merely a formal one. It lacked the support of the broader middle class and the entrepreneurial elite that had formed a close relationship with the political leadership over the years of military regime. The business sector, dominated by big conglomerates that enjoyed government protection, remained passive throughout the process of political democratisation even though it was indirectly its driving force. The transition towards democracy was not complete until after a decade with the victory of the opposition party (Ki, 1993; Stenzel, 2006). The election of a liberal government appears to coincide with Korea's transition to a true market economy as for the first time regulation allowed smaller and medium sized enterprises to break into the monopolies held by the big conglomerates (Yeong, 2015).

The experience of South Korea provides two insights relevant for the study of China's transition. Firstly, it confirms the existence of a link between economic development and the opening up of the political process to civil society. Economic growth and rising affluence amongst the population provided the impetus for some parts of the society to form a democracy movement demanding greater participation in the political process.

Secondly, Korea's pathway highlights that democratisation can take many trajectories, which might not necessarily coincide with Western ideas. Unlike in Europe, in South Korea it was not the working and middle classes that put the country on the road to democracy, but a minority of students and academics. This could possibly explain why the direct successors of the military regime could stay in power for considerable time, even after the first free elections. The delay in the transition towards a truly democratic society further suggests that economic reform does not necessitate the simultaneous dual transition to markets and the democratisation of the political system. In the context of Korea's transition both Friedman's and Seymour's ideas hold true. Markets appeared to have been a driver for democracy, once a certain level of affluence is enjoyed by society at large. Affluence in turn was created by markets themselves. In sum, there seems to be a relationship between markets, democracy and the level of development. It appears difficult, however, to establish a clear order of events or an unambiguous cause and effect chain.

Like South Korea in the 1980s, after a period of rapid industrialisation, China is at a crossroads. Whilst the leadership is looking to reform the economy, there is little sign of a transition of the political system. The Chinese Communist Party remains firmly in control and prevents any opposition from gaining a voice in the political process. In parallel to Korea, China's new private business sector appears to be content to support the regime rather than to demand political change (Whyte, 2009; Dickson, 2008). In contemporary China the state-market boundary appears to be particularly blurred. In literature evidence is presented that non-state business actors have close links to the state and the Communist Party (Breslin, 2007; Wank, 2001). Frequently, private business leaders originate from the party elite, or are relatives or close friends of senior party-state officials (Dickson, 2003). In case individuals lack these connections, they often seek Party membership or affiliate their business to a state-controlled enterprise in order to gain advantage over their competitors (Chen, 2007).

In both, the business sector and civil society, it is difficult to distinguish between public and private spheres (Wright, 2016; Wank, 2001). What is from a Western perspective is considered 'non-state' and 'state' is closely connected and entwined in China. Since the post-Mao reform the state has created opportunities for citizen participation. One significant development has been the emergence of non-governmental organizations (NGOs). The relationship between these organisations and the state is complex, however. Grass root NGOs require official authorisation by the state and are subject to continuous supervision by a government minder. They co-exist with government organised NGOs (the so-called GONGOs). GONGOs are sponsored by the government in order to further its political interests (Lu, 2008; Ma, 2005). The inter-wovenness of state, business and civil society appears to have played an essential part in absorbing potential opposition to the regime in the past.

If a dual reform of economy and society is a prerequisite to succeed in today's global economy, then China has challenged these expectations (Centeno, 1994). The degree to which a civil society exists is debatable (Tai, 2007). There is agreement though that at the moment civil society lacks the autonomy to fully develop outside powerful and all-inclusive State (Teets, 2015). Literature suggests that in the longer run, the rise of an affluent, well-educated and well-travelled Chinese middle class with access to modern technologies such as the internet could give rise to a citizen movement challenging the central role of the political leadership (Huang and Sun, 2014; Stoycheff and Nisbet, 2014; Esarey and Qian, 2011; Esarey and Qian, 2008). A survey by Lei (2011) finds that in contrast to users of traditional print media and television, internet users tend to be more critical about the state and the political conditions in China. They are also more likely to be active participants in collective action. In response to these challenges posed by a modern and more affluent society, China's political leadership is determined to control any activities that are considered to be a threat to the regime. Authorities have increasingly suppressed activities of civil society, groups and individuals in areas that were previously acceptable (Campbell, 2016)[28].

Literature on the democratisation of autocratic regimes and the real-life example of South Korea have shown the implications of economic development in China for more open and participative forms of governance, with a growing educated middle class acting as a potential driver. In spite of its relative stability, over time the political system will have to adapt to an increasingly pluralistic society built on openness, self-determination and individualism in order to avoid widespread discontent with the current political, social, economic and environmental situation. Political change and adaption in this new critical era of government initiated era of markets appears inevitable in the long term.

2.5 Relevance of the Study

China matters. China is the world's biggest polluter. The world's prosperity is linked to China's economy as never before. A national emissions trading scheme was selected as a key instrument to facilitate the transition to the 'New Normal', China's new ideals of an economic model promoting environmental quality and an equitable society. The effectiveness of the scheme to lower carbon emissions has significant implications on global efforts to prevent serious climate change impacts. At national level the emissions trading programme has environmental implications for the population being exposed to pollution as the result of China's 'growth at all cost' paradigm.

In the past the theory of emissions trading has been situated in the context of Western liberal market economies. A plethora of literature evaluating these schemes along multiple criteria was located. In particular, evaluation literature on the EU ETS found that due to its significant socio-economic impacts emissions trading is more than a purely environmentally motivated instrument. Frequently unintended consequence of actions aimed at meeting environmental and economic objectives have unexpected distributional implications on the consumers of emission intensive goods.

Evaluation literature assessing the experience of emissions trading in China tends to focus on technical obstacles with the implementation of markets such as the absence of reliable emission data (Wang, 2013) or the lack of effective market supervision (Liu et al., 2015). Research on the environmental and cost effectiveness of the eight regional pilot markets remains inconclusive due to the short trading period since the inception of the scheme, the lack of reliable data and intransparent analysis techniques. In light of the experience from Western emission trading schemes, it is expected that the national carbon market will have

[28] Document No. 9, an internal Party directive issued as President Xi came to power, considers an active civil society as a risk. The document states: "Advocates of civil society want to squeeze the Party out of leadership of the masses at the local level, even setting the Party against the masses, to the point that their advocacy is becoming a serious form of political opposition" (China File, 2013).

significant implications on the sustainability objectives to be achieved by the 'New Normal'. Publications on the emissions trading situated in a Chinese context, however, appear to pay very little attention to distributional implications of the future carbon market that could affect the achievement of the key equity goals of 'shared and integrated development'. Another area that seems under-researched is the wider consequences of China's move away from exports and traditional manufacturing towards a consumer-driven economy to accomplish the sustainable 'New Normal'.

The discussion on the problem situation presented a number of empirical puzzles that need to be clarified, in particular the implications of a carbon market on the complex relationships between different developmental goals China's leadership is pursuing through the adoption of a novel market-based approach.

The review of literature on China's developmental history illustrated the key role of electricity sector as a driver for advancement and growth as well as a major cause of environmental pollution with serious local and global effects on the livelihoods and wellbeing of people. The electricity sector further epitomises the wide ranging issues which are linked to a consumption based economy. The regulation of electricity generation and consumption by households through an emissions trading scheme has been identified as a suitable case study to investigate the environmental effectiveness, wider socio-economic impacts and distributional implications as well as the institutional feasibility of a carbon market embedded in the political economy of China. Firstly, energy related emissions are expected to be covered by the national market as the combustion of coal by electricity generating plants is one of the main causes of greenhouse gas emissions and other forms of pollution. Secondly, as the experience of the EU ETS has shown, the division of the carbon cost between electricity generators and consumers has significant distributional implications on household. Thirdly, current energy generation and usage patterns are a reflection of the regional differences in socio-economic development and pollution levels. Fourthly, the highly state regulated electricity sector is a reflection of China's economy as a whole. It particularly exemplifies the tension between market mechanisms and state control. Finally, people are at the centre of the sustainability challenge. Rising electricity demand from an affluent middle class, a new driver for economic growth, is threating to unhinge the transition to a low carbon energy system.

In addition to the study on the market-led electricity sector reform another key empirical puzzle emerges which needs to be addressed. As consumption by the affluent middle class is increasingly replacing industry as driver of development residential electricity users become stakeholders in the reform. To date, China's authoritarian regime has excluded citizens from the policy making process. However, their inclusion in all stages of the reform from planning to implementation will be a prerequisite for its effectiveness. Due to the absence of civil society from the political process very little is known about the relative importance people place on the different sustainability objectives pursued by the government. The majority of surveys conducted to understand people's views towards the environment are either very general in nature (for example: Gao, 2015; Liu and Mu, 2016) or enquire about a specific aspect related to environmental behaviour. For example, Sun et al. 2016b and Wang et al. (2016b) both conduct surveys to gauge the public's willingness to pay for clean air. Xiaohua et al. (2017) and Yu and Guo (2016) investigate household energy consumption in rural China. Other studies appear to have a regional focus. Niu et al. (2017) limit their study on residential electricity consumption behaviour to North Western China. Lo and Leung (2000) focus their research on understanding public views on environmental degradation in Guangzhou. Very little appears to be known about people's views on potential trade-off between the sustainability objectives and whether these views vary across regions. The elicitation of interests, priorities and motivations to adopt energy saving behaviour is another important area that warrants further investigation into how a market mechanism in an economy controlled by the state can flourish and lead to the desired effects. The second riddle is related to the fundamental theoretical assumption that development and affluence, in particular when facilitated through markets, are linked to the democratisation of the policy making process.

To the knowledge of the author, no comprehensive empirical research has been conducted to investigate the interplay between competing environmental and socio-economic challenges against the emergence of drivers of unsustainability stemming from rising household consumption. Numerous studies were undertaken to better understand the multi-facetted sustainability challenges China is currently facing. Most of the research, however, compartmentalises these different problems and analyses them in isolation. The analysis and fieldwork in this research seeks to develop an understanding as to how these problems are linked and how they feed back on each other against the backdrop China's transition towards a consumption and market-based economy.

A study on the complex challenges inherent in China's market-based sustainability reform addresses several theoretical puzzles that have affected the country's transition to a market economy. At the outset is the puzzle how a market mechanism in an economy controlled by the state can flourish and lead to the desired effects. The second riddle is related to the fundamental theoretical assumption that development and affluence, in particular when facilitated through markets, are linked to the democratisation of the policy making process. Such analytical efforts will hopefully provide insights into how the concept of emissions trading functions within a setting that does not currently embody the Western liberal ideals of a liberal economic and political system.

2.6 Research Questions

The research questions are designed to better understand the current challenges China is facing during the market-based transition of its development model. The introductory chapter presented the various facets of the country's sustainability problems. It highlighted the complexity and the interdependence of the far reaching issues that are linked to the reform. The residential electricity sector was found to be a useful case study to answer the overarching research question, which is concerned with the effect of emissions trading on region specific socio-economic disparities linked to electricity generation and consumption.

Diagram 2.3 Overview of Research Questions

What is the potential of a carbon market to equitably alter regional generation and consumption patterns of the residential electricity sector in China?

Key Question 1: What are the perceptions of stakeholders on the residential electricity sector reform?

Key Question 2: What are the opportunities and constraints of a price signal to reform of the residential electricity sector?

Key Question 3: What are the opportunities and constraints of a market-based approach for the reform of the residential electricity sector within the particular political, cultural and institutional context of China?

Key Question 4: What is the most equitable outcome of a market-based approach to reform residential electricity sector?

Q 1.1. Who are the stakeholders in the residential electricity sector reform?

Q 1.2. What are their views on the current problems linked to the residential electricity sector?

Q 1.3. What are the priorities for the outcome of the reform for each study region?

Q 2.1. To what extent can a price signal influence drivers of an unsustainable energy system, rising consumption from households in particular?

Q 2.2. What are the intervention points for policy making to regulate the price signal?

Q 2.3. What is the effect of different price-based interventions on regional disparities?

Q 3.1. What are the structural political and institutional barriers to a market-based reform?

Q 3.2. What are the behavioural barriers to the reform?

Q 3.3. What non-price incentives determine consumption behaviour? How does the propensity to react to price and non-price incentives vary across regions?

Q 4.1. Which is the preferred market based intervention in each study region and at national level ?

Q 4.2. Which market based interventions effectively mitigate regional disparities ?

As shown in Diagram 2.3 the overarching question is broken down into four subsets, each investigating a particular aspect of China's market-based transition to achieve the 'New Normal'. The first set of questions examines the views of residential electricity users on the market-based electricity sector reform. More specifically, these questions are concerned with revealing regional variations in perspectives on energy related sustainability issues. The second set of questions seeks to identify opportunities and constraints of a market-based reform from a systems analytical view. The third set of questions examines how political, institutional and cultural factors could support or jeopardise the transition of the residential power sector. The fourth set of questions intends to understand environmental and socio-economic equity implications of different market designs for residential electricity users in different parts of China.

2.6.1 Key Question 1: What are the Perceptions of Stakeholders on the Reform of the Residential Electricity Sector?

This subset of questions deals with understanding the views of individuals and groups that are affected by the reform of the residential electricity sector in China. These questions move away from a state-centric approach and shift the focus to non-state actors instead. Unlike other regimes in recent history, the Chinese State has been successful in controlling shifting currents in civil society demanding personal freedom. The old model of command-and-control relies on one-way communication and 'persuasion'. It appears to be reaching its limits to effectively implement policies, particularly those that are directed at individuals. In the context of a newly introduced emissions market with uncertain outcomes the replacement of command-and-control with citizen engagement and collaboration, however, is far more than a purely politically motivated measure to appease people's demand to have their voices heard.

As the experience of participative policymaking in a Western context has demonstrated, the involvement of those who are affected, the so-called stakeholders, is vital for the effectiveness of an intervention to reach its objective. Collaboratively conceived interventions increase the likelihood of acceptance and feasibility of policy reforms (Grimble and Wellard, 1997; Vervoort et al., 2015). As consumers are increasingly becoming the source behind growth in China, their involvement in certain design aspects of a market based-reform appears vital for its effectiveness to support the government's efforts to reach the 'New Normal'.

This study needs, therefore, to be concerned with understanding the views people have on the different aspects of China's sustainability transition to the 'New Normal'. Of particular importance is to understand how people are currently affected by the sustainability problems linked to the residential electricity sector. This knowledge defines the scope of this study. The priorities for the outcome of the reform, specifically the priorities residential electricity users place on the different sustainable development objectives, need to be established. This information is required to identify the market-based solution that best meets stakeholder interests. Given the significant differences in regional household affluence and people's exposure to pollution, viewpoints and priorities are likely to diverge.

Understanding these differing views is a prerequisite for designing an equitable solution mitigating regional disparities. Equitable solution design is explored by Key Question 4.

2.6.2 Key Question 2: What are the Opportunities and Constraints of a Price Signal to Reform the Residential Electricity Sector?

The second set of questions deals with the implications of a price on pollution for household electricity consumption and the effect of different market-based intervention scenarios on existing disparities between regions. The review of the EU ETS demonstrated that a carbon market, as many environmentally motivated policies, has numerous interdependent environmental, economic social impacts that play out across the entire energy system.

As usage by households is emerging as a new driver for electricity demand, it is vital to understand the extent a carbon market generated price signal could limit future increases in residential consumption. To assess whether emissions trading could be an instrument to effectively tether demand growth, the study needs to gauge the responsiveness of households to a change in electricity tariffs within the specific context of China. More specifically, the second question is concerned with the effect of a price on carbon on the current socio-economic and environmental disparities that exist between regions.

The discussion on China's sustainability issues highlighted that many of these problem are interlinked. The study needs to create awareness of these interdependencies. This understanding is required to gauge how a marked-based instrument could effectively intervene within this web of interdependent components and move the Chinese electricity sector towards a more sustainable model. The location of so-called intervention points firstly creates awareness as to how the effect of a price signal could be influenced through appropriate market design and complementary policies. Secondly, the knowledge of where and how to disrupt the status quo supports the development of intervention alternatives that can be tested to understand the role of a price signal to influence consumer demand and its effect on regional disparities.

2.6.3 Key Question 3: What are the Opportunities and Constraints of a Market-Based Approach within the Particular Political, Cultural and Institutional Context of China?

This set of questions seeks to investigate institutional, political and cultural factors that could pose barriers to a market-based transition in China. The role of the State as inhibitor or enabler of a market-based reform receives particular attention and scrutiny. The understanding gained from this analysis is to provide a context for the lessons learnt from answering Key Question 2.

The first objective is to investigate the specific political and institutional setting in China and the ways in which this setting is supportive or inhibitive for a market-based reform. The experience at the EU ETS has highlighted that market design is de-facto the sum of political decisions that are shaped by the political system of a region. To date all longer running emissions trading schemes have been operational in Western settings, where the state plays a less dominant role in intervening in market proceedings and price setting than in China. The unique political and institutional environment the national Chinese ETS will be embedded in warrants an investigation into the opportunities and constraints of a state centred approach for the effectiveness of the ETS to meet its sustainability objectives.

The unique relationship between the Chinese state and its citizens is the second area that is examined to understand the effectiveness of a market-based scheme within the social and cultural setting of China. China's form of environmental authoritarianism has been credited by a number of studies for delivering quick results through direct command-control measures. However, as drivers of unsustainability are shifting from big industrial polluters that are often state-owned enterprises to households the old approach does not appear effective in controlling the behaviour of individuals. The extent to which a price signal alone can influence households to adopt energy saving actions is investigated in the search for answers to Key Question 2. This analysis is based on the premise of a rationally acting 'self-interested' economic agent, who makes decisions based on achieving a specific objective at the least possible cost (Varian, 2014). The theory at the heart of traditional microeconomics is often questioned by concepts that seek to understand the actual behaviour of individuals. Behaviour based economics (Pollitt and Shaorshadze, 2013; Pesendorfer, 2006; Camerer et al., 2004; Kahneman, 2003) offers psychological explanations of consumption behaviour, including motivations to make a contribution to equity and justice. The exploration of factors influencing pro-environmental consumption decisions could provide additional insights into the effectiveness of a market-based solution to regulate household electricity usage.

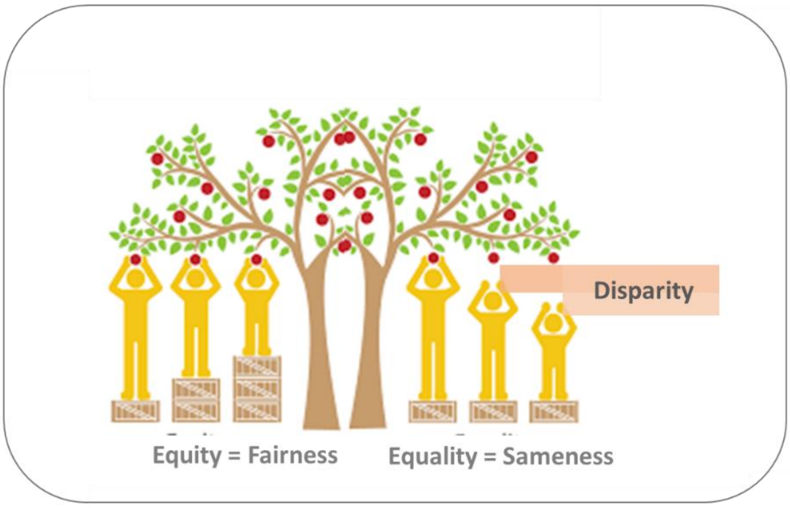
The lessons drawn from understanding the views, values and interests of electricity users (Key Question 1) provide a starting point for the further analysis of non-price based factors motivating households in China to save energy. Awareness of motivations for environmentally friendly behaviour could be useful in understanding what additional measures may be adopted to amplify the price signal generated by the carbon market.

2.6.4 Key Question 4: What is the Most Equitable Outcome of the Reform?

This set of questions is concerned with understanding the equity implications of an ETS facilitated reform of the residential electricity sector. Given the presence of vast socio-economic differences that exist within China, the equitable attribution of burdens and opportunities plays an important role in meeting two of the core objectives of China's new development model, 'shared and coordinated development'.

Equity is closely linked to the principle of fairness. Concepts such as 'justice', 'equality' and equity' have been used interchangeably to define similar concepts (Miao et al., 2015; Agyeman et al., 2002). Equity and equality, in particular, are two terms that are open to interpretation (Alesina and Angeletos, 2005; Konow, 2003; Konow et al., 2016). Over recent years there have been controversies arising from the discussion differentiating between 'equity' and 'equality' (Espinoza, 2007). This study understands equity as being reflected in the process to deliver equality in the outcome[29]. Diagram 2.4 illustrates that equity in the process does not necessarily reflect strict equality in the way burdens and opportunities are allocated.

Diagram 2.4 Equity in Process and Equality in Outcome



Justice implies that action to produce equality has been taken (Noonan, 2008). Distributional justice is achieved through an equitable process when the outcome reflects equality amongst those, who are affected by a situation. For this research the term 'equity' was chosen to best reflect its overarching objective, which is to determine the contribution of an emissions market to achieve justice in the fair distribution of burdens and opportunities between households across China.

The experience of past and present emission trading schemes has highlighted that different policy designs lead to different outcomes across society. The policy environment in the EU that allowed the unrestrained pass-through of fictional carbon costs to residential consumers had serious welfare implications for low income households. In the U.S. at the time of the sulphur trading scheme regulations consumers were at least partially protected from total cost pass-through. Assuming that preferences for the desired solution varies across China, it is unavoidable that households in some regions will win, while others located in a different part of the country will lose depending on a particular market design.

The process orientation inherent in the notion of equity necessitates that this research adopts a participative approach. The idea of a researcher selecting the 'best' solution from the many possible outcomes of a market facilitated reform would undermine the basic premise of equity and fairness upon which this study is built. The question as to what constitutes the 'desired' solution needs therefore to be answered by those who are affected by a situation. The most preferred solution does not necessarily result in the same ('equal') outcome for everyone, in particular when individuals act in their own self-interest and pursue personal objectives. The study needs to ask whether a market-based intervention could close the disparity gap between regions or whether equitable burden

[29] Equality in terms of outcome is one interpretation of the term. Farrel (1999) distinguishes between different forms of equality with respect to access, survival, output as well as outcome.

sharing requires supplementary measures compensating those electricity users that are adversely affected by a particular policy scenario.

Four categories of research questions have been identified. Their presentation and discussion highlighted that these questions are closely interlinked. Exploring them in isolation would not fully answer the overarching research question, which enquires whether a market-based could be an effective tool to transition the residential electricity sector in China to the 'New Normal', a model, which promotes green energy sources, responsible consumption behaviour and equitable burden sharing across regions.

3 Conceptual Framework: Systems Based Assessment of China's Residential Electricity Sector

This chapter presents the theoretical framework of this study. The objective of the framework is to conceptualise the role of a carbon market in the sustainability reform of China's residential electricity sector. It is constructed around the idea that the market-based reform requires deep rooted systemic change in order to equitably facilitate the decarbonisation of the of the electricity sector.

The chapter commences by explaining that the complexity inherent in the reform justifies the adoption of a systems based conceptual framework. The introduction of a market led approach in a highly state regulated electricity sector, the existence of significant inter-regional differences in electricity generation and consumption as well as the growing significance of household electricity usage are important contextual factors whose analysis requires an open and flexible theoretical approach, which is offered by Systems Thinking.

The second section lays out the detailed structure of the conceptual framework adopted by the study. The review of relevant literature found that the term Systems Thinking embraces a plethora of different meanings. Many interpretations of Systems Thinking extend beyond the notion of a theory explaining a system's structure and its optimisation through the application of rigid mathematical models. Treating Systems Thinking as a taxonomy of approaches or theories would not do the concept justice. System Thinking itself is grounded in 'Thinking'. The understanding of System Thinking as a form of divergent thinking, which connects the content and dynamics of a system to its context, is illustrated through the metaphor of an iceberg. The iceberg model is a systems thinking tool systems thinking tool to discover invisible the patterns of behaviour, supporting structures and mental models that underlie an observable event (Goodman, 2002).

The chapter concludes with a critical evaluation of Systems Thinking. Systems Thinking is compared to other approaches which have been traditionally used to study specific aspects of energy transitions. The discussion concludes that the holism and the diverse methodological toolset at the heart of Systems Thinking justifies its adoption as the foundation of the conceptual framework.

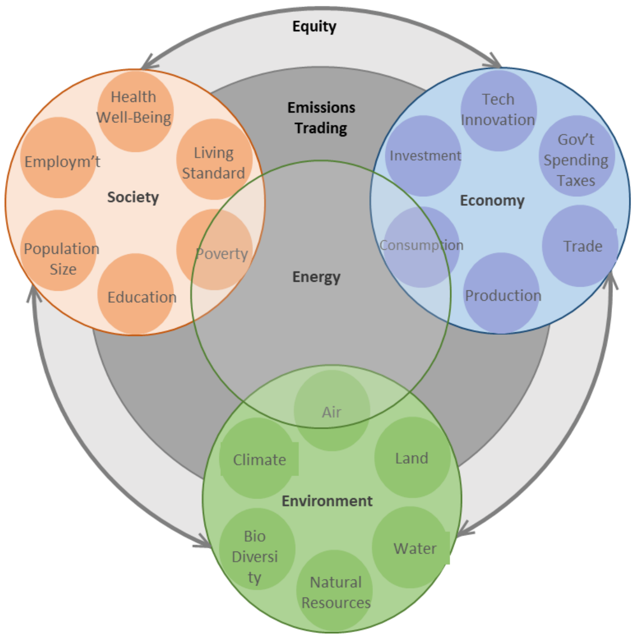
In addition to elucidating the complexity of a market led sustainability reform of the electricity sector, the purpose of this study is to make sense of it. Therefore, the conceptual framework intends not to only answer content related questions such as what an appropriate level of carbon price should be (Key Research Question 2). It also seeks to interrogate deeply rooted contextual factors (Key Research Question 3), cultural, socio-economic and political, which ultimately determine the effectiveness of a market based solution to firstly cut energy related pollution and secondly to share the burdens and benefits of emissions reduction in an equitable way across regions. The framework provides space for the inclusion of different stakeholder perspectives to account for the views of those who are affected by the reform.

3.1 Electricity Sector Reform: A Complex Multiple Stakeholder Problem

The review of relevant literature highlighted that energy transitions embody complicated governance problems, where challenges derive from a multitude of different sources. The reform of the Chinese electricity sector bears all the hallmarks of a complex problem (Rittel and Weber, 1972; Dörner and Funke, 2017).

Energy is the driving force of development. Located at the intersection of economy, society and the environment, the electricity sector encapsulates the challenges which the Chinese government promised to address as part of its drive to move the country onto a more sustainable growth path. China's new development model, its New Normal, focuses on far reaching structural change, which can achieve moderate economic growth of a much better quality in terms of social equity and impact on the environment (Green and Stern, 2015). A reform of the energy sector goes beyond the replacement of pollution intensive coal based capacity with renewables. It is a transformation in the way the Chinese people live, produce and consume.

Diagram 3.1 Energy at the Intersection of Economy, Society and Environment



Literature from natural and social sciences typically refers to several key features of complex problems[30]. Energy reforms share most of these characteristics. Diagram 3.1.

[30] Rittel and Webber (1972) were the first to formally describe the concept of' 'complex' or 'wicked' problems inherent in social planning projects. They contrasted complex problems with "tame" problems encountered in mathematics or chess. According to Rittel and Webber complex problems share ten characteristics:

1. There is no definition of a complex problem.
2. Complex problems are never fully resolved.

illustrates the complexity inherent in the dynamics of the sustainability transition of the energy sector. Complexity stems from energy being the foundation of human development. It is central to the challenge of sustainability in all its aspects: social, economic, and environmental (Sgouris and Csla, 2014).

The following explains the main characteristics of complexity and their relevance to the electricity sector: Interconnectedness, multi-causality, co-evolutionary and path dependent processes, openness and the lack of boundaries, uncertainty, the lack of central control and divergent perspectives. It is important to understand the dimensions of complexity linked to energy related sustainability challenges as the choice of a conceptual framework is dependent on the problem under analysis itself (Bale et al., 2015).

The transition of an electricity sector based on pollution intensive generation capacity to a more sustainable model cannot be carried out in isolation. A region's economy, society and environment are simultaneously affected by changes to energy generation and distribution (InterAcademy Council, 2007). An understanding of these individual parts does not automatically imply an understanding of the whole. One problem is a symptom of many other problems. There is no single root cause. An effective reform needs to consider the interlocking elements and address multiple sustainability issues simultaneously. Pollution from the generation of electricity is often treated as a purely technical problem. Installing pollution control devices slows environmental destruction, but technological solutions do not put an end to it. They treat symptoms but not root causes such as a growing population, an expanding energy intensive economy, changing lifestyles and the emergence of a consumer society. It is human activities leading to the creation of the problem (Kristensen, 2004). The scope of sustainable energy has to be broadened to include non-technical solutions in order to surmount the shortcomings of a purely symptoms led approach. What is required is a cause based approach to address the interconnected root causes. This involves restructuring many parts of the human system (Mochal and Mochal, 2011).

The large number of interacting elements form dynamic networks of interactions and feedback loops. Complex situations often arise from unpredictable consequences due to their multi-causality and long cause and effect chains. Interventions frequently trigger unforeseen, unintended and potentially detrimental consequences elsewhere. Solutions

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3. Solutions to complex problems are not right or wrong, but good or bad.
4. There is no test of a solution to a complex problem.
5. Every attempt to solve a complex problem counts, because there is no opportunity to learn by trial and error.
6. Complex problems do not have a limited set of potential solutions, nor is there a given set of permissible operations that may be incorporated into the solution.
7. Every complex problem is unique.
8. Every complex problem is a symptom of another problem.
9. The existence of a divergent problem definitions can be explained in numerous ways. The choice of explanation determines the problem's resolution.
10. The social planner has no right to be wrong as he is responsible for the consequences of resolution attempts.

change the problem itself. The existence of these interdependent relationships and feedback mechanisms make the cost and benefits of an electricity sector reform uncertain. The positive effects of strict pollution targets on economic development through the establishment of new innovative sectors have been well documented (Wolf et al. ,2016; Zhan and Karl, 2015; van der Veen and Venugopal, 2014; Camagni et al. 1998); also in the context of China (Zhang 2015; Lewis 2013; Nahm and Steinfeld, 2014; Teng and Jotzo, 2014). However, the 'rebound effect'[31] of environmental policy on pollution levels has been explored to a lesser extent. Economic expansion through the stimulus of R&D and innovation typically has a reinforcing effect on the demand for electricity due to improved employment opportunities and subsequently higher living standards. Short term improvements in pollution levels through the adoption of renewable generation technology are offset by increased electricity consumption. In the longer run environmental policy undermines itself.

Complexity is frequently the outcome of co-evolutionary processes, which occur when developments or changes in seemingly unrelated parts of the economy, society and the environment reciprocally affect each other. The energy sector, in particular, is influenced by developments occurring at the interface of society, economy or the environment (Franco, 2017). Subsequently it is subject to constant dynamic transformation as populations and their lifestyles, technologies, economic targets and political priorities evolve. Lifestyle changes may bring demand for new technologies, or in reverse new technologies such as smart metres or energy monitors may alter consumer behaviour (Martiskainen and Ellis, 2009). Stricter environmental targets may bring a push to innovation such as renewable technology which in turn may lead to the requirement for new economic models and vice versa (Foxon, 2011).

Complex situations are often the result of path dependence. The electricity sector, in particular, is subject to strong and long-lived path dependence owing to the longevity of power plants. The state of a country's energy sector is the result of many past interacting decisions, which moved the generation base in a particular direction (Bale et al., 2015). Technological and institutional lock-ins further have important implications for interventions underpinning sustainable development (Foxon, 2002). Many industrial economies are in a state of so-called 'carbon lock-in'. The reliance on emission intensive fossil fuel based energy is the outcome of co-evolving interdependent technological networks, social and political institutions as well as changing behavioural norms. All three factors are tightly intertwined and contribute to the complexity of an energy transition. Path-dependence can act as a barrier to the deployment of innovation (Unruh, 2000; Unruh, 2002).

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[31] The rebound effect is often discussed in relation to individual consumption behaviour, where energy efficiency improvements in household appliances and a subsequent drop in electricity expenditure lead to increased electricity usage in the long run (see for example Berkhout et al., 2000). The same effect can also be observed in the presence of rising income levels, particularly in the context of emerging economies such as China (Chen et al., 2007; Payne, 2010)

Energy challenges are typically complex problems as processes related to energy generation and consumption are not confined to the sector itself. The blurring of the boundary between energy and economy, society and environment in its periphery mean that the problem definition is a matter of interpretation (as illustrated by Diagram 3.1). Openness and the decision what is inside the problem boundaries frame the problem itself (Cilliers, 2011; Williams and van't Hof, 2016). Openness creates complexity in two ways. Firstly, there is the trade-off between an incomplete and arbitrary problem definition and the manageability issue of an ‘all-inclusive’ definition, with the latter inadvertently adding to complexity (Keeney and Raiffa, 1993) Secondly, the drawing of system boundaries could create new issues such as the marginalisation of certain stakeholders and the exclusion of their views, which is critical in situations characterised by inequality (Dahl, 1989).

Energy reforms affect a large number of people. The energy sector includes a diverse and heterogeneous set of stakeholders. Household and commercial consumers, energy providers and distributors as well as economic and environmental regulators operating at different geographic levels (Bale at al., 2015). There is typically no one agent with total control over the planning and implementation of energy related activities. In the presence of complex problems decisions are taken at multiple levels. As in any self-organising group the lack of control adds to the uncertainty of the overall outcome of an electricity sector reform.

Complexity is also a function of different perspectives on situations (Reynold and Holwell, 2010). The relationship and the diversity of interests which exist among those who are affected by a problem determine the degree of a problem’s complexity (Head and Alford, 2015). Individuals connected through unitary relationships typically share values, beliefs and interests. They typically agree on the problem situation and what constitutes the ideal solution. Pluralist relationships are typically characterised by general agreement on basic values but bring with them divergent interests and objectives. Individuals in so-called coercive relationships have few common interests and incompatible basic beliefs. They disagree on the problem situation and the most preferred solution. Unless special provisions are made to include the views of those who are affected, solutions are generally formulated to align with the priorities of who has the most power and influence (Freeman, 1999; Flood and Jackson, 1991; Meinardes et al., 2011).

The wide ranging environmental, economic, institutional and social impacts of an energy reform (Polatidis et al., 2003) suggest the existence of diverse perspectives on the original problem itself and the desired outcome. A diverse set of stakeholders with conflicting basic values and beliefs are bound to be affected by any change to the electricity sector. People affected by an electricity reform are able to adapt and respond to changes. However, they lack the perfect rationality which is assumed by many economic models (Kishtainy, 2017). This makes their behaviour unpredictable and the outcome of any intervention uncertain.

Table 3.1. describes the relevance of the different complexity dimensions for the reform of the residential electricity sector in China (adapted from Conklin, 2005; Howes and Wyrwoll,

2012; Levin et al., 2012; Rittel and Weber, 1972). It draws on the discussion of contextual information presented in form of the literature review above.

The above analysis demonstrated that energy transitions are complex per se. As highlighted in Table 3.1, the situation specific to China adds complexity. Treating the challenge of a market based electricity sector reform as a purely technical challenge would not be helpful in meeting wider social and environmental objectives such the mitigation of inter-regional inequality and the outsourcing of energy related emissions. While integrating these multiple, often conflicting, goals and components appears to be a pre-requisite for a successful reform outcome, it is difficult to put into practice. One main characteristic of a complex problem is the lack of an unambiguous definition of the problem itself. The unique cultural and political setting of China with its regional diversity implies the presence of a wide and diverse range of multi-facetted issues which are closely linked to the generation and consumption of electricity. The complexity of many diverse livelihoods in China makes it unlikely that a generalised solution is an equitable one at the same time. The possible lack of consensus of what actually constitutes the problem further suggests that there is no right or wrong solution. Solution quality is not objective. There might be worse or better responses from the view of a particular stakeholder in the reform (Conklin, 2005). Because of multiple, incomplete, incompatible and changing requirements, understanding the many facets of the problem which a carbon market needs to solve appears to be far more complex and difficult than issues which have been identified for its implementation. The lack of accurate pollution data or insufficient provisions for the Monitoring, Reporting and Verification (MRV) of emission reductions have been discussed at great length (for example Dong et al., 2016; Hsu 2015; Sun et al., 2016a). The next section explores analytical frameworks, which have been used to study energy transitions.

Table 3.1 Main characteristics of complex systems and their application to the residential electricity sector reform in China

Complexity Dimension		**Relevance to the Electricity Sector Reform in China**
Causality and Interconnected ness	A large number interacting elements implies the interdependency of problems. One problem is a symptom of multiple other problems. There is no single root cause.	China's economic growth has been fuelled by carbon. A sustainability transition of the electricity sector has far reaching implications as it questions the country's development model. The multi-facetted problem of rising emissions has also manifested itself in structural economic and social inequalities at regional level. There appear to be multiple causes which require to be addressed simultaneously. Wider equity implications of an electricity reform need to consider reformulating China's development strategy which has traditionally favoured the coastal regions.
Path Dependence	Past action affects the present and the future. Developments are often irreversible.	Investment decisions in the energy infrastructure have long term irreversible implications given the long retirement age of coal plants. (The global average life span of a coal power plant is between 40 and 50 years). If China continues to use coal as currently planned, any additional coal-fired capacity added today represents a major lock-in an emission intensive pathway jeopardising the country's ambitious renewable energy targets.
Co-Evolution	Interactions between seemingly unrelated factors occur over time. Dynamic Interconnected elements produce feedback loops.	Energy systems are made up of technologies, institutions, economic strategies, user behaviour and the natural environment which coevolve and mutually influence each other. Energy systems change over time in response to changing economic drivers, regulation and technological innovations. China has been developing at an unprecedented pace since end of the Mao era. The energy system has facilitated the development of the country. With economic growth came increased demand for a cheap and reliable source of electricity, which was met by the rapid expansion of cool based capacity. Dynamic transformation of the energy sector has occurred over time. Urban migration and the adoption of Western lifestyles, technological advancement, changing economic and political priorities, stricter environmental targets have simultaneously resulted in an increased share of renewables in the fuel mix and rising electricity consumption from household. Co-evolution of socio-economic and political factors and the electricity sector so enforce or offset measures taken as part of an electricity sector reform.

Uncertainty	Interventions trigger unforeseen, unintended and potentially detrimental consequences elsewhere. Attempts to solve a complex problem often lead to unpredictable consequences due to its multi-causality and interconnections to other issues. Solutions can also change the problem itself.	The effect of multiple non-linear feedback due to new interactions or changed behaviours make it difficult to predict the outcome of an intervention. The fast pace at which China has developed affects decision quality. Historical data and assumptions regarding behaviour in a market environment have proved problematic as the transition from the planning system to a modern market system is not yet complete. The 2012 electricity tariff reform was not able to change residential electricity usage patterns. The reaction of consumers to the price signal was misjudged. Causes of lacking pro-environmental behaviour were not investigated. Diversity of the country in terms of socio-economic development adds to complexity. Despite past attempts at solving interregional inequality ('Harmonious Development Programme') the problem has become more intractable as a number of root causes were not addressed (Li et al. 2013). Consequences of energy policy which established carbon intensive forms of power generation and 'dirty industries' in the inner provinces were not foreseen.
Self-Organisation	There is no central control over processes and ultimately the outcome of an intervention.	State dominance in China does not imply that government authorities are in control of all aspects of an electricity sector reform. A diverse and heterogeneous set of stakeholders including household and commercial consumers of electricity influence the outcome of the reform. Behaviour of individuals in particular is difficult to regulate. The planning and implementation of an electricity reform itself falls within the remit of more than one authority in China. The formal policy making process has also become more diffuse. It is characterised by interdependent levels of decision making as a result of institutional diversity as well as a (de facto) polycentric and highly fragmented political system where decision makers operate at various scales and levels. The gradual emergence of civil society as influence on policy making further adds to the dilution of the central state's influence China's leadership has yet to adapt to the new relationship between state, market, and society. New ways need to be developed to integrate new players in policy processes as neglecting them and their concerns could make implementation of a market based reform problematic.

Openness	No clear definition of problem boundaries and the problem itself exists. Interactions with the surrounding environment are in constant flux.	Energy reform affects a region's economy, society and environment. China's reliance on cheap coal based electricity generated in the inner provinces resulted in multi-facetted problems. Rising emissions and poor environmental quality have manifested themselves in structural economic and social inequalities at regional level. It appears that multiple causes will have to be addressed simultaneously. Policy makers are facing the complex task of deciding which areas of concern of an energy reform to prioritise. Defining the boundary of a problem is particularly problematic in the presence of multiple stakeholders with diverging interests and objectives.
Perspective	Problems are socially complex. Equity is stakeholder dependent	A wide range of stakeholders are affected by the reform of China's electricity sector. The diverse set of stakeholders has diverging economic, social and environmental objectives which often conflict with each other. Stakeholders have different perspectives on the best solution based on their explanation of the original problem. China is a diverse country with regions at different stages of development. Priorities for the outcome of a reform do not only vary across different stakeholder groups but also across provinces. Prerequisite for an equitable outcome of an electricity sector reform is the inclusion of different stakeholder views. Given the lack of participatory opportunities in China's policy making process, an equitable outcome of an electricity sector reform could prove difficult.
Bounded Rationality	People typically react in irrational ways. They are not atomised and utilitarian individuals but positioned within a specific historical and cultural context. They do not always act according to 'economic laws'. Reaction to an intervention becomes unpredictable.	China's new market based approach relies on a price signal to regulate demand. The success of a market based reform to control residential electricity demand is depended on households reacting to the price signal as anticipated by the planning authorities. People, however, do not make purely cost-based decisions unlike large organisations which have been the focus of China's government policy in the past. They often act upon less rational influences such as social relationships and values as well as concern for the environment (Simon, 1997). Bounded rationality of households requires awareness of motivations for energy saving behaviour other than cost. Not fully understanding consumer behaviour rendered the 2012 tariff reform ineffective to limit increases in residential electricity usage.

3.2 Conceptualising Energy Transitions

Energy transitions which have been taking place in Western countries since the early 1980s, the 'Energiewende' in Germany (Gailing, 2016) for example, have opened up a plethora of different conceptual approaches interpreting the processes which accompany such a reform. The magnitude of conceptual approaches warrants their review in terms of their suitability to be applied to this study. In order to qualify as framework to study the reform of the Chinese electricity sector such an approach needs to address all dimensions of complexity and delve beyond purely descriptive accounts of policy implementation to unpack the deeper issues at play.

3.2.1 Conventional Conceptual Frameworks Applied to the Study of Electricity Sector Reforms

Many conventional frameworks applied to study energy related challenges tend to focus on particular elements in isolation and do not consider energy related change within its broader context (Geels et al., 2016). They, for example, explore technical feasibility or assess a specific policy relevant criterion such as cost-effectiveness, political viability (Geels, 2014; Schubert et al. 2015), social acceptance (Carrico et al., 2015; Kerkhof and Wieczorek, 2005) and legitimacy (Hendrik, 2008; Branston et al. ,2006; Dickson and Kalapurakal, 1994.) Theories explaining technical change dynamics are used to elucidate aspects related to diffusion patterns of technical innovation such as renewables (Quitzow et al., 2014; Kahouli-Brahmi, 2009; Foxon and Pearson, 2008; Isoard and Soria, 2001). These model based theories typically set out to answer a specific research question related to the monetary costs and benefits of a reform. The review of theories applied to the exploration of low carbon energy transitions brought to light the dominance of economic approaches (Ferroukhi et al., 2016; Gejgus, 2016; Kriegler et al., 2014; Timmons; 2014; Wilson et al., 2013; Negro 2011; Foxon and Pearson, 2008; Freeman and Perez, 1988; Smith et al., 2010). Institutional theories seeking to understand governance related issues appear to be another strand of research which is commonly applied to the study of energy transitions (Andrews-Speed, 2016; Lockwood et al., 2016; Loorbach et al., 2008; Smith, 2005).

Typically, these approaches which have been traditionally used to explore energy related challenges apply accepted knowledge and employ pre-defined and tested models to logically structure simple and static problems with a clear description, an agreed end point based on a shared vision, identifiable root causes, testable solutions and measurable outputs (Ackoff, 1974; Mason and Mitroff, 1981; NORAD, 1999). Contextual factors and dynamic relationships, which are central to understanding a complex problem, are typically not considered. Traditional problem analysis focuses on the individual pieces of what is being studied. It is well suited to explain in detail well-defined problem situations, but as reductionist approaches they allow only little room for ambiguity and different perceptions of the problem definition and its solution (Cropely, 2006).

Given the close correspondence between the research and the features of a complex problem (see Table 3.1), the study requires a theoretical approach which addresses the various dimensions of complexity. The search for a conceptual framework which could be employed to answer the research questions posed by this study led to Systems Thinking.

3.2.2 Systems Thinking as a Conceptual Framework Applied to the Study of Electricity Sector Reforms

Systems Thinking offers the foundations for a conceptual framework which appears to overcome the shortcomings of reductionist theories, inadequate to fully capture the complexity inherent in the context of energy challenges (Hall, 1999; Senge, 2006). Systems Thinking helps to create an understanding as to how a group of interacting, interrelated, interdependent components influence each other within the whole and how the system interacts and responds to its environment and evolves over time (Haines, 2000; Sterman,1994).

Systems Thinking is also referred to as Systems Analysis (Gane and Sarson, 1979), Systems Science (Flood and Carson, 2013), Systems Research (Buckley, 1968) or Systems Theory (von Bertalanffy ,1968). A review of literature found that these terms are often used interchangeably. Frequently the usage of terminology in publications, however, suggests different levels of abstraction where systems analysis is situated nearer the pragmatic end of the scale and systems theory at the opposing end.

The malleability of terminology makes a clear definition of Systems Thinking and the associated concepts difficult (Forrester, 1994). Systems Thinking is characterised by a vast diversity of theories which have evolved over time (Gregory, 1996). The term Systems Thinking has been redefined in many different ways (Arnold and Wade, 2015). The diversification of Systems Thinking is further evidenced by Midgely's seminal four volume compendium which brings together important readings from across the field (Midgley, 2003)[32].

In light of the opacity of systems terminology it is important to delimit the interpretation of Systems Thinking underpinning the conceptual framework of this study from other definitions. Adding to the elusiveness of terminology, Systems Thinking is often regarded a methodology, rather than a theory in itself. However, it offers a lot more than a toolset which is concerned with quantifying the linkages and interactions between the components that comprise a system. As a theory it gives meaning to observable events, rather than merely describing them. Systems Thinking bears further hallmarks of a theory,

[32] Midgely (2003) identified three waves of System Thinking: Early systems theorists such as Ludwig von Bertalanffy in the 1940s described systems in physical terms, borrowing metaphors from science. As limitations in the form of reductionism and mechanism became apparent a second wave of 'soft systems thinking' developed systems approaches to describe human systems, where meaning is central and considered subjective in line with the paradigm of social psychology emerging in the 1970s (Checkland). The third wave, or critical systems school, comprises two strands. It is firstly concerned with the exploration of social reality and knowledge and secondly with the analysis of power imbalances and ideas of liberation (Burton, 2003).

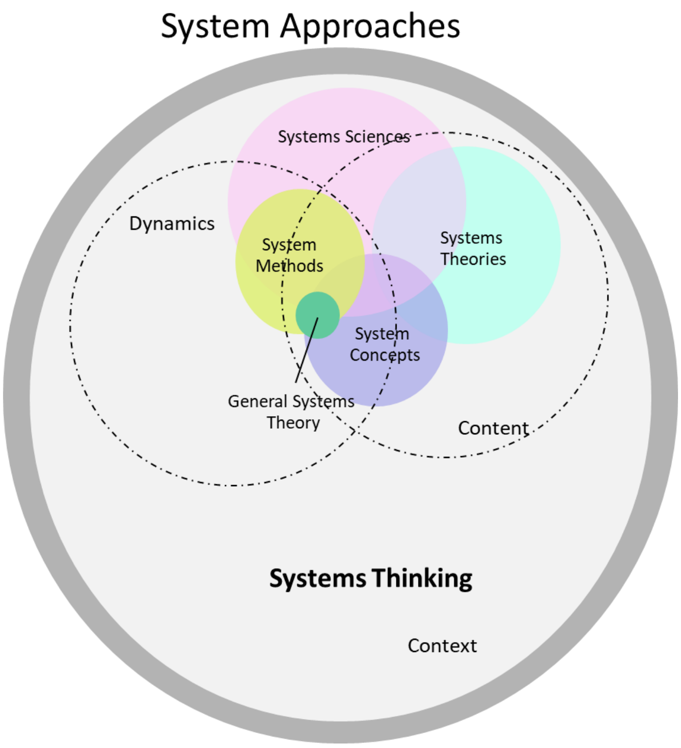
as it also offers “generalization about a phenomenon that explains how or why the phenomenon occurs“ (Frey et al., 1991).

Arnold and Wade (2015) believe Systems Thinking can be viewed as a system itself. Cabrera and Cabrera (2015) attribute the diversity of Systems Thinking to be the product of constantly evolving systems which require an adaptive approach to deal with complexity. Richmond (2000) attempts to define Systems Thinking by describing first what it is not and then by explaining that “Systems Thinking is quite unique, quite powerful, and quite broadly useful as a way of thinking and learning. It’s also capable of being quite transparent— seamlessly leveraging the way we learn biology, manage our businesses, or run our personal lives.”

Following Richmond’s notion of Systems Thinking, Systems Thinking is understood by this study as a way of ‘Thinking’, which draws parallels to divergent forms of thinking (Guilford, 1959; Baer and Kaufman, 2006; Maani and Maharaj, 2003). Divergent thinking is the process of thought where flexibility is used to make sense of a complex situation. In contrast to convergent thinking, which tends to focus on only one idea or one single solution, divergent thinking explores a problem from many different angles and develops as many solutions as possible.

The understanding of Systems Thinking as a theory and a “cognitive endeavor” (Cabrera, 2006) differentiates it from other system approaches. Diagram 3.2 illustrates that system approaches are a loosely related group originating from different fields and are employed by science as processes to study how a particular system or aspect of it behaves. Systems Thinking, however, presents a very different notion. Unlike other systems approaches, Systems Thinking is rather an implicit activity. As a particular pattern of thought it is the foundation for all other approaches. Systems Thinking provides the bridge between the context a system is embedded in and its content as well as the dynamic relationships occurring with the content.

Diagram 3.2 Relationship of System Approaches

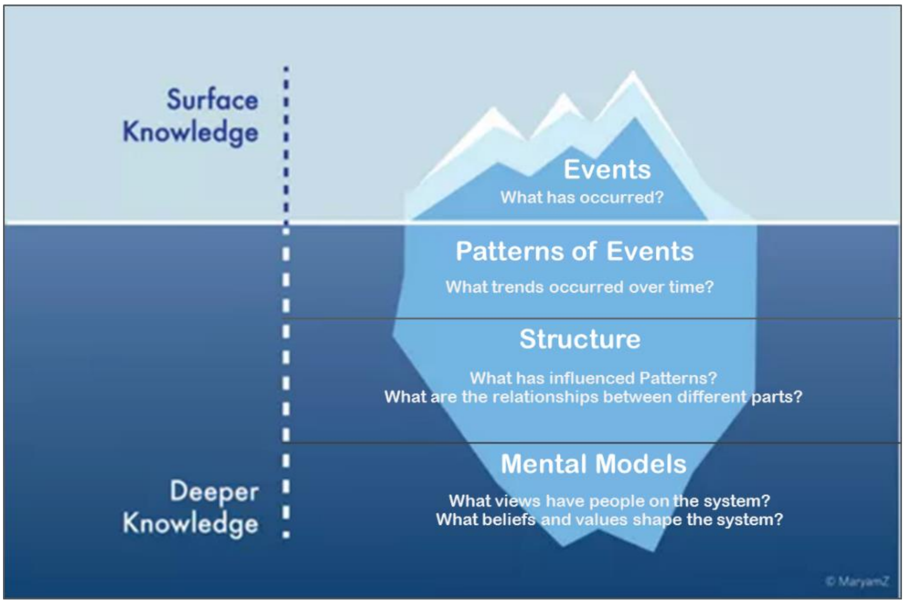


By making connections between 'context', 'content' and 'dynamics', Systems Thinking can reveal the dimensions of complexity inherent in the problem being studied. Context, a frame of reference defined by the position of an observer in the world around us, provides a set of rules to process content and dynamic relationships revealing a deeper understanding of the problem itself and a more complete definition of the solution space (Cabrera and Colosi, 2008; Armstrong, 2006).

3.2.3 System Thinking as an Approach to Thinking about Complexity

The iceberg model shown in Diagram 3.3 below is frequently used to introduce the concept of divergent thinking embedded within a systems based view of the world. The model was originally developed by Shi (1995) to illustrate the different levels of creativity cultivation. It was adapted by Kim (1996) to explain the potential of Systems Thinking to address problems which exhibit signs of complexity. Over time it was refined and modified by numerous systems researchers to suit their own studies (most importantly Senge, 2000 as well as Meadows and Wright 2008; Maani and Cavana, 2007; Nguyen and Bosch, 2013; Riley and Clarkson 2001; Yates and Davidson; for a description of the model also see Vandenbroek, 2015; Monat and Gannon, 2015; Ambler, 2013; REOS, 2010).

Diagram 3.3 Systems Thinking and The Iceberg Metaphor



As with an iceberg most of the world is hidden below the surface. Above the water line are the events. They are observable. When problems are viewed at this level their solution tends to be reactive. A bit deeper, just above and below the waterline, are patterns of events. Patterns form when similar events have been occurring over time. The awareness of patters allows for planning and adapting to problems. At pattern level problems can be anticipated. The visible events are real data. Patterns require the interpretation of the data. Below the patterns of events are the structures which create the foundation causing these patterns. Structures are rules, policies, power structures, cultural norms and rituals. They have been tacitly agreed or explicitly institutionalised. Hidden from view, the structure supports the visible part of the iceberg. Structure is composed of cause-and-effect relationships which create linkages between patterns. Cause and effect are not always a linear series of events. Patterns are often explained by circular cause-and-effect relationships, so-called feedback loops. Structure is important as it provides a deeper awareness of the system. This understanding allows the identification of problem drivers and the prediction of system behaviour.

Systemic structure is frequently held in place by attitudes, beliefs, morals, ethics, expectations, values, thinking or “mental models”. These thoughts exist in the minds of the structure’s stakeholders, the people who created the structure or those that are affected by the way the system operates. The more divergent the views among stakeholders, the more complex the problem (Conglin, 2005). Each Perspective, each common perception of the problem and its solution, is shaped by a particular context captured by a particular problem frame (Goffman, 1974). Inequity is typically the result of the dominance of one frame over another (Kaplan, 2008).

Parts of the system, which are hidden from view, are difficult to identify. Traditional approaches to problem analysis typically only consider the ‘tip of the iceberg’ from one particular perspective. Instead of isolating observable events, which form patterns of behaviour, Systems Thinking works by expanding its view to consider larger numbers of interactions below the surface as an issue is being studied. Solutions to problems that are created at lower levels tend to be more difficult to conceive and to implement. However, the greater the understanding of what is happening under the surface, the greater is the influence over how the system works. Interventions taking place at lower levels tend to be more effective as root causes and not just symptoms of problems are addressed. The awareness of the systemic structure diminishes the chance of unforeseen consequences of interventions and increases the likelihood of lasting change. When successful, solutions targeting stakeholders' mind sets can be procreative in their impact. They can be transformative and bring into existence something new.

The iceberg metaphor illustrates that Systems Thinking is more than a theory attempting to understand 'content' described by dynamic patterns of events. Systems Thinking challenges world views, the images, assumptions, and stories people carry in their minds. It seeks to make sense of the 'context' in which structure is embedded. The iceberg metaphor also demonstrates that Systems Thinking is a theoretical approach which differentiates itself from other constructs (Cabrera, 2006). By being a form of divergent thinking Systems Thinking allows to understand the different dimensions of complexity through the lens of those who are affected by the observable events occurring within the boundaries of a system.

Unlike Systems Thinking, other forms of system based analysis focus on understanding and explaining patterns of events by assuming scientific objectivity of components and their relationships. Systems Thinking, however, is founded on the notion that there are many truths. Humans view the events occurring in the world from a particular position 'within the system'. What an individual sees and how he perceives what he sees varies greatly with his perspective which in turn is determined by his personal situation and past experiences (Reiss and Sprenger, 2017). Despite being visible, events are perceived differently by each stakeholder. Every time events and event patterns are explored from the perspective of a particular stakeholder a new view of the problem itself is generated. System boundaries are implicitly drawn by the number and the diversity of different perspectives subsumed into the system under study. The decision whose 'truth' to consider is a value judgement made by the researcher. She decides whether or not any given truth is worth pursuing based on her own mental model, which perceives the world in a certain way (Kitcher, 2011). The implications of researcher bias on the study will be explored in more detail as part of the discussion which explains the ontological and epistemological position of this study (Chapter 4).

Despite its potential to provide novel insights into content, dynamics of relationships and contextual factors, Systems Thinking has not been without criticism. Limitations of a theory need to be assessed prior to its application.

3.3 Critical Appraisal of Systems Thinking

In light of the conceptual and methodological diversity of systems based approaches it has proven difficult to locate a critical evaluation of Systems Thinking as understood by this research.
As will be demonstrated in the next chapter, which introduces the methodological framework of this study, the idea of understanding Systems Thinking as a way of thinking about a problem itself is not an attempt to dismiss the pluralism inherent in a systems based approach. This study intends to use Systems Thinking as a framework to leverage the advantages of methodological pluralism. Taking a multi-faceted theoretical position which encompasses complexity occurring at content, dynamic and contextual levels involves drawing upon different methods from different schools of systems based analysis (Jackson, 1991; Jackson, 2000; Midgley, 1992; Midgley, 2000). The evaluation of the proposed framework therefore requires the review of general system critiques as well as the scrutiny of appraisals assessing different paradigms, theories, concepts, methods.

A great amount of the criticism levelled at System Thinking is attributed to the theory's promotion of holism. Holism considers systems to be more than the sum of their parts. It takes into account a system's structure and the dependencies and relationships between components. Critics of system approaches point out that attempting to create awareness of the 'big picture' neglects the detail, which needs to be understood in order to fully grasp a complex problem. Extending the view from events to event patterns, to system structure and finally to the mental models, which shape and sustain the system could further distract from understanding important detail such technical barriers that is required to solve a problem in the real world (Jackson, 1990).

Another problem of holism is that holism itself tends to add to complexity because of and despite the valuable insights it delivers in terms of comprehensive problem analysis. As analysis ascends through the levels, events, patterns, structures and mental models emerge. The scope of the problem under investigation increases and becomes less manageable. The problem itself becomes more and more abstract and thus increasingly difficult to grasp. Despite the appearance of holism being all-inclusive, views of certain stakeholders, which are not considered as significant, are excluded. Problem boundaries could be drawn seemingly randomly by the researcher herself. Other criticism levelled at systems related approaches addresses drawbacks of particular schools of systems theory, each concerned with a distinct aspect of complexity represented by a particular layer in the iceberg model.

The school of systems theory, which originated in the disciplines of natural sciences and was later adopted by operational research (Bertalanffy, 1968; Rapoport, 1966), is often criticised for its focus on 'content' and its lack of social 'context'. The interpretation of a system as network of interrelated elements, often referred to as 'general systems thinking or 'hard systems approaches', places emphasis on the optimisation of processes occurring within the system boundaries. Patterns of events are analysed through the application of scientific modelling and evaluation processes. Contrary to systems thinking generally being associated with holism, general systems theories are accused of being reductionist in their approach to problem analysis because of their focus on creating laws and rules defining how the system operates (Keys, 1990). Determinism and the accompanying assumption that system approaches set out to mimic present reality (Solow, 1972; Simon, 1981; Keys, 1990; Hayden, 2006) or extrapolate events into the future (Ansoff and Slevin, 1968; Sharp and Price, 1984; Jackson, 1991; Lane, 2000; Forrester, 2001) have been refuted by proponents of general systems theory. Forrester (1961), Senge (2006) and Sterman (2000) point out that the value of systemic analysis is to gain a better understanding of the internal structure of a system which creates patterns of behaviour. According to Forrester (1985) and Radzicki and Tauheed (2007), the design process provides more valuable lessons in the form of insights into systemic structure than the actual model itself.

In response to general systems approaches being faulted because of their reliance on mathematical modelling leaving insufficient room for the 'human factor' (McConell, 1996) a new breed of system approaches emerged. The concept of 'Soft Systems Thinking' leaves behind the abstract interpretation of a system as a network model of interdependent elements. Soft system approaches are based on the notion to involve those affected by an issue and to create agreement among stakeholders about its resolution. They are concerned with creating awareness of the 'context' in which stakeholders face a certain problem situation (Checkland, 1981). They seek to understand the mental models which underpin the system structure by eliciting the often diverging perspectives, interests and objectives of those who are selected to be within the system of consideration. As structural aspects of a system are typically not considered, general or hard systems thinkers believe that soft systems thinking offers a limited perspective on why problem situations occur (Jackson, 1991).

Much of the criticism drawn by the adoption of Systems Thinking as a theoretical approach appears to lie in the lack of a clear definition of the concept itself and the subsequent ill-informed choice of a particular conceptual approach (Doolan and Leatherhead, 2012). General (or hard) systems approaches applied to problems where contextual influences drive the system have proved not very useful in addressing complexity stemming from human factors (Barlas, 2007). The application of soft system theories to the study of event patterns caused mainly by the complex relationships between system variables appears equally unsuitable.

Systems Thinking is viewed by some as a framework that is inferior to traditional reductionist models that have been employed to study energy transitions on the basis of misjudgements made regarding its suitability to be applied to a certain study area. The lack of a clear and unambiguous definition might prove problematic from the point of view of scientific rigor. The openness and flexibility of Systems Thinking, however, provides a platform to unify different approaches and to "celebrate the synergies, or avail ourselves of cross-fertilization opportunities, where these occur." (Richmond, 2000).

3.4 Application of Systems Thinking in the Study of Energy Transitions

Complex systems thinking has a long tradition in exploring complex sustainability challenges spanning the human and the environmental domain (for example Meadows, 1972; Kay et al. 1999; Folke, 2006; Rotmans and Loorbach, 2009; Maani and Cavan,a 2007). Systems related approaches have been increasingly employed to study sustainable energy transitions. Several studies evaluate physical structure of energy systems and build different scenarios (Chi et al. ,2009; Naill, 1977; Conolly, 2010; Feng et al., 2010). They investigate the link between energy usage and economic factors such as GDP (Naill, 1977). The second group of researchers applied system models to analyse environmental effects of pollution, in particular energy related CO_2 emissions (Trappey et al., 2012; Anand et al., 2005; Rafieisakhaei et al., 2016). The examination of energy security issues is the third group of research which adopts a system thinking approach (Naill, 1992; Rios et al., 2017). A fourth group of studies analyses a variety of economic and environmental effects of replacing fossil fuel based generation capacity with renewables (Aslani et al., 2012; Mediavilla et al., 2013; Krutilla and Reuveny, 2006; Bennett, 2012)

The plethora of studies examining sustainability challenges and energy related problems in particular through the lens of a systems approach appears to suggest that adopting a systemic view of the complex transition of the Chinese electricity sector could provide a suitable conceptual base for this study. It has been noted, however, that the majority of studies use a systems approach as a heuristic technique rather than a conceptual model. Referring back to the definition of system approaches as illustrated in Diagram 3.2. the above-mentioned system studies set out to study a particular content-related or dynamic system aspect rather than adopting the idea of Systems Thinking as an implicit activity underlying the examination of a complex problem. Creating a detailed level of understanding on a particular issue is important and appropriate when examining structured and well-defined problems. However, employing a systems approach as a heuristics, a technique or a set of methods rather than a conceptual model, only considers a single view of an issue. The far reaching and deep rooted transformative change which takes place during an energy transition cannot be understood merely from one perspective. The presence of stakeholders with diverse and potentially incompatible views as well as the existence of multiple drivers and dimensions require a more complete view of the world.

Not many systems based studies could be located in the context of China. Nevertheless, there appear to be a number of studies that investigate energy or sustainability related challenges specific to China through a systems lens. Liu et al. (2015) analyse the potential of policy pathways to achieve CO_2 emission targets under different growth scenarios. Feng et al. (2013) investigate the effect of a changing fuel mix on emissions from urban energy consumption in Beijing. Wei et al. (2009) develop a system dynamic model to investigate the impact of consumption on urban sustainability. The contribution of cities to China's energy usage and CO_2 emissions is also the subject of systems based research by Dhakal (2009) and Fong (2013). Han et al. (2008) perform a system dynamic analysis of CO_2 emissions from the Chinese transport sector. Energy security is at the centre of the studies by Wu et al. (2011) and Hsu (2012). As observed with other system studies, most research appears to apply system based toolset to investigate a confined problem.

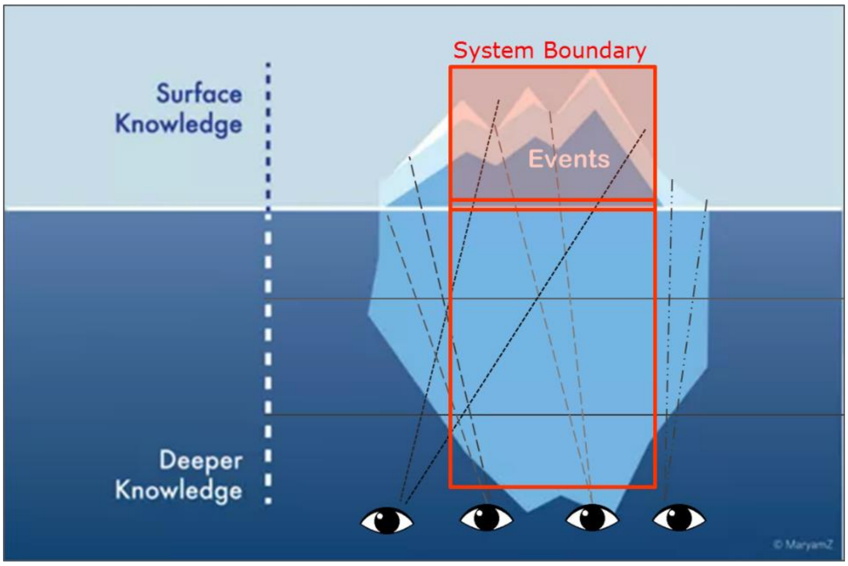
The small number of systems based studies opens up the opportunity to test the conceptual framework within the setting of a rapidly developing economy such as China and the complex challenges inherent in an energy transition against the backdrop of deep rooted socio-economic disparities.

3.5 Overview of the Conceptual Framework

This section presents a more detailed description of the conceptual framework adopted by this study. It is based on four pillars which link a particular approach of 'Thinking' to one or multiple complexity dimensions which have been identified as present in the reform of the Chinese electricity sector (Table 3.1).

The main requirement of the conceptual basis underpinning this research is to create understanding of the context in which the reform takes place. Content and dynamics both play an important yet secondary role. In line with Churchman (1967), who stated that "the systems approach begins when first you see the world through the eyes of another", the conceptual framework facilitates the investigation of different perspectives of stakeholders. The aim is to identify and understand areas of concern from the 'inside', as they are seen by those affected by the reform.

Diagram 3.4 Setting the Systems Boundary through the Selection of Stakeholder Perspectives



The selection of stakeholder perspectives to be included in the study firstly addresses the complexity dimension of openness. The decision of whose views to consider draws a boundary around the system under investigation. The system boundary defines the problem itself. Secondly, in addition to revealing perspectives themselves, shared as well as conflicting views amongst different stakeholders are disclosed. The decision of whose views to include has direct implications for the requirements for the solution. Diagram 3.4 illustrates how the boundary setting could exclude certain stakeholders from the analysis. The decision which stakeholder views to consider is of outmost importance, in particular as the study is concerned with equity implications of an electricity reform.

Diagram 3.5 Understanding Complexity through Systems Thinking

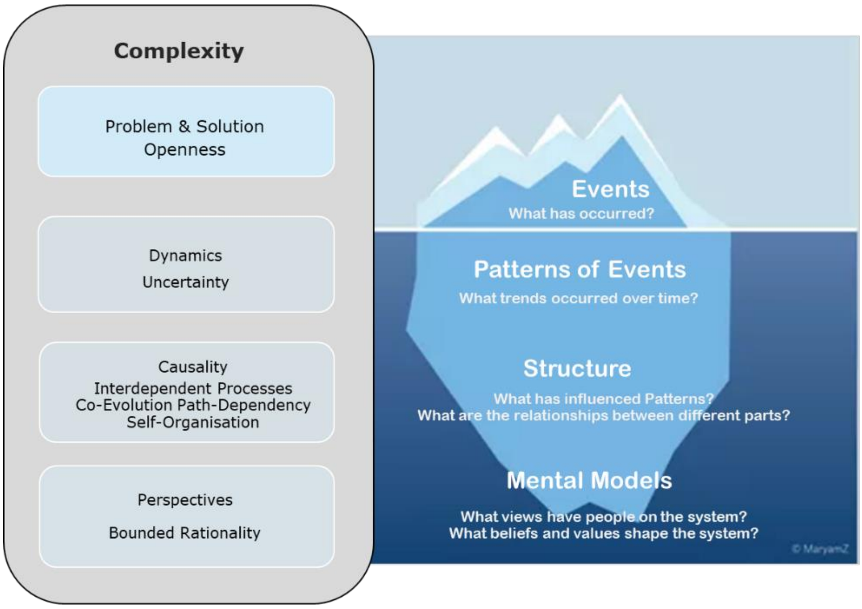


Diagram 3.5 uses the iceberg metaphor to illustrate how each of the complexity dimensions relevant to an energy transition (see Table 3.1) link to a particular way of Thinking. This distinction could be useful for the development of a methodological approach in the next chapter.

The first pillar of the framework is concerned with identifying and understanding the events which fall within the system boundaries. These events are observable but perceived differently depending on the position within the system from where they are viewed. Relevant events could include a pollution incidence, relate to the general economic climate, people's living standards or personal well-being and health. The identification of events forms the starting point of understanding parts of the problem which manifests itself as trends, patterns of events and the causal structure of the system. The system boundary determines which events form the basis of the analysis. It provides clarity on the definition of the problem as well as the solution. Excluding environmental concerns for example (i.e. by excluding stakeholders, who regard environmental quality as important, from the study) would result in the derivation of a system structure where energy related pollution is dropped as an objective of the electricity reform. Ignoring certain events could compromise an equitable outcome of the reform.

The second pillar is concerned with understanding patterns of events. Observable patterns link events with each other and provide a starting point to identify the dynamic relationships which occur within the electricity sector. Complexity at this level is related to the uncertainty of how dynamic relationships generate and change events through complex feedback mechanisms, delayed and non-linear (i.e. disproportionate) responses to a change of a system variable. Understanding these mechanisms which underlie the causal relationships is key to understanding how a change to any system variable, affected by a carbon market for example, influences other seemingly unrelated parts of the system over time. Recognising the dynamics of a system requires awareness of the system structure itself.

The third pillar of the conceptual foundation is concerned with understanding the causal relationships underlying the structure of the system. Cause-and-effect relationships are shaped by complexity inherent in co-evolutionary, path dependent and self-organising processes. The intention of any intervention is to influence causal relationships between system variables. The introduction of a carbon market changes cause-and-effect relationships, which translate into new or different dynamics, patterns and ultimately events.

The fourth pillar of the conceptual framework closes the analysis by making sense of the system structure. It does this by attempting to grasp the complexity of social reality which is captured by the structural systems model. The analysis goes deeper than the investigation into stakeholder objectives and preferences (Pillar 1). It seeks to establish the influence of cultural and social norms, personal attitudes on the problem itself. These are the factors which are not explicit in the system structure (Pillar 3) and its underlying dynamics (Pillar 2). People making decisions within a particular political, social and cultural setting do so under conditions of 'bounded rationality'. Price based policies, in particular, are vulnerable to unforeseen and intended reactions of people. When faced with economic decisions, people often do not follow the ideal of the perfectly rational 'homo economicus' of traditional economic theory (Sterman, 2000). Understanding attitudes towards the environment and motivators for pro-ecological behaviour could provide valuable lessons for the prevention of policy resistance and policy failure.

3.6 Conclusion

The complexity inherent in energy transitions makes the investigation into the reform of an electricity sector an overwhelming challenge, particularly as the focus shifts from developed nations to fast developing countries such as China.

A framework based on Systems Thinking can assist the analysis by elucidating the various dimensions of complexity. This chapter demonstrated that there appears to be value in applying approaches and models that incorporate Systems Thinking. By framing Systems Thinking as a way of 'Thinking' rather than a heuristic, complexity inherent in the market based changes to the Chinese electricity sector can be revealed and understood. An iceberg was used as a metaphor to represent a model illustrating the hierarchy of levels of understanding. An iceberg consists of a relatively small amount of ice above the surface and a much larger mass of ice underneath the surface. In the hierarchy of explanations of observable events and invisible patterns and structures, the lower level of the iceberg gives context and meaning to the higher level (Vandenbroek, 2015). Typically, interventions attempting to solve a problem target a single event and disregard the enormous mass of structural factors that are underneath the surface. Well-intentioned efforts frequently lead to policy resistance as there is no or only little awareness as to how a system will adapt in response to the intervention. Interventions are delayed, diluted or defeated by the unforeseen reactions of people and the environment (Sterman, 2000).

The Chinese government has been committed to sustainable development as a policy goal. In particular, the reform of the energy sector has been supported by an array of new policies. Despite progress in some areas such as the deployment of renewables, socially and environmentally motivated policies failed to achieve the intended outcomes often due to factors linked to the political, social and cultural factors, which need to be considered in the ‘human’ context of a residential electricity sector reform. The chapter demonstrated that Systems Thinking could provide the conceptual basis to deal with the complexities of an energy sector reform. What is required now is a methodological approach to create knowledge to further elucidate complexity occurring within the invisible parts of the system.

4 Methodological Framework: A Participatory Study of China's Residential Electricity Sector

This chapter explains the methodological approach and research design. In addition to providing a basis for answering the research questions related to the energy sector reform, the intention of this chapter is to present a methodological advance to the historically difficult question of how to understand equity in the context of the trade-offs inherent in the sustainability transition (Thomopoulos and Grant-Muller,2013).

In order to cope with the technical complexity and uncertainty of the reform as well as potentially contradictory social preferences, an amalgamation of soft and hard systems approaches provides scientific modelling techniques and participatory processes which are used to study equity implications of a market-led reform. The overarching framework of the methodological approach is provided by a regional case study.

This chapter is structured as follows. The first section explains the case study strategy which is applied to this research. It also illustrates that the epistemological and ontological position taken in the theoretical framework is supported by a case study methodology. The case selection process and the advantages and limitations of the approach are then discussed within the context of energy related equity issues encountered in China.

The following section explains data collection, modelling and analysis techniques. The case study seeks to understand the complexity, uncertainties and considerable long-term impacts of the reform on the populations in different parts of China. Given the central role of stakeholders as source of information, the concept of stakeholder analysis is introduced as justification for the employment of participatory information collection methods. Stakeholder analysis also provides the link to the bespoke data analysis framework. A causal model based on stakeholder input is developed. It elucidates the complexity linked to system structure. Simulation in a dynamic model tests the effect of different carbon market scenarios on the current event patterns, which play out differently in each of the case study locations. Causal and dynamic models are developed in order to answer key research questions linked to opportunities and barriers of a carbon market to reform the residential electricity sector. Multi-Criteria Decision Analysis is employed to analyse modelling output in order to provide insights into the potential of different market designs to deliver an equitable outcome across the case study regions. Stakeholder preferences for the outcome of the reform are the basis of the analysis.

The final part of this chapter is concerned with cultural and ethical issues that require particular attention throughout the fieldwork stage of this study. The chapter concludes with a discussion of the limitations of the research design and their implication for future studies.

4.1 Case Study Approach as Overarching Research Strategy

There is no universally accepted definition of a case study (Dubois and Gadde, 2002). Generally, the case study approach is regarded as a research strategy rather than a method or a specific research technique. Case studies are typically used in research that focuses on the holistic examination of one or multiple cases linked to a social phenomenon (Goode and Hatt, 1952; Thomas, 2015). A case study approach lends itself to a theoretical framework based on Systems Thinking as both see the world as an interconnected whole. A case study aims to develop a detailed understanding of a case creating awareness of its complexity and context encountered in real world situations (Punch, 2013).

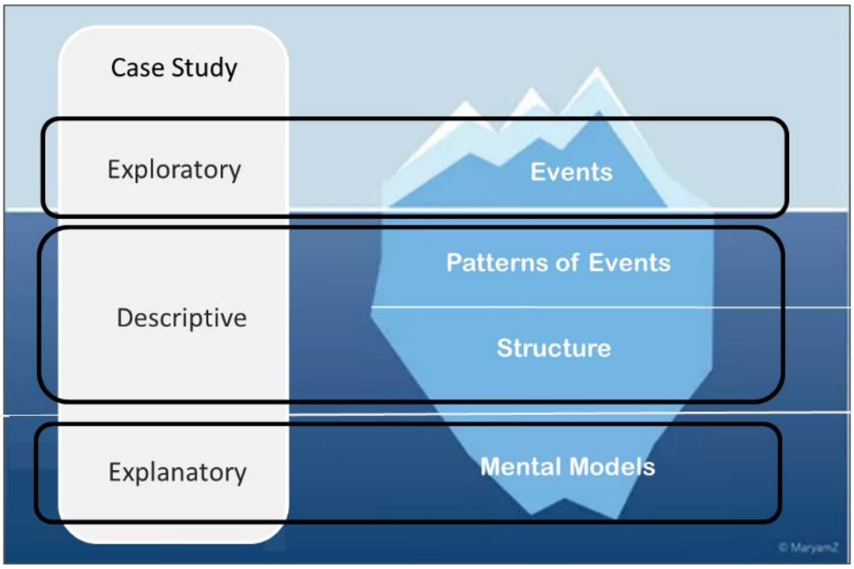
A case study draws on different types of data often originating from multiple sources. In an experiment where a limited number of variables is collected to describe a phenomenon, data collection is deliberately isolated from its context (Zaidah, 2003). While experiments are useful in the setting of linear and well defined problems, one of the strengths of a case study approach is its applicability in complex social situations as data is mostly generated within the context of its use (Yin, 1994). Data derived from the requirements of a stakeholder embedded in a particular context can improve the quality of research in the face of complexity.

The application of a case study approach is not limited to a particular phase of the research. Case studies can be classified to fall into three categories (Yin, 1994): Exploratory, descriptive and the explanatory. According to Yin (1994), there is no exclusivity between exploratory, descriptive and explanatory case studies; in fact some of the best case studies combine all three elements.

Exploratory case studies set out to discover any observable phenomenon or event. This approach is useful when little is known about a particular problem or the context it occurs in (Zainal, 2004). Insights into the general problem situation typically prompt further examination in the form of descriptive and explanatory studies (Schell, 1992). Descriptive case studies focus on understanding a particular issue or a specific aspect of behaviour. Descriptive case studies are useful to gain awareness of causal processes. The study may open up questions about 'how' and 'why' issues or behaviour contributed to a particular outcome. These questions are explored through an explanatory study (Hakim, 2007).

Each element of the case study is intrinsically linked to the collection of data, the generation of information and its subsequent examination. Diagram 4.1 shows how the empirical study, its approach to data collection and analysis, fits within the iceberg metaphor, which was used to explain the conceptual model based on Systems Thinking.

Diagram 4.1 Linking Methodological Framework and Conceptual Framework



Once the complex problem situation inherent in an electricity sector reform has been explored through interviews with stakeholders, particular content related issues can be focused. Based on stakeholders' areas of interest and concern, data is collected to elucidate these aspects of the reform. Event data as well as a model of causal relationships linking system variables leading to these events provide input for a system dynamic model. The system dynamic model identifies and quantifies event patterns and tests how a carbon market could influence them. Explanation of system structure and dynamics require an understanding of social factors. Explanatory elements of the case study investigate deep levels under the surface in order to explain how the modelling output is influenced by an individual's values and beliefs. Personal attitudes towards energy saving behaviour or views on fundamental trade-offs between development and environment are elicited through interviews and a questionnaire. The questionnaire acts as a source of data for Multi-Criteria Decision Analysis which evaluates a number of market based intervention alternatives in terms of regional equity. The various elements of the methodological framework are explained in more detail in the remainder of this chapter. The study's approach to data collection, generation and analysis is explained in Section 4.2. Particular attention is paid to the involvement of stakeholders in the data gathering and analysis process.

The following section demonstrates how a case study approach fits well with the conceptual framework based on Systems Thinking through its ontological and epistemological position.

4.1.1 Epistemology and Ontology Linking Case Study Methodology to Systems Thinking

A case study approach is selected as overarching methodological framework of the research as it is able to support a bespoke approach which is required for the analysis of equity issues inherent in a market based sustainability transition of China's electricity sector. By combining instruments from a variety of different disciplines for data collection, data generation, data modelling and data analysis, the framework is able to create an understanding of how a carbon market could function under specific regional conditions. The methods adopted are the result of the research questions to be analysed (Wendt, 1992). The development of the overall methodological strategy, however, is driven by the conceptual approach. The epistemological and ontological position of this study acts as a bridge between the two frameworks.

Literature on social research methodology finds a case study approach to be a suitable strategy in the face of complex problems that require in-depth study. According to Yin (1994) a case study approach should be considered as research strategy when the study intends to answer “how” and “why” questions through an empirical inquiry with the objective to investigate a contemporary phenomenon (or ‘observable event’) within its real-life context, when the boundaries between the phenomenon and the context it occurs in are not evident. Simons (2009) makes a similar point. She describes “a case study as an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular project, policy, institution, programme or system in a ‘real life’ context.” Stake (1995) unites both definitions by stating that a case study is concerned with understanding the particularity and complexity of an activity rather than defining a case study as a set of methods.

The adoption of a case study as a strategy to investigate complex issues links the methodological framework to the theoretical foundation of this study. The latter recognises that complexity arises from the interaction between system content and dynamic relationships occurring within a stakeholder specific context. Events or ‘phenomena’ are observable and provide multiple sources of evidence in form of data. This data could provide input for the quantitative as well as the qualitative elements of the study.

A case study approach supports Systems Thinking from an ontological and epistemological point of view. The ontological starting point of this study presumes the reality of systems. Systems come into being as parts of wholes existing in the form of entities with specific structural properties and behaviours (Mingers, 2006; Grieves; 2008). Epistemology characterises what constitutes ‘legitimate’ knowledge (Mir and Watson, 2000). Coupled with a realist ontological perspective, the study adopts a constructivist epistemological approach which asserts that knowledge is not objective as it is socially constructed through mental models which attempt to approximate reality (Cabrera, 2014). At the centre of ontology is a complex economic, social and political system. It defines an explanatory framework of cause-and-effect relationships with which the research questions are concerned. The system, its architecture, linkages and mechanisms may be interpreted differently depending on perspective. The constructivist epistemology of case study methodology therefore fits well with the theoretical framework of creating a mental system model reflecting the unique reality as it is perceived from a particular position within the system.

The strength of a case study is the close relationship between the researcher and the participant in the study (Crabtree and Miller, 1999). Participants are able to share their point of view and interests. They are able to describe their views of reality. This enables the researcher to construct a more realistic model of the system (Lather, 1992; Robottom and Hart, 1993). Pluralism and not relativism is at the heart of the equity problem. This means that each human being with a unique personal identity must be recognised (van Bigovic, 2006). The selection of a constructivist methodology is therefore justified by the central research question of this study. The decision on how to select the case to study is a very important one that merits some reflection. Case selection plays an important part in finding answers to the numerous questions posed by the study. Ill-informed case selection can jeopardise the validity of the research as a whole.

4.1.2 Case and Boundary Definition

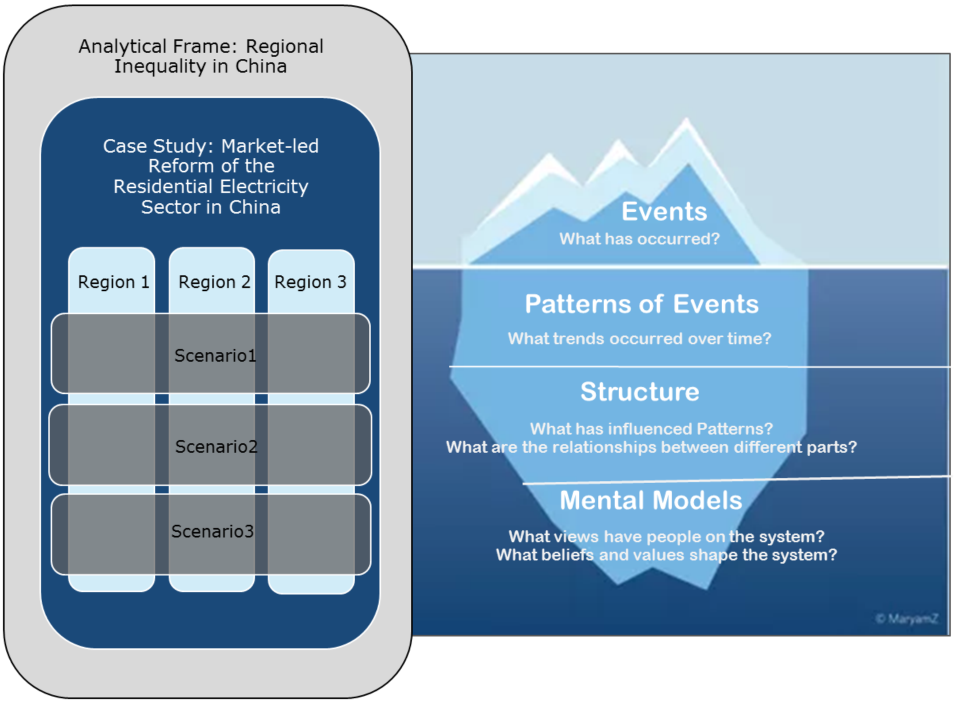
The starting point of designing a case study is to establish 'the case' (Mitchell and Bernauer, 2004) and to define and describe the boundaries of the case as clearly as possible. The case is defined by Miles and Huberman (1994) as "a phenomenon of some sort occurring in a bounded context" or expressed differently the case is "in effect, your unit of analysis". The unit of analysis can vary from an individual to a group or from a single site to multiple locations, from observations made at a particular point in time to a longitudinal study (Zainal, 2004). Other authors understand a case as an event or a situation (Mitchel, 2006). The case can also be seen as a rationale for how elements are linked together and influence each other (Thomas, 2015).

In order to define the subject of the study, each case should have a boundary which defines its scope. The case boundary defines the types of evidence to be gathered as well as the priorities for data collection and analysis. Given the subject under investigation, the determination of a case for this research adopts a multi-level definition. At the top level the case is the 'Reform of the residential electricity sector in China through a market based intervention. The study period covers the years 2015 to 2035'. This definition sets the case apart in terms of space (China), situation (reform of the electricity sector), event (introduction of a carbon market) and time (2015 to 2035). This definition draws a boundary by excluding geographies outside China, policies not concerned with deep-rooted changes of the country's residential electricity sector and events occurring outside the study period. The case is selected not because it is representative of any other case, but because of its uniqueness. As in an intrinsic case study, the case is selected purely on "its own merits" (Stake, 1995).

The study of regional impacts of the planned carbon market suggests the division of the overarching case into geographic units of enquiry. Collective or multiple case studies offer the advantage of allowing comparisons to be made across several cases. In multiple cases, each individual case is meaningful in relation to the other cases studied. Multiple case study research uses cases which are related in some ways (Stake, 2006). The identification of provinces which share certain criteria allows the examination of regional equity impacts of a carbon market on households in the different parts of China. The uniqueness of criteria delimits one case from another and thus allows the researcher to infer the findings of the study to other regions sharing a case's characteristics.

In this vein, Wievorka (1992) offers a more complete definition of a case by suggesting that for a subject to be a case it needs to present a "practical, historical unity" as well as a "theoretical, scientific basis". Regarding a case as a situation or space provides its definition as a 'subject' of a case study, but lacks the analytical frame or the 'object'. According to Wievorka (1992) it is not enough to declare the observation and analysis of an event (electricity sector reform or the introduction of a carbon market) or a social phenomenon (rising consumption) a case. In order for a situation or an event to be a case it needs to be embedded in a context in order to be meaningful. Context is given by China's unique economic and political setting and the socio-economic and environmental disparities, which exist at regional level. The investigation of equity impacts within this context provides the analytical framework or the object to the subject of the case, which is the market-led electricity sector reform. The structure of the case under study in terms of content (subject) and context (object) is shown in Diagram 4.2. The diagram also illustrates that the study is concerned with the investigation of multiple cases at spatial level. Each case is concerned with a distinct spatial unit (i.e. a region or province in China), which is embedded in the context of China and the disparities between the country's different regions.

Diagram 4.2 Structure of the Case Study



Intervention scenarios are an integral part of the case study. Intervention scenarios depict the future consequences of an intervention. They describe the future state of the economy, society and the environment under the influence of a carbon market. Case studies are a powerful learning device which informs the process of thinking about an intervention. Scenarios suggest how an intervention should operate. Intervention design is given the opportunity to apply the acquired knowledge. Once the effect of an intervention is known, feedback is given about the choices being made.

4.1.3 Stakeholder Led Case Selection

Selecting criteria for the determination of regional cases is a criterial task as it sets the fundamental direction of the research. Most studies appear to define case criteria based on events which are observable ('i.e. the tip of the iceberg') and manifest themselves in data. The literature review and the perusal of news reports have brought to light a multitude of events or phenomena that directly and indirectly relate to an energy transition.

As explained in the previous section it is the uniqueness of a case which sets it apart from another. Regions that share similar event patterns are subsumed within the same case. Diversity between regional patterns determines the number of cases to be studied. The identification of event patterns requires the interpretation of the data by the researcher. Case definition solely based on a review of literature could lead to the introduction of bias through the implicit prioritisation of certain factors over others (Pannucci and Wilkins, 2010). The definition of cases is closely related to the drawing of boundaries around the system under investigation. It determines whose views are considered. The constructivist position of the case study approach requires that the views of those who are affected by the subject of the research are taken into account right at inception during the exploratory phase of the analysis, when the design of the study is considered. Stakeholders decide the factors that delimit one case from the other. Their perspectives on the problem situation guide the case definition and selection. Stakeholder consultation has the aim to prevent the introduction of prejudice in the research design.

The identification of cases at spatial level will be discussed in more detail in Chapter 5 as stakeholder perceptions emerge from the analysis of interviews. The following section discusses the limitations of a case study. It also describes how the overall research design intends to mitigate potential problems which could compromise the validity of the study.

4.1.4 Limitation of a Case Study Approach

Case studies have various advantages. They support the empirical study of complex real life situations and they provide insights into unobservable behaviours and processes. However, case studies have attracted criticism, in particular for their lack of scientific rigour, their inability to generalise results and their labour intensity (Yin, 1994; Baxter and Jack, 2008; Flyvbjerg, 2006; Gerring, 2006; Tellis, 1997; Zainal, 2007).

First, case studies are often critiqued for their absence of rigour resulting from the application of equivocal evidence and biased views, which could influence the entire process from research design to the inference of conclusions (Yin, 1994). This study attempts to mitigate the problem of subjectivity by basing the research on a multiple case approach which seeks to investigate impacts from a carbon market on a number of different study locations. Research bias is further contained by drawing on stakeholder views on the problem situation for the case selection.

Second, grounds for establishing reliability and generality of the case study approach are also subject to scepticism, particularly in the presence of singular case studies and case studies which investigate events or phenomena affecting a large population (McLeod, 2010). Even though this research is conducted across various study sites, the overall study sample is expected to be negligible in comparison to the size of the population that is affected by reform of the electricity sector. It is recognised that the limited number of study participants makes generalisability and transferability problematic. The selection of locations and the selection of study participants is therefore critical. In particular, as the study is concerned with the investigation of equity impacts, the consideration of perspectives representative of China's population is required. Transparency regarding selection criteria is of paramount importance in order to infer the extent of generalisability and transferability of the research conclusions to other populations. In this vein, Hamel et al. (1993) point out that the setting of the research is far more important in a case study approach than a big sample size.

Third, case studies are considered to be labour intensive and time consuming. The study of complex real life situations typically requires the collection, generation and examination of a considerable amount of data (Gerring, 2006). There is a danger that the vast amount of data is not managed and organised systematically. It may become subjective and the validity of the research as such is in jeopardy. As the literature review demonstrated the study of China's energy transition requires the consideration of many different factors due to its far reaching impacts on the country's economy, society and environment. Typical for case study research, multiple data sources are required to corroborate evidence (Elram, 1996) covering the different elements of complexity inherent in the reform (Table 3.1). During the exploratory phase, event level data such as pollution data, socio-economic data, technical data regarding energy generation, data on electricity usage are gathered mostly from government statistical yearbooks. This data has to be integrated with the qualitative information elicited from study participants. Their views on the problem situation, their solution preferences and factors influencing their behaviour add to the amount of information which needs to be managed, analysed and incorporated into the study during the exploratory and explanatory stage. Quantitative output from system models obtained at the descriptive phase of the study increases the onus on a carefully thought through plan of data management and data analysis.

The majority of criticism appears to stem from the lack of a well-defined and formalised methodology. The weakness of lacking rigour is at the same time the strength of case study research. The flexibility of case studies allows researchers to move beyond rigid and prescribed approaches of data collection and data analysis. None of the drawbacks of case studies appear to be innate in the approach itself. On a practical level they can be addressed and managed through careful research design and planning. Openness and transparency providing the rationale for case selection and the choice of data collection and analysis techniques appear to counter-balance the lack of prescribed methods.

4.2 Data and Information Collection

Case study research does not imply the use of a particular type of evidence. Case studies can be based on either qualitative or quantitative evidence. The evidence may come from a variety of primary and secondary sources such as official statistics, literature, research reports, interviews, observations, or any combination of these. A case study approach does not imply the use of a particular data collection method (Yin, 1981). Data, however, needs to support the research objective. The design of an effective data collection strategy is important as it sits between the research questions and the data analysis (Punch, 2013).

The central research question of this study revolves around important equity issues inherent in an electricity sector reform. Data collection is largely stakeholder driven. Stakeholders define the problem situation, which subsequently determines the detailed data requirements in terms of the data itself, the source and the collection method.

At the core of the data collection is the elicitation of information from stakeholders in the form of qualitative interviews and close ended questionnaires. Experts in the Chinese energy sector and carbon trading as well as residential electricity users are interviewed in order to obtain their views on a market-led reform of the electricity sector. The problem situation itself presents variables and evidence which need to be obtained from various sources in order to be able to construct a causal description of the energy sector. In addition to stakeholder input these variables are identified through the review of relevant literature.

Quantitative socio-economic and electricity sector data quantifying these variables and the causal links between them is required to test solution alternatives in a systems dynamic model. Primary data is mainly obtained from official government publications. Past research serves as source of data which could not be located in official records.

In light of the participatory element of this study it is important to understand the difference between data and information. Data are facts while information is interpreted facts. Information gives meaning to data (Scheaffer et al., 2011). Information is, therefore, subjective and dependent on the perspectives of the one interpreting the data. The output from the consultation of stakeholders is data from the point of view of the researcher as she has not analysed and processed it. However, as people see the world through their own specific lens, stakeholder observation of the events is considered information.

The combination of various data collection methods is vital in this research as it establishes strong links between what people think (interviews) and what they want (questionnaires) in terms of a solution with a carbon market at its core (written documentation including official statistics and literature; system modelling).

4.2.1 Socio-Economic and Environmental Data

Official government statistics at national and provincial level such as Statistical Yearbooks published by National Statistical Bureau of China were consulted to obtain socio-economic and environmental data. When the data analysis brought to light gaps between the retrieved data and the required data, the attempt was made to fill the void with data originating from previous research.

In order to better understand in the context of a carbon market, numerous pieces of formal documents such as policy papers plus hundreds of informal documents (mainly news reports) were collected via different channels such as the internet and print media over the course of the study. The information and ideas conveyed through these documents provide clues as to why certain event patterns have emerged over time. They offer insights into the structure of the system, give evidence for the existence of norms and rules and allow a glimpse of prevalent mental models in a particular social setting. Despite their usefulness, documents require careful interpretation as relevant questions regarding their origin and the author's intention need to be addressed before incorporating information into the study (Hammersley and Atkinson, 1983*)*.

4.2.2 Stakeholder Information

The consultation of stakeholders forms the central pillar of the empirical study. The views of stakeholders on the electricity sector reform are the basis of the analysis, from which data requirements for systems modelling and Multi-Criteria Decision Analysis are established.

Before explaining the study's approach to sampling and information elicitation, the next section provides the rationale for employing stakeholder analysis as methodology to support the information and data collection.

4.2.2.1 Stakeholder Analysis

There is growing evidence that the assumption of all stakeholders having similar interests leads to the failure of initiatives and engenders resistance and resentment of those affected.

In the private and public sector stakeholder consultation has gained in importance over the years as there is growing realisation that those affected by a decision could influence the success of its implementation (Brugha and Varvasovsky, 2000). Grimble and Wellard (1997) specifically connect the importance of participatory stakeholder analysis to the trade-offs inherent in sustainable development.[33]

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[33] Grimble and Wellard (1997) state that "Clearly there is a link between the three E's [economic efficiency, equity and environmental objectives] and various social or economic groups or stakeholders with differing spheres of interest, concerns and priorities. Stakeholder analysis (SA) has been developed in response to the

A plethora of different approaches and definitions give rise to confusion over what is really meant by stakeholder analysis (Donaldson and Preston, 1995; Stoney and Winstanley, 2001; Weyer, 1996). A review of relevant literature revealed a difference of opinion over who or what exactly stakeholders are. Most definitions seem to be derived from Freeman's (1984) seminal work on stakeholder theory. According to Freeman stakeholders are those who affect or are affected by a decision or action. He recognises that "stakeholders (are) in a system". Decision makers or experts, who frame and structure a problem and present implications of interventions, are usually included in the first category.

The second category includes all those who are affected by the decisions made by others. In the context of environmental pollution, Coase (2013) classifies stakeholders as polluters and victims. Polluters can implement change by altering the level of pollution and the victims are those who are directly or indirectly affected. Checkland (1981) rejects the idea of stakeholders being 'helpless victims' relying on someone else, an actor, to resolve the problem. He believes that whoever is affected by a problem should be a part of the process to solve it. The definition of stakeholders as active participants in the process of solution formulation adopted by this study is the one provided by Checkland. The understanding of stakeholders being part of the solution finds direct application in Multi-Criteria Decision Analysis. The requirement to consider the views of different stakeholder groups is commensurate with the 'inclusiveness' notion of equity that is the central theme of this research. For the avoidance of doubt, it shall be mentioned that the study is not concerned with the legitimacy of stakeholder groups, their level of decision making authority or their capacity of getting attention. The common understanding of a stakeholder which only considers individuals and groups upon which an organisation relies for its survival (Mitchell et al., 1997; Pajunen, 2006; Neville et al., 2011) appears to be too narrow for the purpose of this study. This definition would exclude marginalised stakeholders with no political clout or limited financial resources. The exclusion of stakeholders could lead to the implementation of unequitable solutions.

Stakeholder analysis is closely related to the central notion of soft systems methodology (SSM), which regards the direct involvement of stakeholders as the key to successful intervention design, in particular in the presence of complex sustainability related problems with many inherent trade-offs. Soft systems approaches are concerned with creating awareness of the 'context' in which stakeholders face a certain problem (Checkland, 1981). Soft systems methodology seeks to understand the mental models, the concepts and beliefs individuals hold and use to make judgments about reality (Elsawah, 2015). Stakeholder analysis provides a toolset to elicit the, often diverging, perspectives, interests and objectives of those who are selected to be within the system of consideration.

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challenge of multiple interests and objectives and added to the basket of approaches available for the analysis and formulation of development policy and practice."

4.2.2.2 Stakeholder Sampling

Stakeholder identification and selection are a critical part of the study as the precondition of inclusion determines whose views are considered and so define the boundaries of the system of interest. Miles and Huberman (1994) noted that "you cannot study everyone everywhere doing everything." Even though it is desirable to understand as many views as possible, it is not practical to study everyone who is affected by the residential electricity sector reform in China. Sampling is concerned with the selection of a subset of individuals from within a population (Tranter, 2014).

It is reiterated here that stakeholder input is required at two points during the empirical phase of the research. Firstly, stakeholders are interviewed to support the qualitative part of the study which is concerned with better understanding the problem situation, which presents itself with the introduction of a carbon market for residential electricity users. Secondly, stakeholders state their preferences for the outcome of the market based reform in a questionnaire, which provides quantitative input for a Multi-Criteria Decision Analysis. Sampling is as important in qualitative research as it is in quantitative research. However, there are differences in sampling in qualitative and quantitative research (Punch, 2013). In quantitative sampling the focus is on identifying a sample which is representative of the larger population being studied. Qualitative research tends to use a form of deliberative sampling, with a focus on a particular purpose.

A thorough and organised approach of stakeholder analysis is important at the beginning of the participatory process. This is particularly relevant in complex situations to avoid the haphazard identification and selection of stakeholders. There is a great variety of sampling approaches in qualitative research to suit different research purposes and settings (Punch, 2013). Miles, Huberman and Saldana (2013) identify around 20 different sampling methods. Janesick (1994) and Patton (2002) highlight the existence of even more.

Common approaches for stakeholder sampling fall into top-down and bottom-up methods. The strength of a top-down approach is that it is a systematic way of discovering stakeholders. Its very broad and generic nature allows it to identify a wide range of stakeholders. Top-down identification minimises the chance of leaving out central stakeholders which could lead to crucial questions not being asked (Bryson, 2004). Identifying stakeholders 'bottom-up' contributes to minimising researcher bias which subconsciously could prioritise certain views and exclude others. Snowball sampling is a commonly used stakeholder identification technique where initially located individuals identify new stakeholder groups or individuals during interviews. Snowball sampling is a convenient way to increase the size of the sample as the process continues (Reed et al., 2009).

The main criterion of choosing a sampling method needs to be based on the objective of the study and the questions it seeks to answer. In the context of this study the combination of theory based sampling, a top down approach, and a snowball approach is considered to be most suitable to fit the purpose of the research. Theory based sampling is used in a purposive way to set the sampling frame. The sampling frame provides a map that identifies individuals or groups to be included in the study (Willmot, 2005). The basic conceptual model of the system, which is being studied, is used as a sampling frame. It guides the identification of the stakeholders affected by the carbon market based electricity sector reform.

Although the important first step in any participatory approach, stakeholders are often identified randomly on an ad-hoc basis. This carries the risk of marginalising certain individuals or groups, not addressing the actual problem and leading to a biased and unequitable outcome (Reed at al., 2009). A carefully thought-through approach to sampling can address this risk. A systemic view allows the identification of different stakeholder groups and their position within the system. In order to be able to answer the main research question which is concerned with the equity aspect of the reform, the process of sample selection needs to ensure that the majority of the system elements are being represented.

Top-down analysis based purely on desk research and published material, however, entails the danger to close down the identification of stakeholders prematurely. Lacking the divergence of perspectives could potentially undermine the idea of systems based research, which seeks to fully understand an issue. The adoption of a bottom-up approach as the empirical study evolves could mitigate this risk.

It has been noted that there is a clear trade-off between the number of stakeholders and the feasibility of the study in terms of data collection and analysis. In light of the vast number of stakeholders in the reform and the great variety of different groups affected by the introduction of a carbon market, the sampling criteria therefore need to consider the 'level of affectedness' to make the task of stakeholder identification manageable within the time and resource constraints of the research. The issues involved in identifying and selecting individuals as well as obtaining their commitment to take part in the study within the cultural setting of China are discussed in 4.5.

Sampling in the quantitative part of this study is people sampling. The idea behind people sampling is that the researcher uses data collected from the sample in order to infer findings back to the entire population that is being studied. Representativeness is a key concept. The extent to which it is applicable depends on the objective of the study. As data collection supporting the quantitative part of the study involves the completion of questionnaires by the general public, there is the practical issue of gaining access to a large and representative sample. Convenience sampling (Etikan et al., 2016), where the researcher takes advantage of a particular situation which provides access to study participants, is expected to play an important part in obtaining quantitative data for further analysis. Convenience sampling must not be carried out haphazardly in order not to compromise the sampling frame determined by each of the study cases.

It is anticipated that secondary analysis, which involves the perusal of data collected and analysed by other researchers, supplements the insights gained from evaluation of own survey data. This approach could mitigate the lack of representativeness of the data collected during the fieldwork stage of this research (Procter, 1996). Despite the potential of secondary data analysis to improve the quality of this study, it needs to be recognised that methodological difficulties could arise caused by different research objectives and incompatible conceptual frameworks (Reeve and Walberg, 1997).

4.2.2.3 Stakeholder Information Elicitation Techniques

Elicitation, in which knowledge is sought directly from human beings, is usually distinguished from indirect methods such as gathering information from written sources. In the context of this study the conclusions from the extensive review of literature covering a wide range of issues and topics is underpinned by tacit knowledge elicited from a variety of stakeholders. The success of stakeholder involvement in terms of gaining a deeper understanding of the situation and the requirements for a solution are greatly influenced by the techniques employed during the elicitation stage.

4.2.2.4 Qualitative Data Elicitation: Semi-Structured Interviews

There are many different elicitation techniques ranging from observations to close ended quantitative surveys. The decision to use interviews as the main technique to gather information is based on the study's requirement for participatory research. Qualitative research interviews typically reveal 'subject perceptions' (Kvale, 1996).

The objective of the initial information elicitation phase is to enhance the knowledge gained from the literature review by understanding different perspectives on the electricity reform. In line with stakeholder identification through purposive sampling, interviewing experts in the Chinese energy sector as well as actors in the reform appears to be the most efficient way to discover tacit knowledge on the political factors and technical details which have not appeared in mainstream literature. Stakeholders representing residential electricity consumers, who are not professionally, politically and academically linked to the Chinese energy system or the reform, are also consulted. Semi-structured interviews are carried out to discover an individual's personal areas of concern and his view on the wider issues linked to the consumption of electricity.

Semi-structured interviews, in contrast to fully structured or unstructured interviews, appear to be the most suitable interview type for systems based research. Open ended questions are thought to be an appropriate method to identify the key issues associated with energy modelling and sustainability analysis. The pre-set structure allows for a degree of consistency to ensure comparability between stakeholder/expert groups (Bryman, 2008). The open nature of the queries provides a flexible approach well-suited to explore topics or issues as they emerge with a series of follow-up questions or probes.

For the great majority of the pre-arranged meetings a list of 'key areas' is identified, that the interview intends to cover. This list is sent to the interview partner in preparation for the meeting. Despite the structured approach, the open ended nature of the questions allows for variation in responses. In addition to allowing the possibility for the exploration of novel themes, this flexible type of interviewing technique appears useful as it permits to tailor the communication style to the interviewee. A catalogue of questions serves as reference for the researcher during the interview. This ensures that all relevant areas were covered. In the case of non-English speaking interview partners the questions were formulated prior to the interview, translated by a research assistant into Chinese and forwarded to the interviewee.

4.2.2.5 Quantitative Data Elicitation: Survey

The choice of survey as a research method for collecting information regarding people's views on issues linked to residential electricity consumption is driven by the prospect of being able to collect a lot of information over a relatively short period of time. The versatility of the survey in the form of a standardised questionnaire allows to gather a great variety of information which can be analysed with computer based spreadsheet applications.

The survey is developed to collect information to answer the research questions regarding people's preferences for the outcome of the reform and their priorities regarding economic development, environmental quality and regional equity, the key sustainability objectives of the 'New Normal'. Another requirement for the questionnaire is to capture attitudes towards the adoption of pro-environmental behaviour. These different dimensions need to be operationalised through the adoption of indicators once relevant questions for the questionnaire have been developed.

Questionnaires can be administered in person, by post and electronically. It is anticipated that the study locations identified as part of the stakeholder led case definition (Chapter 5) influences the mode of survey delivery. Self-administered (internet) questionnaires, which do not require the presence of an administrator, can boost the overall number of surveys completed, particularly in regions which cannot be visited due to resource or time constraints (Meadows 2003; Wright, 2005).

A number of potential issues have been identified with the surveying approach adopted by this research. The most common criticism levelled at survey based information collection is the issue of researcher imposition. When developing the questionnaire, the researcher is making his own decisions and assumptions as to what is and is not important (Oppenheim, 2000). The chosen sequence of questions can also sway people to choose particular answers. In order to minimise the effect of researcher bias, prior to its administration a draft version of the questionnaire is reviewed by a variety of people including an expert in survey design, academics with a background in the energy related issues and members of the Chinese public.

Another frequently cited problem associated with survey based research is that respondents interpret questions differently and sometimes are not truthful in their answers. Personally administered surveys can mitigate the first risk while increasing the likelihood of respondents not being frank in the presence of the researcher. Respondents to self-administered surveys tend to be more truthful in their answers, while in the absence of a researcher no clarification of the questions can be sought. It is hoped that through the mix of submission methods both risks can be minimised. Ensuring study participants of their anonymity can further encourage openness.

The survey consists of close-ended questions which invite respondents to choose an answer from a number of different options presented on a Likert scale. Likert response formats capture attitudes or levels of agreement/disagreement with a statement along an ordinal scale. Unlike a simple "yes/no" question, a Likert scale uncovers degrees of opinion (Bowling, 1997; Burns and Grove, 1997). A decision needs to be made about whether to use even or odd numbers of points along the rating scale. An even point scale represents forced choice. Respondents either agree or disagree. The balanced odd-point scale illustrates an unforced choice where the selection of the middle point signals neutrality. As the topic of the questionnaire is a highly charged issue, one cannot be apathetic about, an even-points (forced response) scale was selected. There is a risk that forcing respondents to make a choice could increase the incidence of incorrect selection, may cause someone to omit the question or abandon the survey all together (Allen and Seaman, 2007; Garland, 1991). In order to lower the chances of alienating respondents an even point scale was chosen, which includes on an additional option that is an unforced choice ('Prefer Not to Answer').

It is understood that multiple-choice answers developed by the researcher cannot fully capture people's views. Capturing information through open ended questions was contemplated but eventually ruled out due to the impracticality of operationalising answers. By recording survey responses along a Likert scale quantitative data is obtained, which means that the data can be recorded with relative ease and serve as input for a further (quantitative) analysis (McLeod, 2008). The intention of only administering the survey once implies that only a snapshot of the participants' views is recorded at a particular point in time. Unlike in a longitudinal study attitudes changing over time cannot be captured.

The plethora of data and information gathered needs to be analysed and processed in order to provide answers to the research questions. The methods employed for data analysis are based on the conceptual framework built around the notion of System Thinking.

4.3 Data Analysis

Complex systems approaches offer a rich set of methodological analysis tools based on Hard Systems Methodology (HSM) and Soft Systems methodology (SSM). Each approach has its strengths and weaknesses and applicability is dependent on the type of complexity being examined. In the following it is demonstrated that the combined use of soft systems methodology and hard systems methodology provides a suitable framework to elucidate complexity as part of the descriptive phase of the case study.

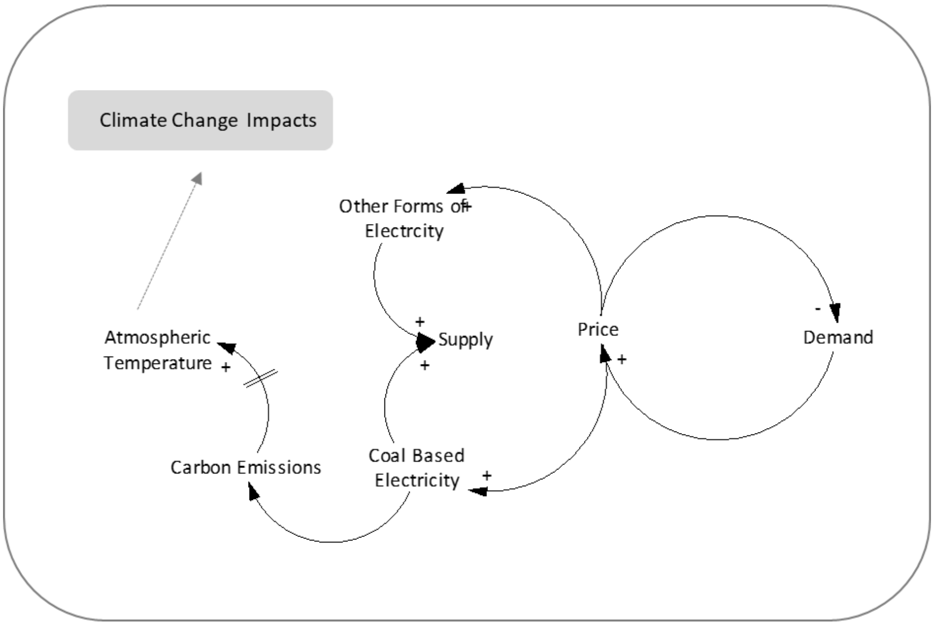
4.3.1 Hard Systems Methodology

Hard systems methodology, frequently referred to as general systems theory or system dynamics, identifies driving forces of problems, explores cause-and-effect relationships and the dynamic linkages between different systems components.

Hard systems methodology has been used extensively in the study of environmental and energy systems. It provides a powerful toolset to develop an understanding of complexities inherent in a multi-facetted problem. Concerned with technical factors it is a scientific approach to problem-solving. It uses computer simulations to quantitatively analyse the structure of the system under investigation.

Causal loop diagrams (CLD) explain the causal relationships that exist within a system. They create an understanding of the causes and effects of a problem and how different parts of a system interrelate. A CLD depicts a system as a collection of connected variables and feedback mechanisms created by these connections (Forrester, 1994). One or more of the variables represent the symptoms of the problem. The rest are part of a causal chain contributing to the problem under investigation (Haraldsson, 2000; Bala et al., 2017). Arrows and signs to illustrate cause and effect relationships and directions of the relationship. The plus and minus signs at the arrow heads indicate the direction of the change. A positive sign means that both variables change in the same direction. Conversely, a negative sign describes an interaction where the increase of one variable results in the in the decrease of another variable. Diagram 4.3 below shows a simplified CLD of an energy system. Changes to the problem, the rise of atmospheric temperatures because of carbon intensive electricity generation, does not arise from individual variables. It is created by the link between supply, price and demand. A CLD helps to pinpoint locations of where the fundamental forces causing a problem are coming from. In this example, the price of electricity appears to the key variable to influence the level of carbon emissions from power generation.

Diagram 4.3 Example of a Causal Loop Diagram

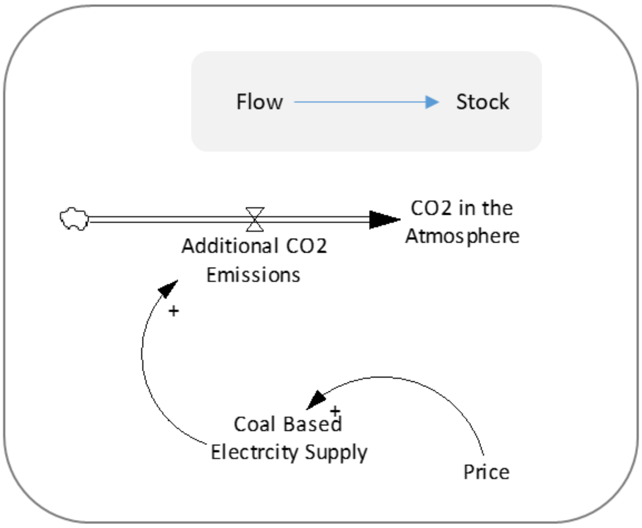


Objective of system dynamic modelling is to establish how certain system variables interact over time. Interactions are dependent on the internal structure of the system. As previously noted, system structure is a reflection of content related complexity stemming from path dependence, self-organisation, feedback mechanisms and the co-evolution of events. Adopting the metaphor of the iceberg, system dynamic modelling identifies and quantifies unobservable event patterns, which are linked through the system's structure.

Stock and flow diagrams enhance the understanding of dynamic behaviour of complex systems. Stocks determine the current state of a problem (e.g. the amount of CO_2 accumulated in the atmosphere). Stocks therefore often provide the basis for designing interventions. Changes to stocks occur via flows that are expressed in a unit of time (e.g. the amount of CO_2 emitted in a year). Key to solving a problem is to regulate flows into stocks (Sterman, 2000; Quelhas and McCalley, 2002). Diagram 4.4 depicts a basic stock and flow model. It illustrates how the price of electricity influences system behaviour and has mitigating or exacerbating effect on the problem of climate change. More specifically, the model demonstrates the extent to which the price level determines the flow of carbon from energy generation, which ultimately accumulates as a stock of CO_2 in the atmosphere.

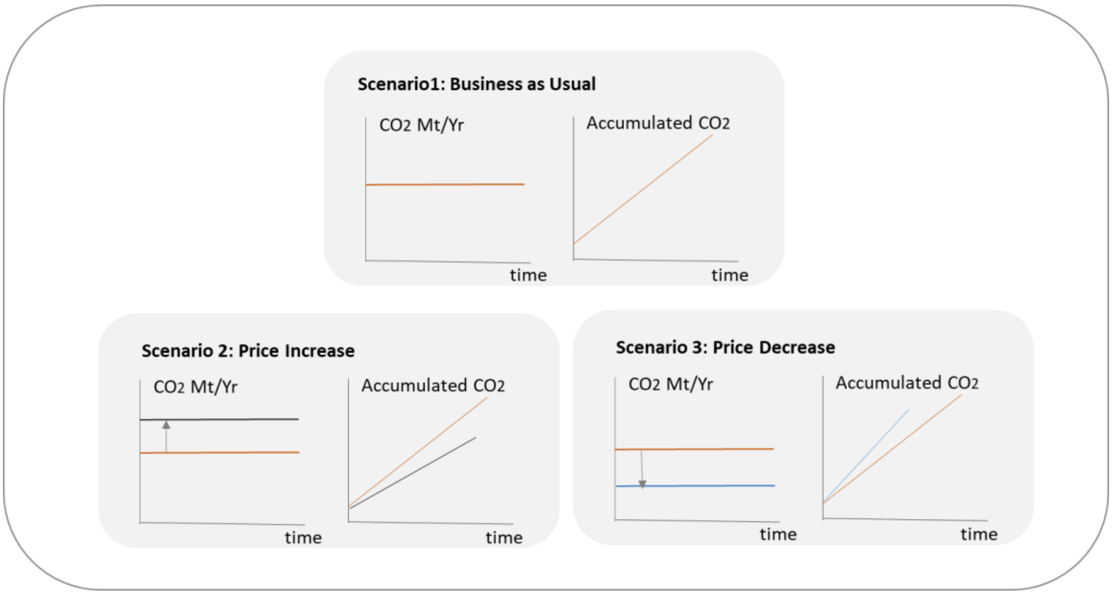
A stock and flow model studies the system in a quantitative way. Relationships between variables are described by equations that are executed during simulation runs. The real power of system dynamics is utilised through these simulations. In the example, simulations in the stock and flow model (Diagram 4.4) provide the opportunity to test the potential of various price-based interventions to solve the problem of energy related carbon emissions. Simulations also help to better understand the effect a change in price has on other parts of the system (the economy for example). Diagram 4.5 shows the sample output of three system simulations testing the effect of different price levels on energy related CO_2 accumulating in the atmosphere.

Diagram 4.4 Example of Basic Stock and Flow Diagram



Scenario modelling has been traditionally used to project different possible pathways into the future. It is increasingly applied as a learning tool to understand the long-term consequences of interventions. Scenario modelling is closely linked to systems based analysis as it acknowledges the higher degree of complexity existent in systems, unlike the study of individual projects or technologies. Scenario modelling is also closely linked to the case study approach adopted by this research (Section 4.1). System simulation in a stock and flow model is merely a tool to operationalise the scenario approach and to capture the effect of a particular intervention scenario on pre-determined variables (i.e. 'stocks') within the system.

Diagram 4.5 Example of System Simulation Output



In context of this research system dynamic simulation intends to show how the introduction of a price on carbon affects the stakeholder areas of concern. Variations in the carbon price level are simulated to ascertain the effect of a price signal on changing usage behaviour. The scenarios are executed for a particular province or city which is representative for each study region (‘case’). Interventions are simulated against socio-economic and energy sector related data specific to the case in order to reflect the effect of a specific carbon market design on the region. The simulation of scenarios is carried out in the systems modelling software package Vensim.

A systems dynamics model requires a number of inputs: Firstly, it requires the decision of which systems variables to include in the model. Secondly, it requires a description of the relationships between these variables, i.e. the knowledge of how the variables interact with each other as well as the data which is used to quantify relationships. Thirdly, it requires the selection of variables that are used to measure the effect of a market based intervention.

The system variables are implicitly defined by the stakeholders themselves. Variables are part of the causal chains which describe the areas of concern highlighted by stakeholder during the interviewing process. Insights gained from stakeholders and the review of literature are used to formulate the simulation equations, which describe the relationship between these variables. Socio-economic and environmental data from official sources supplemented by secondary data from relevant research provide the quantitative basis for the model. Hard Systems Methodology relies on tools associated with Soft Systems Methodology to provide the causal foundations for the system dynamic model.

4.3.2 Soft Systems Methodology

Soft Systems Methodology problematises the relationship between system dynamic models and the many realities that exist for those who are affected by a particular situation. Systems approaches recognise that the construction of a problem situation by different stakeholders varies dependent on personal interests, values and beliefs.

In order to elicit, integrate and incorporate the different stakeholder perceptions participatory instruments linked to stakeholder analysis are used to verify and complete the understanding of the problem and its potential causes. Insights gained from the interviews with experts and those directly affected by the electricity sector reform are translated into a ‘problem oriented causal diagram’ which forms the basis for intervention simulation in a systems dynamic model. Stakeholders are asked to identify areas they are most concerned about in context of a reform. As described in the previous section the effect of a particular intervention on these stakeholder areas of concern is measured through system dynamic simulations in stock-and-flow diagrams.

Hard systems methodology and soft systems methodology are often presented as two incompatible ways to operationalise the concept of Systems Thinking. Soft system approaches are regarded to be suitable to address the ambiguities involved in messy ‘human’ problems where different views are involved, rather than well-defined technical problems, which should be analysed by a hard systems approach (Checkland, 2000).

A number of studies concerned with complex problems involving both a ‘human’ and ‘technical’ aspects highlight that the two methodologies complement rather than exclude each other (Lane and Oliva, 1998; Mingers, 2000; Pit et al., 2016). Awareness of people’s mental models creates an understanding of the system’s structure. The internal structure manifested in the dynamic relationships between system variables, explains patterns and identifies ways to re-shape them.

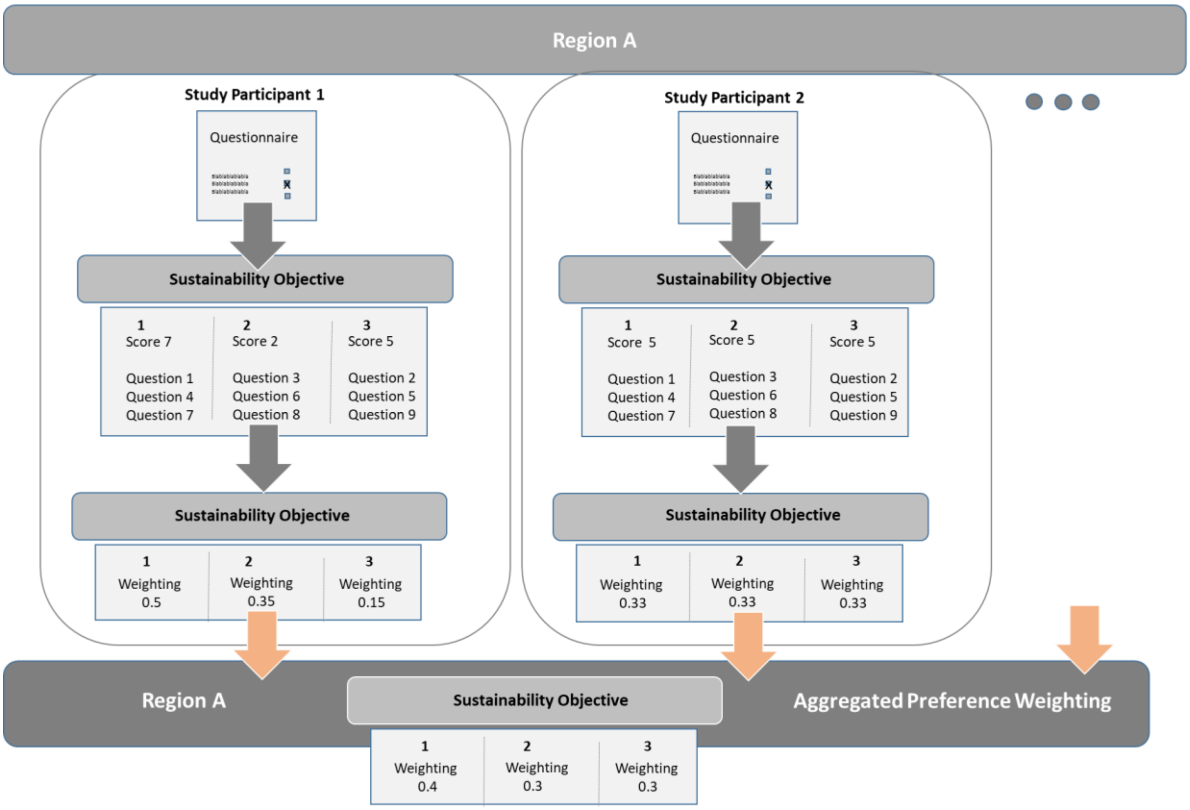
4.3.3 Multi-Criteria Decision Analysis

One fundamental assumption in this study is that there is no ‘best’ solution that could be identified through the application of a scientific method such as system dynamic modelling in a stock and low model. In line with the complexity inherent in sustainable energy transitions the research recognises that solution design is subject to a high degree of uncertainty and ambiguity (Stirling, 2001, Stirling and Mayer, 2001; Foxon et al., 2008). People’s preferences for a solution often contradict the rationality of human behaviour assumed by economic models. This was described earlier as the problem of ‘bounded rationality’. A discussion in wider society is needed to understand not only what the actual problem is but also what the most adequate and favourable solutions are.

Multi-Criteria Decision Analysis (MCDA) has proven to be a useful tool for the evaluation of solution designs in the presence of multiple and diverging stakeholder objectives for the sustainability reform. It has been applied in a number of case studies (Stagl, 2003; Kowalski et al., 2009). A key component of MCDA is the elicitation of stakeholder preferences (Marsh et al., 2017). During the empirical part of this study stakeholder preferences are captured in a close-ended questionnaire. Analytical Hierarchy Processing (AHP), a form of Multi-Criteria Decision Analysis (MCDA), is adopted to act as a participatory decision framework. AHP provides a toolset to determine regional preferences for a particular solution.

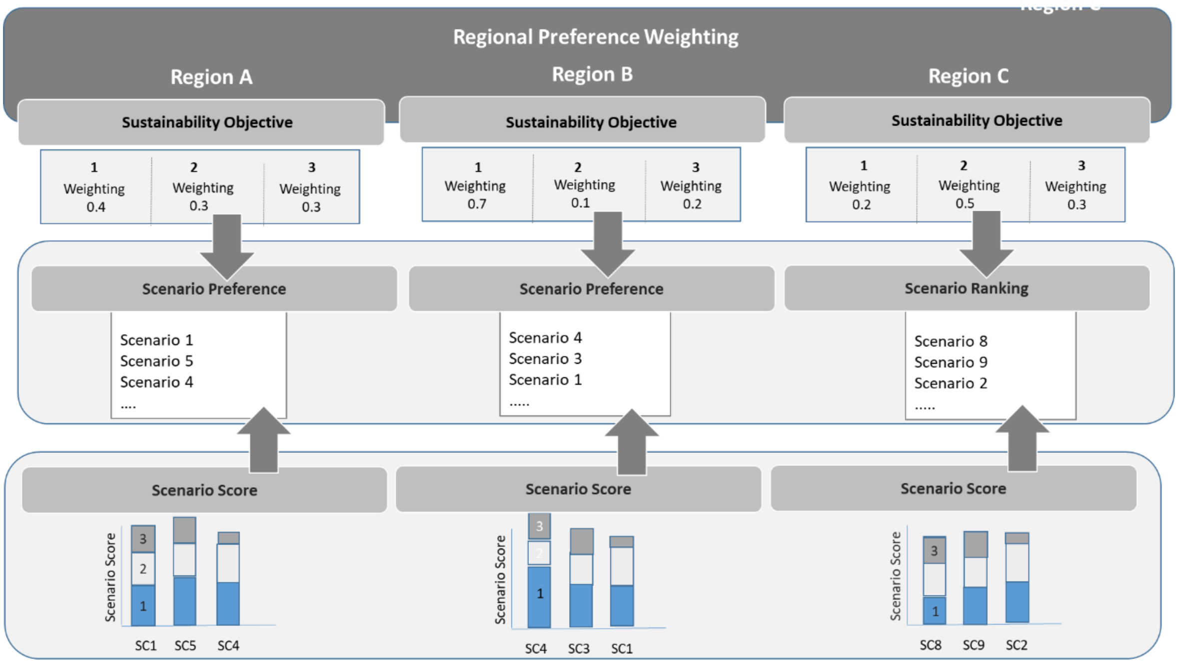
AHP involves several steps, which are executed in the spreadsheet application Excel. Diagram 4.6 illustrates the sequence of steps required to complete the analysis. Firstly, questionnaire responses are coded numerically in order to be scored. The decision criteria are the sustainability criteria which were highlighted as important by stakeholders earlier in interviews. Preferences for each criterion are explored through a number of questions. Secondly, an algorithm is applied to translate the survey responses for each criterion into a score along a pre-defined preference scale (1 to 10 for example). Thirdly, based on the score for each criterion relative weightings are calculated for each study participant. This figure indicates the relative importance an individual attaches to the sustainability objective. In the final step individual preference ratings are synthesised for each of the study regions.

Diagram 4.6 Derivation of Regional Preferences for Sustainability Objectives through Analytical Hierarchy Processing



The second part of the analysis is concerned with ranking the intervention scenarios according to the aggregated regional preference ratings. AHP is applied to determine a ranking for each scenario in terms of regional preferences for a particular sustainability outcome. As shown in Diagram 4.7 the process involves two steps. Firstly, a rating is calculated to indicate the extent the outcome of a scenario meets a particular sustainability objective. Secondly, a scenario score is calculated based on aggregated stakeholder preferences in each of the study regions. A score evaluates scenarios in light of the trade-offs that exist between the sustainability objectives.

Diagram 4.7 Derivation of Regional Preferences for Intervention Scenarios through Analytical Hierarchy Processing



Aggregated regional preference scores enables the researcher to identify the scenarios which were most accepted and the scenarios which were most contested in light of people's priorities. The analysis is carried out for each regional case. To arrive at an overall score at national level regional scenario preferences are weighted according to population size.

4.4 Methodological Framework Adopted by the Study

The methodological approach of this study seeks to harness the strengths of various systems approaches by integrating different tools, models and techniques as in their combination they can best respond to the complexity, turbulence and heterogeneity of the problem situation.

Diagram 4.8 Methodological Framework Adopted by the Study

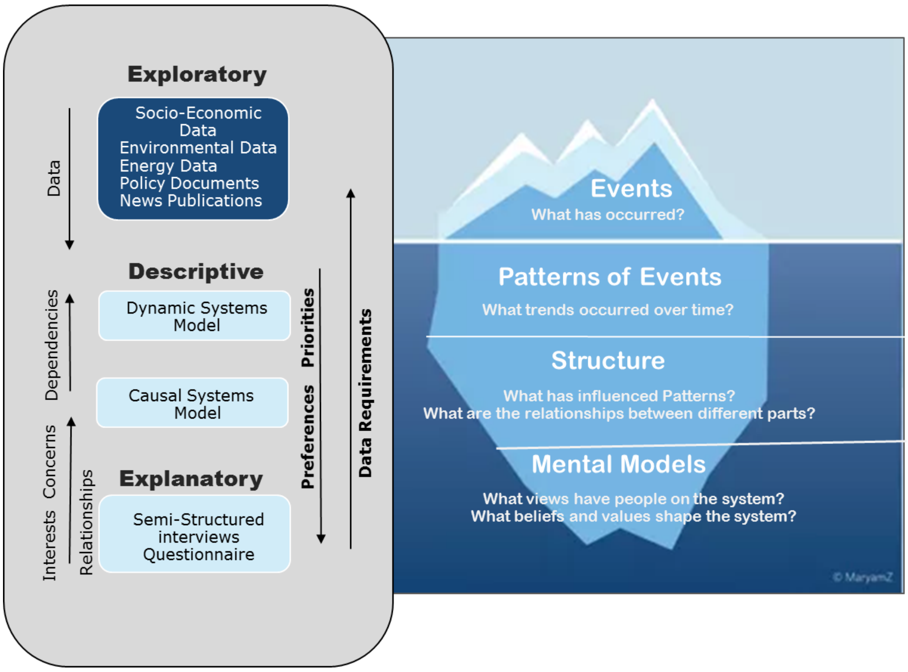


Diagram 4.8 highlights the interdependencies between the different methods in the form of input and output that is passed between them. A case study approach provides the overarching frame for the analysis of a complex real-world situation, which requires the modelling and evaluation of a vast amount of data and information collected from a variety of different sources. The data modelling is based on a synthesis of approaches linked to Soft Systems Methodology and Hard Systems Methodology. Evaluation of modelling output in light of stakeholder preferences is provided by Multi-Criteria Decision Analysis.

The participatory element of the study acts as thread connecting the various elements of the methodological approach. The engagement of stakeholders is at the centre of the methodological framework and a prerequisite for the study to fully answer the research questions.

4.5 Conducting Research in China

Researchers are challenged with many issues when carrying out their research with people in different cultural settings. Conducting research in China is rife with methodological and ethical challenges (Harkness et al., 2003; Heimer and Thøgersen, 2006; Pieke, 2000; Sæthe, 2006).

A lot has been written about practical challenges encountered during fieldwork in foreign countries such as the unfamiliarity with cultural and behavioural norms and language barriers (Smith, 2016). Therefore, this section focuses on issues that specifically relate to practical and ethical challenges of data collection, which is to a great extent influenced by the unique cultural, social and political setting of China. This section explores the potential implications of these challenges on the quality and validity of this research.

4.5.1 Accuracy and Reliability of Official Data

The reliability of China's officially published emission and economic statistics has been widely questioned. China's authorities including the National Bureau of Statistics[34] have acknowledged problems affecting the quality of their data (Mathews and Tan, 2015).

Inaccuracies are often blamed on technical issues, poor coordination among monitoring agencies and corruption. Studies such as the one conducted by Brombal (2017) highlight that problems with the reliability of official environmental data have far deeper institutional, political, and ideological roots. The bureaucratic incentive system, conflicting agency goals, diverging objectives between central and local authorities and private economic interests appear to be the cause for the reporting of inaccurate data rather than technical problems associated with a fast growing economy.

A number of studies suggest mismatches between official pollution data and self-measured data or data retrieved from other sources. Based on discrepancies between their own calculations and official data Guan et al. (2012) discover that national CO_2 emissions were underreported by 1.4 Gt in 2010, which was equivalent to the annual carbon emissions of Japan in the same year. A study by Wang et al. (2009) find differences between self-measured and published PM_{10} values in Beijing. They estimated that self-measured data was 1.3 times higher than officially reported air quality levels over the period from July to October 2008. Discrepancies between air quality data provided by the municipal authorities and the U.S. Embassy in Beijing provide further proof for irregularities with reported air quality. The case of Beijing does not appear to be a geographically isolated one. Ghanem and Zhang (2016) calculate that about 50% of cities reported dubious PM_{10} pollution levels. They conclude that certain reporting patterns provide clues for the manipulation of air quality figures.

Suspicions of data falsification extend beyond pollution data to economic statistics. Official GDP figures often fail to reflect true economic condition. Over many years the total of provincial figures has exceeded the national GDP. Officials at local level frequently report over-optimistic growth figures as their performance is largely measured against their ability to meet economic targets (Wildau, 2016).

These issues with data accuracy directly affect the quantitative analysis of this research. More specifically, the lack of reliable data questions the validity of conclusion drawn from

[34] The National Bureau of Statistics of the People's Republic of China (NBS) is an agency directly under the State Council. The NBSC collects and publishes statistics related to the economy, population and society at national and local levels. Some of the data can be accessed online: http://www.stats.gov.cn/english/.

systems dynamic modelling which requires a wide range of national and provincial data in the equations underlying the scenario simulations. Publications by the National Bureau of Statistics, however, are frequently the only source of primary data accessible to an academic researcher. In the presence of limited alternative sources of regional and national data for economic growth, income levels, air pollution, residential electricity consumption as well as data on the pollution intensity of a region's generation capacity, official statistical yearbooks provide most of the data for the quantitative analysis of this study. Problems with the reliability of official data might suggest that studies based on China's economic and environmental statistics should be rejected outright. When treated as estimates rather than accurate figures, analyses based on official statistics can still generate useful insights as long as explicit statements about the reliability of the underlying data accompany any conclusion (Sinton, 2001).

4.5.2 Gaining Access to Interview Partners

Yeung (1995) suggests that securing an individual's commitment to take part in an interview depends on various factors ranging from the financial support for the study to the reputation and nature of the organisation and interviewer's position and level of influence. The limited official support for this research project and the researcher's limited ability to entice the interest of potential interviewees could contribute to the ineffectiveness of securing interviews through directly contacting ('cold-calling') potential interview partners. According to accounts of other researchers who conducted fieldwork in China, the status of a researcher does not seem to have influenced an individual's decision to accept an invitation for an interview when an introduction was made through a contact. However, it seemed to have again played an increasingly important role after the second or third round of interviews when a snowballing approach was adopted. Lai (2007) and Wang (2014a), who encountered these problems during their fieldwork in China[35], ascribed the reluctance of individuals to take part in their research to the terminology of Renqing (human feeling).

Renqing refers to a set of social norms that the Chinese value highly and which keep good relationships with others (Khan et al., 2016; Wang et al., 2008). Renqinq is the behavioural aspect of Guanxi. Guanxi is a tight knit network of interpersonal relationships (Yeung and Tung, 1996) from which an individual can draw resources or advantage in various social or professional situations (Davies et al., 1995; Warren et al., 2004) through the exchange of Renqing, i.e. favours providing mutual benefits (Pearce and Robinson, 2000).

Lai (2007) and Wang (2014a) both found that their social network was willing to make introductions as they thought they had obligations to keep Renqing with the researcher

[35] Lai (2007) conducted fieldwork in Shanghai when she undertook personal interviews with the Chinese respondents to examine the relationship between state institutions and global finance capital. Wang (2014a) interviewed business people to understand how the arrival of transnational corporations had transformed the supply networks in China.

themselves. Likewise, the newly introduced interview partners agreed to share their knowledge with the researcher as they felt indebted to the people who contacted them rather than having any sense of obligation to contribute to the study itself. Therefore, as snowballing progressed beyond the second round, interviewees were free to make the decision as to whether to make further introductions as they did not owe the researcher a favour, i.e. they had no an obligation of Renqing.

It appears that Renqing is an extremely important factor, which could prove a major obstacle to conducting participatory research in China. However, a number of measures may be taken to mitigate the impact of Renqing on the quality of the study. Widening the social network through the attendance of wide range of events such as conferences or informal social gatherings could provide access to first round 'interviewees'. Individuals working at international organisations might be less influenced by Renqing and therefore more likely to commit to taking part in the study.

4.5.3 Ethical Considerations

There are a number of ethical issues to be taken into consideration throughout the various stages of data collection phases, which take place over the field work stage of this study. Prior to the fieldwork stage, ethical concerns were identified through the review of literature, the consultation of researchers who had previously conducted participatory studies in China as well as in discussions with Chinese nationals who provided valuable information on the social and cultural setting of the country.

Some of the potential ethical dilemmas appear to be more relevant in China than in a more liberal Western context, for example potential limitations to the freedom of expression or the risk of coercion. Most other concerns relating to the confidentiality of information and the anonymity of study participants were found to be applicable to all participatory research, irrespective of the study location. These risks are discussed in more detail. The following also presents the procedures which are established for the protection of participants and the control over the information obtained from them.

4.5.4 Freedom of Expression

It is recognised that free speech and the expression of opinion can be problematic in China. However, the research topic which is concerned with environmental policy and its impact on socio-economic development per se is not considered a contentious issue. The country's premier himself has stressed the importance of green growth and societal equity when announcing a paradigm change ringing in the departure from the 'growth at all cost model'. The current Five Year Plan also stresses the urgency to put China on a sustainable development plan. Environmental NGOs are typically allowed to operate relatively freely albeit under government supervision. Groups and activists who dedicate their work to more sensitive issues such as labour relations or are part of the democracy movement attract closer scrutiny and are more frequently subject to oppression.

For the avoidance of doubt, it is stressed here that the participatory methods employed by this study merely explore general attitudes towards sustainable energy generation and consumption. The survey or interviews are not designed to discover any radical opinions, which could be in disagreement with the current policy agenda of the state party. Despite the government's relatively tolerant attitude towards environmental issues, a small risk remains of an individual or an organisation being reprimanded in response to the dissemination of sensitive information. This cannot be totally avoided but mitigated through the adoption of measures safe-guarding the anonymity of study participants and the confidentiality of the information they provide.

4.5.5 Confidentiality of Information and Anonymity of Study Participants

Anonymity and confidentiality of participants are central to ethical research practice involving the collection of information from people (Wiles et al., 2008). No individual recruited from the public to complete a close-ended questionnaire is asked to disclose their identity. The participant is invited to share general demographic information such as gender, income group or educational status. No names or other personal information are noted. Only the study site is recorded. If the survey is administered in paper format dependent on the situation, effort will be made to ensure the questionnaire is filled in by the study participants in private.

To increase the sample size and to obtain responses from regions which cannot be visited during the fieldwork stage, an online version of the questionnaire is uploaded to Sojump, a Chinese internet based survey platform. In addition to the ethical concerns generally linked to the administration of surveys, further complications arise in the case of online surveys. Online surveys cannot normally be assumed as being anonymous. Even though participants are not asked to provide their name or other personal information, the IP address of the device they use to complete the questionnaire is recorded and could potentially be used to identify individuals. It was not possible to fully ascertain the privacy policies underpinning the survey company. Therefore, it cannot be fully ruled out that the information recorded could be retrieved by other parties. It is unknown whether government agents have access to the database that is used to store survey responses.

The identity of experts and other individuals consulted in semi-structured interviews is only known to myself, the researcher, and the assistant. In case the interview partner does not speak English the accompanying research assistant provides a translation of the questions and answers. No information which could allow the identification of the individual is included in any documentation, which can be accessed by anyone other than the researcher and the research assistant. Research assistants with access to any information elicited from interview partners and the questionnaires are required to sign a confidentiality agreement. The interview participants are further guaranteed confidentiality through the anonymisation of personal data such as their name. Anonymity and confidentiality are preserved through the use of pseudonyms for participants, for the affiliation of the participant to a particular organisation as well as the location where the interview took place. Should parts of the study be published, information gained from study participants is presented in a way which does not allow the identification of the source. All data is kept secure on a personal laptop or documented on paper which is locked away.

4.5.6 Study Participants in Dependent Relationships

Despite the non-controversial nature of the study a low risk to study participants in dependent and unequal relationships remains, if sensitive information was to be disclosed to the researcher. A similar risk would also be encountered in the setting of a Western democracy.

Employees of carbon exchanges, electricity providers and other private or state-owned corporations could risk disciplinary action, if they were to provide information which is not in line with company policy or conflicts with the views of managers and colleagues. Academics, researchers, lecturers and students, who are in dependent relationships could experience the same dilemma. This risk is mitigated by the anonymity and confidentiality measures described above.

4.5.7 Coercion

The nature of Chinese society may mean that people feel psychologically coerced into responding to questions that they do not wish to give. Even though efforts are made to minimize the risks of this occurring through obtaining informed consent, the risk of coercion cannot be completely eradicated.

Efforts are also made to undertake the survey and any interviews in private where possible to allow participants to freely express their views. As the quality of responses given in situations of coercion is questionable, it is noted if a survey respondent or interview partner appears to have been under pressure into participating. Notes that record the researcher’s observations and those of the research assistant further help to assess the validity of the response.

4.5.8 Lack of Consent

Having identified suitable participants, every effort is made to obtain genuine consent at individual level to signal voluntary involvement in the study. In cases where consent is not forthcoming or appears to be forced, individuals are not surveyed or interviewed. As part of obtaining consent from study participants it is made clear as to who the researcher is and her affiliation, what the research project is about, and how information is processed and stored.

There might be situations in which it could be inappropriate to obtain written consent. In this case or when a participant is not comfortable to give written consent, oral consent is sought. In order to mitigate the risk of instances where consent is expressed but not actually meant, the participant is given the opportunity to withdraw from the survey or interview at any point.

The ethical clearance of this research was issued by the School of International Development at the University of East Anglia prior to the field work in April 2016.

4.6 Conclusion

This chapter clarified the methodological issues that underlie the design and analysis of this research. The choice of methodology is driven by the conceptual framework. It is also interlocked with the epistemological notion of constructivism which was adopted as a major paradigm to frame the research methodology. The epistemological position of this research requires participatory methods to explore the research problem.

A case study approach was selected as overarching methodological frame as it allows the integration of multiple methods. Based on this research strategy, three methodological techniques, data and document analysis, semi-structured interviews and questionnaires are identified as resources for data generation. Each of these methods is used to reveal different facets of the interactions and social processes. The synthesis of different methods for the analysis of data is required to elucidate the complexity inherent in the research problem. Instruments borrowed from the two main schools of system analysis, Hard Systems Methodology and Soft Systems Methodology, are employed to model causal relationships and to test the effect of different carbon market intervention scenarios. Multi-Criteria Decision Analysis is used to evaluate the intervention scenarios in light of regional stakeholder preferences.

Diagram 4.9 explains how the methodological toolset is used to operationalise the theoretical framework of this study. Each instrument helps to understand one or multiple dimensions of complexity. In combination they can answer the overarching question this research intends to answer regarding the potential of a carbon market to equitably alter generation and consumption patterns of the residential electricity sector. Diagram 4.10 illustrates how the toolset provided by the methodological framework discovers answers to each of the research questions.

Diagram 4.9 Overview of the Theoretical and Methodological Framework

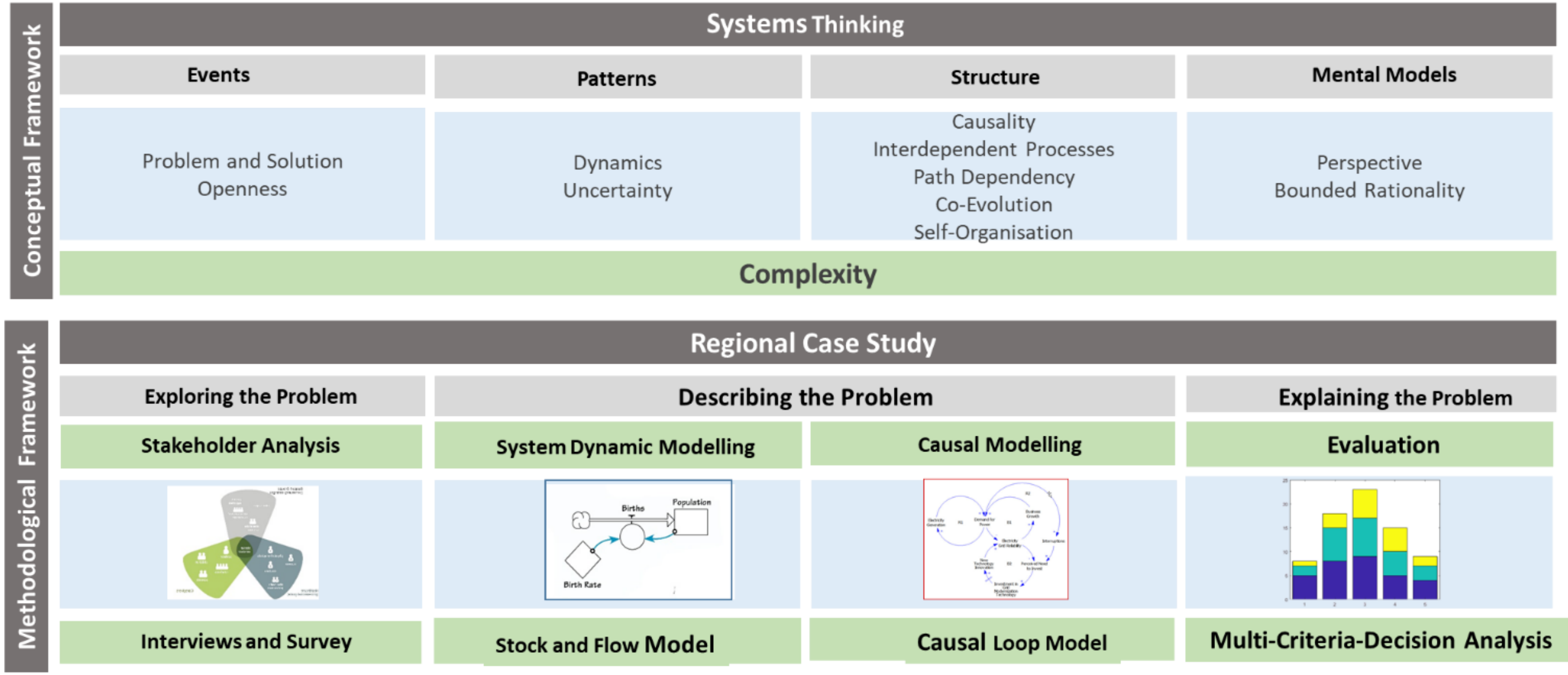
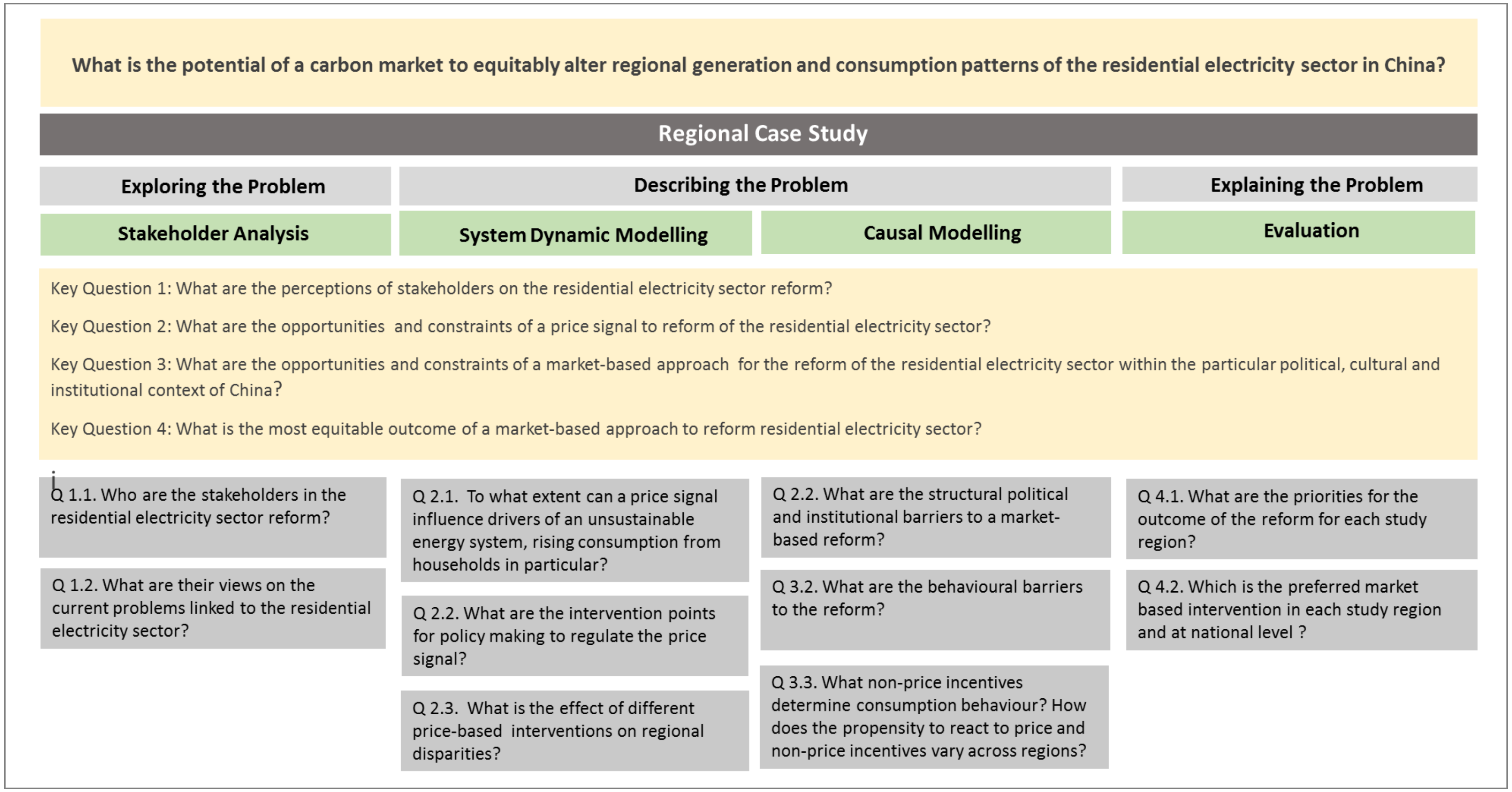


Diagram 4.10 Methodological Framework and Research Questions



The methodological approach of this research is not without its limitations. The study relies on the availability of a wide range of data. Practical and ethical challenges encountered in the unique setting of China could impact the accuracy and reliability of data, thus jeopardising the validity of the study and its ability to fully answer the research questions. Government data is considered unreliable. The experience of other researchers has highlighted the difficulty in obtaining data in a participatory setting.

Research results need to be interpreted with caution. Modelling output should be treated as estimates rather than accurate forecasts. Findings based on stakeholder information need to be assessed in the light of the representativeness of the study demographic. However, in line with understanding a systems methodology as a tool of learning, the process of model building and analysis should be regarded as more important than the output itself. It allows the researcher to explore the in-depth cause and effect relationships and the context of some of the major problems encountered during a market-led energy transition. The construction of the causal and dynamic system models provides the opportunity to reveal the ‘black box’ of a carbon market within the context of China by understanding hereto unknown processes.

5 Understanding Stakeholder Perceptions on the Challenges of a Residential Electricity Sector Reform

This section explores stakeholder perceptions on the reform of the residential electricity sector in China. The introduction of a national carbon market is used as a case study to analyse challenges related to regional equity from the perspective of stakeholders in the reform.

In-depth interviewing with experts in the energy sector as well as residential electricity consumers explores their perspectives on the current situation and their views on a market-based reform of the electricity sector. This information provides context to the insights gained from the review literature on China's sustainability problem and from the analysis of statistical data and other written documentation. In combination, academic literature, news reports, socio-economic and environmental data as well as the awareness of experts and the perspectives and opinions of electricity users offer a more complete picture of the complexities inherent in the reform.

The understanding developed from the interpretation of these different sources of information is used to construct a causal diagram of the energy system, which finds itself at the interface of the socio-economic systems and the environmental system. The causal diagram captures the status quo of the Chinese energy system. It links areas of concern elicited from stakeholders, residential electricity consumers, and tracks interdependencies between them.

Through the process of constructing the causal model a deeper understanding of the complexities occurring at structural level is developed. Experts shed light on the complexity inherent in the path-depend nature of the coal based electricity sector, co-evolutionary processes occurring across systems as well as the complexity arising from the partial lack of central control over developments in the residential energy sector and related areas. The decision whose views to represent in the causal models defines the scope of the study by drawing boundaries around the system under investigation. Boundary setting is the first step in addressing complexity by creating a commonly agreed definition of the problem itself.

The causal model provides the foundation for the empirical study of China's market-led energy transition. The model is refined to reflect more technical details of the Chinese electricity sector. It is then translated into a dynamic stock-and-flow diagram to test the effect of different market-based intervention scenarios (Chapter 6). The output of the scenario simulations forms the basis of intervention evaluation in light of stakeholder priorities for a preferred reform outcome (Chapter 7).

This chapter is structured as follows. The first section discusses the recruitment of study participants. It also describes the practical issues encountered during the stakeholder recruitment phase.

The second part of this chapter explores the insights gained from around 50 interviews with experts and members of the public. Input from interview partners fundamentally shaped the study: Firstly, by focusing the research, secondly by identifying new areas of investigation and thirdly, by providing valuable background information. Causes and effects of patterns involving events, which stakeholders pointed out as relevant, are captured in problem trees. Causal chains are analysed in light of structural complexity derived from self-organising, co-evolutionary and path-dependent processes. One discovery of the analysis is that event patterns play out differently dependent on locality. The variability of patterns at spatial level is adopted as criterion for regional case identification. Linkages between different system areas are traced in a causal-loop model of the Chinese energy system. The model illustrates the complex relationships between the drivers underlying the problems and their effect on people's quality of life.

The chapter concludes with a reflection on the extent to which the participatory approach has elucidated the equity issue which is the focus of this study. The implications of the study design on exploring equity is also reflected upon.

5.1 Eliciting Stakeholder Perceptions

Although Stakeholder Analysis originated from business sciences, it is evolving into a field which now spans a wide range of disciplines, mainly economics, political and environmental sciences (World Bank, 2017a). Most academic research still regards stakeholders as passive audiences for research results, rather than using their knowledge and expertise to directly identify priority areas and to inform study design (Brugha and Varvasovszky, 2000). The key element of the empirical study is to overcome drawbacks of traditional research. The focus of traditional research is often driven by a narrow or incomplete comprehension of the issue leading to research outcomes that are poorly aligned with the information requirements of real-world decision-makers and disregard the needs of those affected by the decision. Another issue in academic study is research bias, which often prevents the researcher from the unprejudiced consideration of a question (Pannucci and Wilkins, 2010). Research in cultural settings that is different from the environment of the researcher can be particularly challenging. It is often difficult to overcome partiality from pre-conceived ideas shaped by a narrow and selective review of literature and media reports (Keene, 2011).

The main objective of this work is to explore the sustainability issues of China's energy transition through the eyes of those how are affected. The practice of stakeholder analysis across multiple stages of the research process helps to minimise the divide between the researcher and 'the objects of his study'. Engagement of the researcher with a set of diverse stakeholders enhances the objectivity, utility and relevance of the analysis. Stakeholder involvement also creates a level of confidence that the work is responsive to the research and data requirements of the problem under investigation. The engagement with stakeholders provides an opportunity to check whether the research questions asked are relevant.

5.1.1 Identification of Study Participants

Research involving stakeholders starts with their identification. Both identification and selection criteria implicitly determine the scope of the research through the selection of the views that will be considered; those inside and those outside the system boundaries. Prior to identifying study participants, it is important to understand who is considered as a stakeholder. The introduction of the methodological framework highlighted the existence of a plethora of different stakeholder approaches and definitions. It is reiterated here that the study adopts the definition provided by Checkland (1981). He regards stakeholders as active participants in the process of solving a problem, irrespective of their potential to influence the outcome of a solution, their decision making authority or their capacity of getting attention. Contrary to the conventional interpretation of the term[36], in Checkland's definition the boundary between actors and stakeholders becomes blurred as everyone who is affected by a problem is given the opportunity to define the problem and influence its solution.

Despite this open characterisation, the exact definition of the term stakeholder remained problematic over the course of the study. The study initially made a clear distinction between experts and stakeholders. The differentiation between the two groups determined the type of information sought from either group. Experts were consulted to provide background information on China's governance system (Interviews 10a, 10b, 16, 17, 26a, 26b, 31a-d, 36) and a more detailed understanding of the wider issues inherent in the sustainability transition of the electricity sector (Interviews 9,10a, 10b, 22, 31, 39). Knowledge elicited from experts was useful to supplement the insights gained from the literature review. In contrast, stakeholders were involved to better understand the interests, values and experiences of those directly affected by the introduction of a carbon market through their usage of residential electricity. As the study progressed, practical experience showed that the distinction between stakeholders and experts remained ambiguous. In light of the study's open definition of a stakeholder 'as someone who is affected' the entire adult population of China has a stake in the reform[37]. Experts are no

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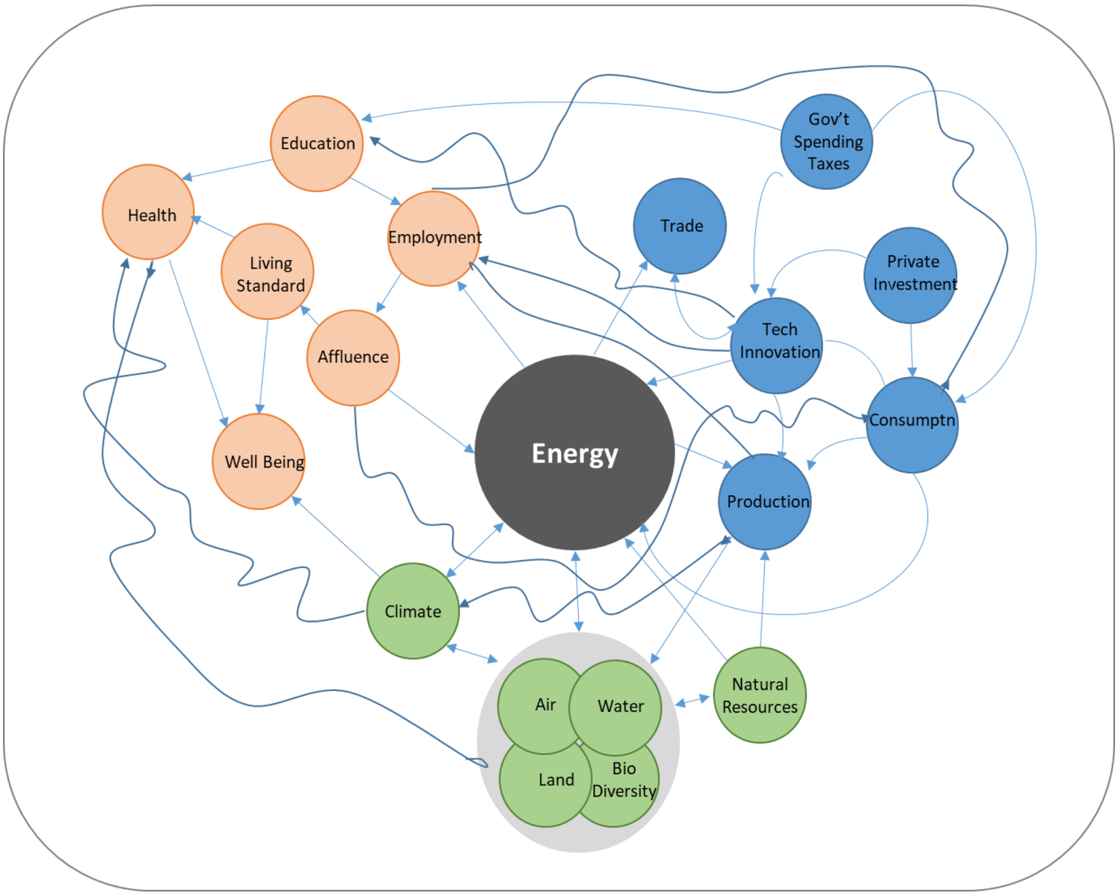
[36] Most interpretations differentiate between actors and stakeholders. They imply that stakeholders are passive and rely on decision makers to resolve the problem. Some definitions deliberately exclude marginalised individuals as they are unlikely to influence the outcome of an intervention. For example, Lindenberg and Crosby (1981) only considers actors with a role in decision making as stakeholders. Stakeholder analysis revolves around gauging their importance and gathering information about their interest and support for a specified outcome. Overall objective is to eliminate 'marginal' ones and to "concentrate (…) attention on those actors (…) who will make the final decisions". Montgomery (1974) and Brinkerhoff (1991) take a similar approach to stakeholder analysis, which focuses on power relations. A review of literature found that with increasing awareness of equity issues, the term stakeholders was opened up to include those who have an interest or a 'stake' in a problem, regardless of the level of influence these groups or individuals have an on a particular outcome (Kaine et al., 2017;Berbés-Blázquez et al., 2016; Engeström et al., 2016).

[37] China's electrification rate of 99.7% suggests that almost the entire population has access to electricity. This figure merely reflects connectivity of any electric cable to a home. A number of rural households in remote provinces such as Xinjiang, Sichuan and Qinghai do not have access to a stable and sufficient supply of electricity and rely on off-grid facilities such as small hydro plants (Poon, 2015). Given the relatively small

longer neutral observers as they themselves are stakeholders (i.e. residential electricity consumers) in the reform.

In some instances, interests were intertwined to an even greater degree. Conflicts of interest presented themselves in circumstances in which professional judgment was at risk of being influenced by a secondary interest, such as financial gain or career advancement. Some of the experts consulted were convinced of a specific technology and invested heavily in their development and deployment (renewables) (Interviews 46). Employees of state or private organisations with links to the electricity sector or carbon trading formed another group with vested interests in the reform (Interviews 18, 29, 37). Others, such as financial institutions or investment firms, had a financial 'stake' in the carbon market (Interview 47).

Diagram 5.1 Generic Causal Model of an Energy Sector



The basis for the identification of stakeholders was the review of literature carried out at the outset of the research. Past studies, policy papers and news reports created awareness

number of households affected and connectivity related issues being outside the scope of this study, it is assumed that all households across China have access to electricity.

on the wider issues of the sustainability transition of the Chinese economy, including valuable information on the carbon market-led reform of the energy sector. In an attempt to organise the vast material a generic causal diagram of an energy system was created. Diagram 5.1 shows the components within the human and environmental systems that are altered by the generation and consumption of energy. Each of the different components affects individuals in one way or another. Linking people to parts of these systems provided a starting point for the discovery of experts and other potential study participants.

The approach adopted for stakeholder identification was introduced in the methodology chapter. Both top-down and bottom-up methods have been employed as part of this study. A top-down approach was employed to identify individuals, groups or organisations who are directly or indirectly linked to the energy sector. Diagram 5.1 was the starting point for the top-down identification of stakeholders. The systematic way of discovering stakeholders, in particular experts, appeared useful in complex situations affecting a large system. The omission of certain individuals or groups could result in a poor or partial definition of the problem.

Diagram 5.2 Stakeholders in the Electricity Reform and their Position in the System

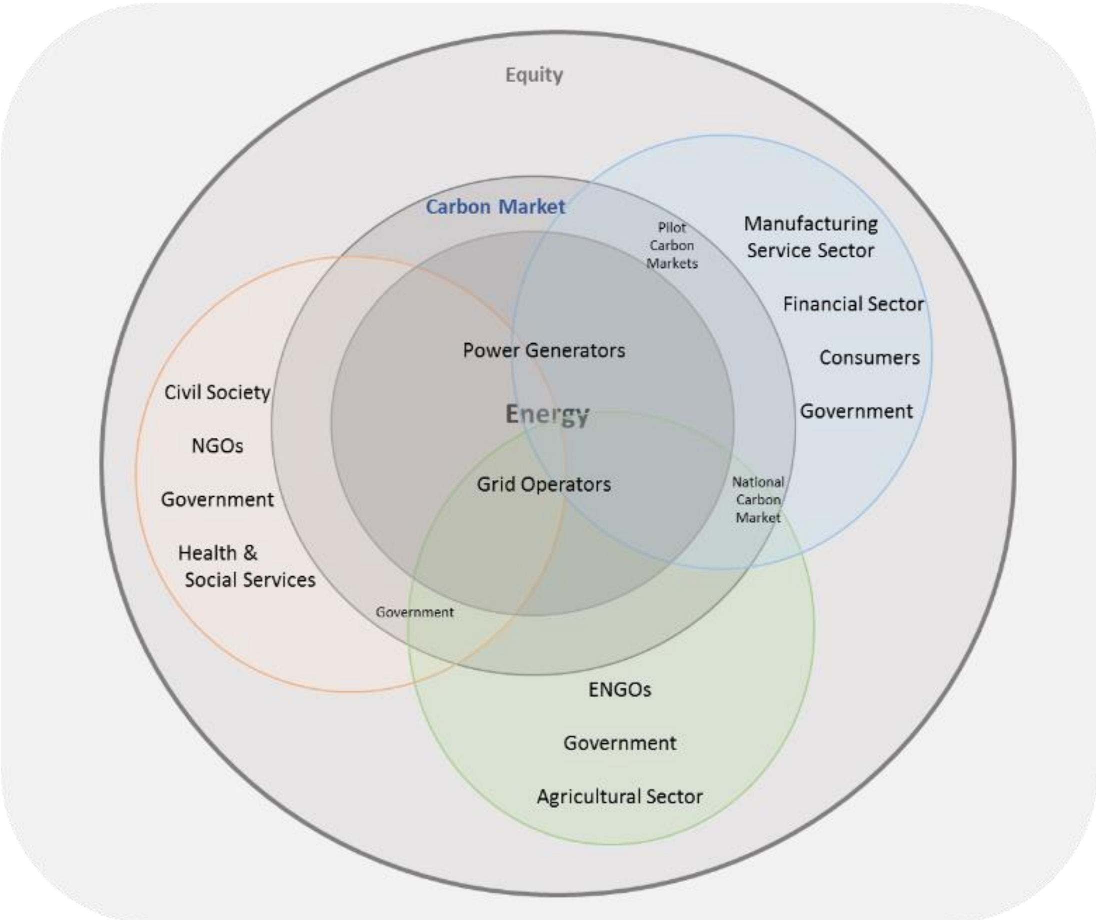


Diagram 5.2 provides an overview of the stakeholder groups that were identified over the course of the study based on the different system components depicted in Diagram 5.1. It quickly became clear that the engagement of stakeholders with expert knowledge in a particular system area could substantially improve the quality of the research by providing context to the insights gained from publications. Analysing the underlying interests of residential electricity users in the reform and encouraging them to contribute to the research also appeared helpful. As discovered during the literature review, there appears to be a gap in research investigating personal views on sustainability issues linked to consumption in China.

The diagram highlights the substantial overlap between the socio-economic and environmental parts of the system. The introduction of a carbon market, a financial instrument, results in an even greater area of intersection between the energy sector and the socio-economic and environmental sectors. Energy related activities affect a wider system area than prior to the establishment of a carbon market, when the government relied on command-and-control measures to control pollution. More individuals and groups in terms of numbers and diversity are affected by the adoption of a market-based approach.

5.1.2 Meeting Practical Challenges of Stakeholder Identification

Stakeholders identified top-down included formal and informal representatives, national or local government authorities, civil society organisations and groups with special interests, the commercial sector and companies as well as academic experts with relevant research interests. About six months into the study a comprehensive list of around 50 organisations, private companies and government bodies were identified as valuable participants to cover the stakeholder categories identified earlier. Names and contact details were located through internet based research carried out in the UK.

Involvement in a project (not related to PhD research) with a Chinese provincial government to introduce a UK style approach of carbon control offered the opportunity to conduct ”elite interviews” (Harvey, 2010) with government officials and experts in the field of environmental policy as well as other relevant stakeholders, policymakers at national and provincial level (including officials involved in the design of the national carbon market) as well as prominent Chinese academics and scholars involved in environmental and socio-economic policy research.

These contacts led to further introductions to employees and consultants at three of the carbon market pilots, a regional environmental exchange, the Shanghai Stock Exchange, state organisations involved in the energy sector, private carbon off-set companies as well as representatives from various ENGOs (international organisations and smaller local groups). Over time, new stakeholders were identified. The list of experts grew over the period of the study up to the evaluation stage as new individuals and groups with knowledge and interest in the energy sector reform were located.

An advantage of reaching the majority of potential study participants by the recommendation of the researcher's social networks was that these individuals usually agreed to meet. The referrer initiating the contact was typically in a position of influence, which in China plays a key role in gaining access to people in senior positions. Securing an individual's commitment to take part in an interview depends on a number of factors ranging from the financial support for the study to the reputation and nature of the organisation and interviewer's position and level of influence (Yeung, 1995). The limited official support for this research project and the researcher's limited ability to advance interests of the potential interviewees appeared to have contributed to the ineffectiveness of the cold calling approach, which was adopted in the early stage of the study[38].

A drawback of using social networks meant that the process of searching for potential study participants is to a certain degree out of the researcher's control. The previously conducted top-down identification of key stakeholder groups minimised the element of randomness such an approach could entail. As representativeness across study participants is a key requirement, the personal contacts were provided with clear instructions in terms of the kind of attributes that were expected.

In addition to experts, members of the public, not professionally, politically and academically linked to the Chinese energy system, were approached with the request to participate in the study. Starting point were acquaintances met during previous visits to China. They were instrumental in the introduction to middle to high income professionals. Over time, it became apparent that most individuals who agreed to take part in the study were university educated and spoke English. Input from marginalised and so-called 'fringe stakeholders' (McCarthy and Muthuri, 2016) had so far been neglected. The poor and those whose views are often considered disruptive by policy makers and other influential or affluent stakeholders seemed to have been excluded from the analysis. To overcome this deficit the decision was made to seek out members of the public representing these groups to obtain their view on sustainability aspects of the current Chinese energy system and its planned reform. Organisers and members of locally registered NGOs and other non-profit initiatives helped with access to interview partners from the migrant worker community in Shanghai, for example. Some of the organisations were involved in activities of raising public awareness on environmental and social issues (Interview 21), while others offered practical solutions to such problems (such as schooling of migrant children (interview 34); collection and disposal of electronic waste (interview 27). During meetings members of these groups shared many invaluable insights into their work with often very deprived communities located throughout China.

[38] As explained in Section 4.5 of the previous chapter Renqing refers to a set of social norms that the Chinese value highly (Wang et al., 2008). Renqinq is the behavioural aspect of Guanxi. Guanxi is a tight knit network of interpersonal relationships (Yeung and Tung, 1996) from which an individual can draw resources or advantages in various social or professional situations (Davies et al., 1995) through the exchange of Renqing, i.e. favours providing mutual benefits (Pearce and Robinson, 2000).

The majority of interviews with members of the public took place in Shanghai during the initial phase of the study. Later in the research a smaller number of interviews were conducted in the Jingjinji region (Beijing-Tianjin-Hebei).[39] It is understood that focus on one geographic area could lead to a certain degree of response bias. In order to mitigate the effect on the outcome of the study, a diverse demographic was interviewed.

By comparing the list of identified expert stakeholders and the list of interviewees it became apparent that in a particular area no interview partner with expert knowledge could be identified or persuaded to take part in the study. As mentioned before, contacting potential interviewees directly was largely unsuccessful. The experience at the beginning of the study was repeated throughout the fieldwork phase. Despite best efforts it proved impossible to recruit interview partners directly involved in the generation and distribution of energy. To at least partially overcome this limitation, experts located in Europe were contacted with the request to participate in the study. Representatives from conventional and green energy providers shared useful information by drawing on their knowledge on the deployment of renewables and (wholesale and retail) price determination in a liberalised market (Interviews 52, 53). In interviews with carbon trading analysts the most recent developments in the EU ETS and the California-Quebec cap-and-trade program were explored along wider issues of emissions trading in a Western setting (Interviews 51, 54).

5.1.3 Interviewing Process and Data Collection

The main objective of the interviewing stage was to consult experts with diverse knowledge in the sustainability transition of the Chinese electricity sector. Interviews were designed to collect to elicit the views of experts on the sustainability objectives pursued by the 'New Normal' – their relevance as well as dependencies and trade-offs between them.

Interviews were conducted in a semi-structured format. Semi-structured interviews, in contrast to fully structured or unstructured interviews, is the most suitable interview type in the early research phase of problem discovery. As explained in the preceding chapter, the open nature of the queries proved a flexible means well suited to explore topics or issues as they emerge. The pre-determined structure allows for a certain degree of consistency to ensure comparability of responses between expert (Bryman, 2008).

A total of 58 meetings with experts took place between March 2013 and July 2016. Interviews as part of stakeholder consultation were spaced out over the course of three years, which was in keeping with the overall iterative approach of the study. The long time frame of the participatory part of the research was suited to the topic itself. Policies and targets underpinning China's sustainability transition were subject to change. For instance, the ratification of the 13th Five Year Plan and China's submission of its Intended Nationally Determined Contributions (INDCs) in preparation for the international climate negotiations in Paris 2016 provided new input. Altogether 56 individuals were interviewed. Some key

[39] The Jingjinji region is prone to heavy pollution, mainly from energy intensive heavy industry and coal based power generation. Toxic (above national average) levels of air pollution are common, particularly during the winter months due to a higher demand for energy and regional weather patterns in the (Jia and Wang, 2017).

experts such as employees at one of the ETS pilots and experts on Chinese policy were met multiple times over the course of the study.

To gain commitment for participation most expert stakeholders were offered for the interview to be conducted at their work place or in the case of some private individuals it was often proposed to meet at their home or in a public place nearby. Three interviews were carried out via Skype as participants were in a remote location or abroad (outside of China). Some expert interviews took place at an ad-hoc basis during workshops or conferences. Despite their impromptu nature the interview generally followed the pattern of the pre-arranged meetings. Pre-arranged meetings typically lasted between one and one and a half hours.

5.2 Mapping Stakeholder Perceptions

The qualitative evaluation of stakeholder interviews was an important first step in the construction of a causal model of the energy system. The objective of the evaluation is to define the scope of the empirical study by delimiting the system under investigation from its environment. Awareness of the system's boundary and the system's content addresses the complexity dimension of openness, i.e. the lack of a clear and unambiguous definition of the problem. Stakeholders, experts and electricity users identified events related to the consumption and generation of electricity that they considered important. These areas of concern formed the basis of further analysis.

5.2.1 Defining the Scope of the Problem

The following presents the main insights gained from the consultation of experts and residential electricity users. Lessons drawn from the interviews enhanced the study in several ways. Stakeholders focused the study through prioritising the research. Stakeholders created awareness of issues that were not discovered through desk-based research. Stakeholders made the research more relevant by highlighting areas, which were originally not considered to be within the scope of the study.

The review of literature and news reports brought to a light a wide diversity of environmental and socio-economic problems linked the electricity sector. Diagram 5.1, despite its simplicity, depicts a system model of unmanageable scope. In order for this research to produce meaningful results within a constrained time frame, areas of study needed to be prioritised. In systems terminology the boundary issue needed to be addressed. The consultation of stakeholders was instrumental in identifying what is critical to the outcome of a residential electricity sector reform. In addition to experts, members of the public were consulted to identify areas they considered relevant. Their input contributed to the prioritisation of certain areas of research. Stakeholder input also identified new areas of study, which were previously not included in the scope of the research. By focusing on the salience of issues, the scope and the various aspects of the problem under investigation became clearer as the study evolved over time.

There was general agreement on the urgency to address environmental issues caused by the emission intensive electricity sector. However, it was not climate change impacts most members of the public and experts, academics and officials alike, were most concerned about. Climate change, in fact, was hardly ever mentioned during most interviews, unless the topic was brought up by the researcher. Local pollution, poor air quality in particular, was regarded by most interview partners as the most pressing problem. Despite its severity, the problem of localised air pollution was noted, but originally not included in the study. Initial focus of the research was on the control of carbon alone as only CO_2 emissions are regulated by the national ETS. The overarching research question, which is concerned with disparities between the inland and the coastal provinces, appears to justify framing the concept of regional environmental equity around local air pollution rather than the global impacts of carbon emissions. The rationale for the shift in research focus is explained in the following.

Firstly, the scale of the problem, its impact on society and the urgency to mitigate air pollution seems to dwarf the challenge of climate change in China. Studies located on the social and economic consequence of air pollution highlight the scale of the problem. Crane and Mao (2015) estimate that the economic cost equates to 6.5 % of China's gross domestic product each year for the years 2000 to 2010. Public concern about poor air quality has increased considerably since January 2013, when the stretch of toxic air enveloped Northern China. The so-called 'airpocalypse' resulted in a widespread outcry and officials gave green light to Chinese news media to openly report on the problem (New York Times, 2013). As China experiences more and more high-profile environmental and health related problems, worries about poor air quality became apparent during many interviews. The topic also came up in the many informal discussions with members of the public. A survey administered as part of this research confirmed that urban 'haze' or smog is generally regarded a more severe issue than climate change. Air pollution followed by food safety topped the list of public concerns (see Chapter 7 for an in-depth analysis of responses to the survey). The World Health Organization estimated that nearly 7 million premature deaths per year were due to air pollution (WHO, 2014), making air pollution the third largest risk factor contributing to premature deaths globally, and almost all of these deaths are directly and indirectly related to energy. A study on the main sources of air pollution leading to premature deaths in China attributed 86,500 deaths in 2013 to ambient PM2.5[40] from coal burning at power plants (GBD MAPS Working Group, 2016).

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[40] $PM_{2.5}$ is fine particulate matter can penetrate deep into the lungs. Research has strengthened the evidence that exposure to PM2.5 is implicated with a range of very serious health outcomes. Sources of particulate matter are primary (i.e. emitted directly to the atmosphere) or secondary (i.e. formed by the chemical reaction of other pollutants such as SO_2 or NOx .The main source is combustion, e.g. from vehicles and power stations. Other man made sources include quarrying and mining, industrial processes. Natural sources include wind blown sand, sea salt, pollen and soil particles. PM_{10}, larger size fraction of particulate matter, is also known as 'black carbon' and a cause of climate change. It is caused by the same processes as $PM_{2.5}$. (Defra, 2016).

Secondly, the combustion of fossil fuels for electricity generation contributes to both global climate change and local air pollution and results in two interrelated environmental policy problems. The emission of CO_2 and the emission of air pollutants are driven by the same energy production and consumption patterns. During exchanges with academic experts it became apparent that there is a need for interventions which maximise the 'co-benefits' between air quality management and greenhouse gas mitigation. In China the analysis of 'co-benefits' has emerged as an important research area in academic study over recent years (Aunan et al., 2006; Jiang et al., 2013; Yang and Teng, 2016; Zeng et al., 2017). The systemic view of the synergies between carbon control and air pollution measures is useful when assessing the cost of policies. A study (Crane and Mao, 2015) based on conditions in 2012 estimated that the net annual costs to clean up China's air would amount to approximately $140 billion to $160 billion. According to Xie Zhenhua, special representative for climate change affairs at China's National Development and Reform Commission, it will cost China over $6.6 trillion (41 trillion RMB) to meet the greenhouse gas (GHG) reduction goals laid out in the country's Intended Nationally Determined Contributions (INDC) (Reuter, 2016). A carbon market simultaneously addresses both air pollution and climate change. Given the high costs involved in meeting air quality targets and GHG goals, the economic evaluation of a carbon market needs to include an assessment of its potential to lower air pollutants.

Thirdly, unlike CO_2, which spreads globally, the impacts of air pollution are mostly felt regionally and locally. Some air pollutants move across entire continents. The majority of air pollutants, in particular sulphur dioxide (SO_2) , nitrogen oxide (NO_X) and particulate matter, which are a by-product of coal combustion (Mao et al., 2014; Zhao et al., 2008), have their greatest impacts close to the location of their production. Collectively, air pollution risks are much more localised than risks associated with CO_2 emissions. Policies with the objective to mitigate the effects of carbon emissions are formulated in the knowledge that the gains will be long-term and effective on a global scale. The short-term and local effects of measures aimed at controlling air pollution are therefore more closely linked to questions of regional equity than the contribution of interventions to reduce CO_2 (Ramanathan and Feng, 2009).

In addition to prioritising study areas, stakeholders identified entirely new areas of study, which were not previously considered or were deliberately excluded as they were not thought to be relevant. Despite adding to the scope of the study, this input helped to focus the research and made it more pertinent to specific concerns of residential electricity users in China. Members of the public welcomed the prospect of a cleaner environment. A small number of interviewees stated the potential impact of a reform on their livelihoods as a concern. The possibility of a tariff increase opened new lines of enquiry. Consequences of a carbon market on a household's material standard of living appeared to at least partially outweigh the positive effects of a reform on pollution levels in the minds of some of the electricity users involved in the study (Interviews 58, 59, 68, 72).

The prospect of rising electricity prices for residential users as a reform outcome was noted at the outset of the research (in the setting of the EU ETS), but not considered as an issue which would require special attention in the context of China. As noted in the concluding remarks of the literature review, studies on emissions trading in China appears to focus on technical issues such as market compliance and MRV. Socio-economic impacts are studied to a much lesser degree. Generally, the pricing of utilities in China is another topic that has not received adequate research attention. As the study evolved during the fieldwork phase, the effect of a carbon market on people's livelihoods gained in salience and therefore was included in the scope of the study.

The carbon market as a facilitator to promote innovation accelerating the restructuring process of the Chinese economy away from traditional industries is well documented. However, technology is attributed a much more expansive part in the transition than originally considered. The central role of technology to resolve environmental issues was pointed out by many experts, including those who do not have any links to industry or have any financial interests in the reform. Even technologies, which are typically associated with a certain level of risk, were generally endorsed (Interviews 25b, 28, 32). The dangers of nuclear energy were widely disregarded. Carbon Capture and Sequestration technology (CCS), despite hazards such as leakage and its unknown long-term consequences on the environment, universally received support as a medium to long term measure to control carbon from coal based energy generation. The relatively uncritical appreciation of these technologies was a reappearing theme in discussions with well-informed experts in the field of energy and the environment. A survey conducted by The Energy Group at the University of Cambridge (Reiner and Liang, 2012) with representatives from the government, power companies and academia confirmed this impression. Only a small number of the respondents voiced concerns over the risks associated with CCS technology.

The interviews created the impression that individuals generally believe that new technology alone can solve environmental issues, particularly those related to the energy sector. The emphasis on technological solutions is echoed by the prominent role innovation is given in the current Five Year Plan. A lively debate on changing lifestyles has been dominating the environmental movement in most Western societies. The obliviousness of interview partners towards the role of consumption behaviour was unexpected and prompted a more in-depth exploration of behavioural attitudes through further interviews and a survey administered to the public. The analysis of the survey submissions is presented in Chapter 7.

Professionals linked to the financial sector (Interviews 47, 49) including the ETS pilots (interviews 23a-d, 30, 31a-c, 40, 41, 45) and a carbon credit company (Interview 29) provided a different angle on the motivations of China to adopt a market approach. In addition to the environmental and economic benefits, a carbon market firstly provides prospects to experiment with financial products such as derivatives, whose trade is currently restricted and to a large extent controlled by the state (Prasad, 2016; Seth, 2015; Elliot and Yan, 2013). Secondly, a national ETS provides new opportunities for a growing financial sector with companies offering services such as brokerage and clearing

(Environomist, 2016). Thirdly, the carbon market enables the continued development and issuance of carbon off-set credits (Chinese Certified Emission Reductions (CCER)) after the de-facto collapse of the Clean Development Mechanism (CDM), one of the pillars of the Kyoto Protocol (Grubb, 2016; Lo, 2015; Lo and Cong, 2017). [41] These insights are reflected by Lo (2013)'s analysis on the factors motivating the government to establish a carbon trading scheme. He argues that the adoption of carbon trading is driven by the perceived agreement of a financial instrument with economic development rather than the prospect of a positive effect on the environment.

Finally, the engagement with stakeholders improved the cultural competency of the researcher by helping to discover the social meanings attached to norms, values and practices embedded in a culture very different from her own. Insights gained from stakeholders into the specific context of China provided context to enable the meaningful interpretation of results and allowed a glimpse into the 'mental models' of those who are affected by the reform.

5.2.2 Defining the Problem Itself

China's 13th Five Year Plan has put forward a road map to steer the country towards the 'New Normal' focusing on inclusive growth that is also green, open and innovative. The far reaching reforms can be expected have a direct impact on people's lives. This raises the question whether the population shares the leadership's vision of making China a "moderately prosperous society" by 2020.

There was general agreement amongst the households interviewed on what mattered to them. From the view of electricity users, objectives of the market-led reform should include the improvement of environmental conditions and the continued access to affordable electricity. During the field work stage pollution incidents were experienced personally. Poor air quality in particular, was found to be a regular occurrence. Unsurprisingly, interviewees were very concerned about poor environmental quality (Interviews 58, 62, 64, 66, 68, 71, 72). Some reported personal health problems they attributed to poor air quality (Interviews 75, 77). Others, however, were less concerned about health impacts (Interviews 57, 76), but yet thought that pollution from the generation of electricity (and heavy industry) is a major issue, which needed to be addressed urgently (Interviews 65, 67, 69).

Rising unemployment and increasing expenditure on food, rent, utilities and other basic goods appeared to be a major concern for most people. While the price of residential

[41] 60% of all CERs (Certified Emission Reductions) issued globally were generated in China. This is significantly more than in India (11.5%) and Brazil (5%) combined (UNFCCC, 2017).
In China, the biggest host of CDM projects, the carbon off-set sector has evolved into a key economic factor. Firms are involved in a variety of consultancy services as well as credit development, certification and brokerage. The decline of the sector would have a significant economic impact. Possibility to convert CEERs into CERs (Certified Emission Reductions) accepted by the national carbon market appears to be a deliberate decision to mitigate the impact of a disappearing (CDM) market for CERs.

electricity is currently held at a low level through government subsidies, future affordability in the face of potential tariff increases was considered by many as a potential threat to their livelihoods. A number of people felt that their standard of living could be impacted as China's economy is going through a restructuring process to end its overdependence on heavy industry (Interviews 60, 63, 72, 75, 79).

Disparity between regions appeared to be of a lesser concern to the interviewees. Only when directly asked interviewees acknowledged that differences between provinces pose a problem that could jeopardise the stability of society. However, over the course of the field work stage a number of official and unofficial (i.e. not registered with the government) grass-roots initiatives that work to alleviate poverty in some of country's most deprived regions were encountered (Interviews 1, 2, 11).

Diagram 5.3 Critical Events Observed by Stakeholders Defining the System Boundary

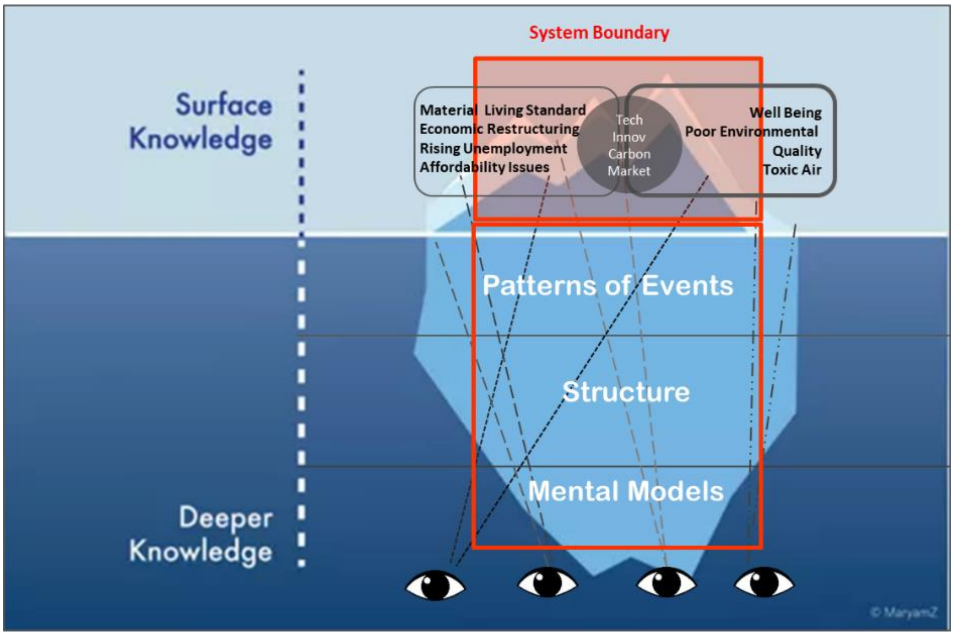


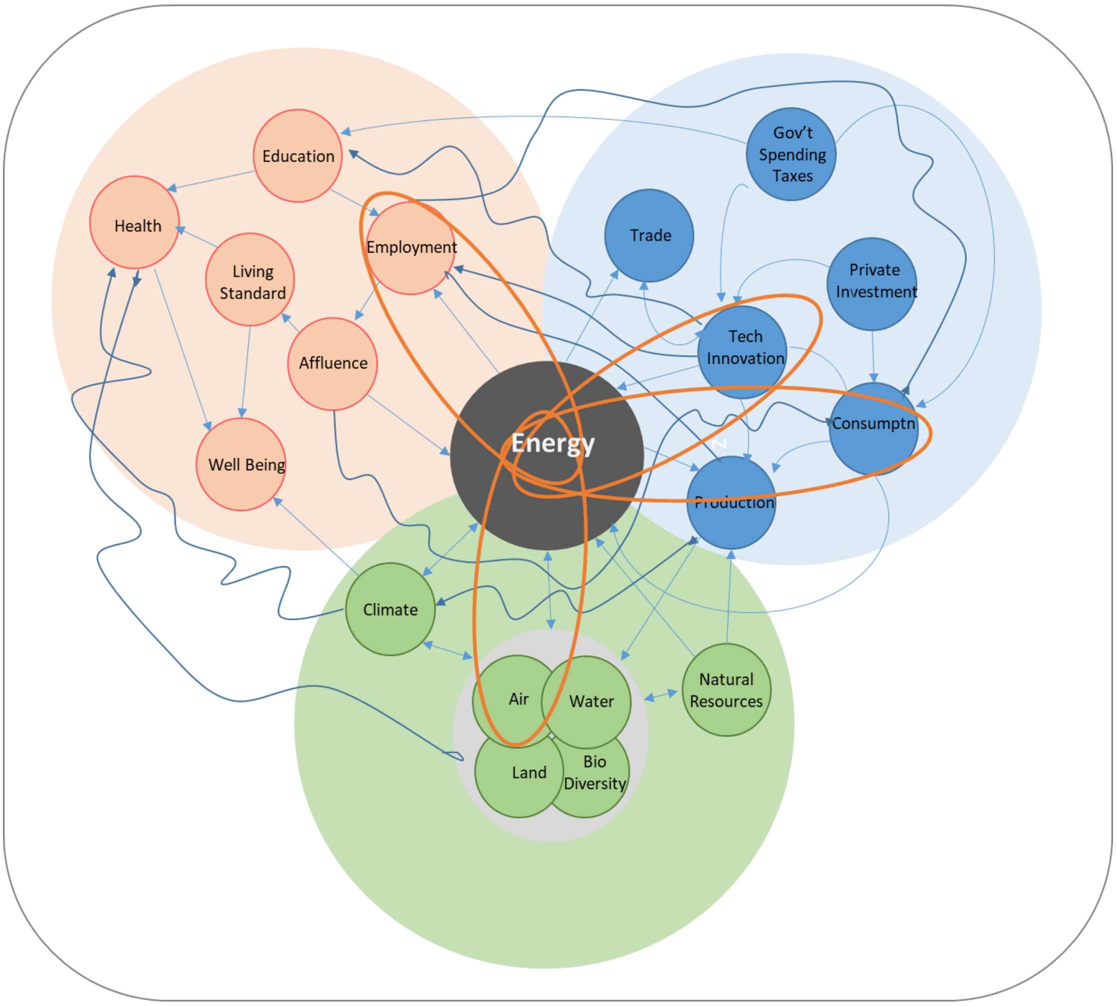
Diagram 5.3 illustrates the problem, which needs to be tackled by a carbon market facilitated electricity sector reform from the perspective of most electricity users. Deteriorating environmental quality observable as poor air quality as well as economic developments apparent in rising unemployment and higher costs of living were identified as major areas of concern. The establishment of an innovation sector was highlighted as critical for the reform of the energy sector. System components linked to these concerns define the environmental, social, economic system boundaries, the scope of the study and ultimately the criteria for the evaluation of the market-based intervention.

In sum, the individuals, who took part in the interviews, appeared to share the concerns with policy makers regarding current sustainability issues. However, the question remains whether the policy response in form of emissions trading is an adequate instrument to put

China onto a more sustainable development trajectory. Answering this question requires a deeper understanding of the causes underlying these issues.

As can be seen from Diagram 5.4 the research focuses on four key areas, which span the environmental, social and economic systems. The diagram illustrates the high level systems components which trigger the events observable by stakeholders. Components directly linked to environmental quality are levels of air pollutants as well CO_2 emissions from the combustion of coal for power generation. Components directly linked to people's material standard of living are opportunities of employment and consumption. Technological innovation has an impact on all three elements - pollution, employment and consumption.

Diagram 5.4 Systems Boundary within the Causal Model of an Energy System



The next step in the analysis to identify and understand the patterns underlying the events which have been manifesting themselves in stakeholder concerns of poor air quality and changing economic conditions. Patterns come into existence because of linkages between events. The presence of patterns indicates that an event is not an isolated incident or a temporary phenomenon. For an intervention to be effective in delivering desired solutions, it needs to disrupt and change existing patterns to produce the desired outcome. The following section firstly seeks to identify event patterns. Secondly, it attempts to develop an understanding as to how these patterns come into existence.

5.3 Identifying and Understanding Patterns

A trend is a general direction in which something is developing or changing. Patterns can occur within a downward or upward trend or mark the beginning of a new trend. A pattern repeats itself in a distinguishable way within a confined space. There are a number of techniques for detecting space-time patterns. The most straight forward way is through the examination of historic data relating to observable events, which repeat themselves over time within a defined area (Ayres, 2008).

This section is concerned with identifying and understanding patterns linked by stakeholders to an unsustainable energy system: Deteriorating environmental conditions, in particular poor air quality, and a slowing economy manifesting itself in rising unemployment and slowing growth of real incomes. Data supporting the analysis was derived from official Chinese government publications. Secondary data from relevant studies has been used to supplement the analysis. In order to identify factors driving these patterns, problem trees were created. A problem tree maps a causal chain of events. The causal event patterns are explained through a discussion on the structural complexity of the Chinese socio-economic and political system manifesting itself in self-organising, co-evolutionary and path-dependent processes.

5.3.1 Identifying Pollution Patterns

The issue of local air pollution in China is not new. Poor air quality has been plaguing vast parts of the country since the industrialisation of the early reform years. Stakeholder perceptions on the high level of pollution and emissions are supported by numerous studies. Only eight of the 74 Chinese cities monitored by the central government managed to meet official minimum standards for air quality (annual mean $PM_{2.5}$ level below 35 $\mu g/m^3$) according the Ministry of Environmental Protection in 2014 (Worland, 2015). A report by Zhang and Cao (2015) on fine particulate matter found that less than 1% of China's 500 largest cities manage to stay under the World Health Organization's more stringent air quality guideline of 10 $\mu g/m^3$.

China has reported success in reducing emissions since 2011, despite its economy growing at more than 7% per year coal use, a major source of air pollutants, has been stabilised. In Beijing, for example, the annual average $PM_{2.5}$ level was 73 $\mu g/m^3$ in 2016, down by 9.9% from 2015 and 18% from 2013 due to improvements in both SO_2 and NO_x levels (Nielsen and Ho, 2017). Contrary to the downward trend of air pollution, the North Western Jingjinji region (also known as Beijing-Tianjin-Hebei) has continuously experienced major air pollution incidents that reached emergency proportions over the winter 2012/2013. Again, in December 2016 and January 2017 Northern China suffered one of the worst episodes of air pollution the country has seen, affecting 460 million people (Carny, 2017). The main cause of air pollution incidents is the large amount of coal burning in the region. The biggest air polluters are the coal-fired powered stations outside Beijing. There are about 22 major plants, which work at full capacity over the winter months to provide power for the energy intensive steel and cement industry and additional electricity and heat to the cities and homes in Northern China. These pollution events are temporary, short-term and triggered by unusual meteorological conditions, such as low wind speeds (Jia et al., 2015). Even though annual average pollution levels decline, it is these events that shape people's perception on the state of the environment.

As discovered through the review of literature the electricity sector has become increasingly accountable for China's pollution problem. The development of an energy intensive industry is largely responsible for the expansion of coal based generation capacity. Past economic policy finds expression in regionally different emission patterns. Dong and Liang (2014) find that absolute emissions increase from Western regions to eastern regions, while emissions per GDP show an inverse trend. Liu (2016) uncovers significant differences in carbon emission intensity among provinces, implying a widening disparity of technology levels among regions is responsible for spatial patterns of pollution. His study concludes that regional differences in terms of technology, energy mix, and economic development are the main drivers of China's carbon intensive economic structure. Less developed provinces with a much higher energy intensive economic structure are increasingly contributing to a national rise in emissions. While policies of promoting the establishment of new innovative industries are set to control local pollution in the advanced urban centres along the coastal region, the environmental situation in the less developed inner provinces is set to deteriorate further as inequity in industry structure and technology levels persist.

Stakeholder engagement provided new perspectives on the topic, which differ from the majority of academic literature. China's regional development policy is typically associated with the ('unfair') preferential treatment of the coastal regions, putting the rest of the country at a disadvantage (Demurger et al., 2002; Brun et al., 2002; Chen and Zheng, 2008; Lemoine et al., 2015). Economic development was regarded by many, in particular provincial government officials (Interviews 25, 32), as justification for China's pollution problem. In this vein, government policy 'encouraging' the relocation of traditional emission intensive industries from the Eastern region to the central and Western provinces was welcomed by the great majority of interviewees (Interviews 7, 23d, 28, 45) . Motivation behind this policy was attributed to the government's plan to provide new economic opportunities for less developed parts of the country rather than the intention to outsource pollution or to pave the way for the establishment of innovative industries in the already affluent East.

Expert views put economic and environmental issues associated with regional development policy into perspective. The relocation of traditional industries including activities linked to the generation of power could indeed be a blessing for the less developed provinces. However, it presents a challenge and the potential impact on local populations needs to be considered carefully. The question arises whether the continuous move of energy generation from the Eastern region to the inner parts closes the gap between provinces or rather widens it, and how a carbon market could influence these patterns.

In summary, there is a link between economic expansion, the structure of the economy, technological advancement and pollution from energy generation. This relationship manifests itself in distinct regional patterns. In the Eastern metropolitan areas pollution levels have shown a downward trend, whereas the environmental conditions in the inner provinces have been deteriorating with increasing coal combustion to support local energy intensive industry and to meet increasing electricity demand in other parts of the country.

5.3.2 Identifying Patterns of Economic Slow Down

Study participants, experts and the general public alike, were concerned about the slowing economy. In 2015 China grew at its slowest pace since 1990. In a departure from double figure growth rates the country recorded GDP growth of mere 6.5% according to official figures during the first quarter of 2016 (NBSC, 2017). Many interviewees revealed their concerns regarding the uncertainty of the future and rising unemployment, the possibility of stagnating and falling household incomes in real terms and the subsequent drop in the standard of living (Interviews 60, 63, 72, 75, 79).

Unemployment is typically negatively correlated with GDP[42] growth. China, however, does not appear to conform to this pattern, with official statistics reporting constantly low and stable unemployment rates[43]. A study by Feng et al. (2015), who calculated unemployment rates based on household survey data, found that the actual unemployment rate from 2002 to 2009 was approximately 11 %, which is more than twice what official government data suggests. According to official figures, national unemployment rates have hovered around the four percent mark since 2010 despite a dramatically slowing economy. In a study based on economic activity[44] Eaton (2016) calculates China's real unemployment figure as 10% in 2015 and 12.9% in 2016. It is difficult to gauge the accuracy of these

[42] The short-run relationship between output, a proxy for GDP, and the labour market, was documented by Okun (1962) for the United States. Ball, Leigh and Loungani (2016) show that Okun's Law has validity in a set of 20 economies. The responsiveness of employment to output appears to vary across countries. In developing economies, labour markets are typically less responsive to output fluctuations compared to advanced countries. Nevertheless, a link between economic growth and changes to employment is maintained.

[43] According to the China Labour Movement (2017) "China's official unemployment rate is largely irrelevant in assessing the actual state of the employment market. The official rate has hovered persistently at or just above 4%for the last five years: In 2015, it was at 4.05%, slightly down from 4.09 % in 2014. This rigidity stems from the very narrow base the statistics are drawn from. Only workers with an urban household registration (about half the total workforce) are included in the data, and the unemployment rate only refers to the proportion of officially registered urban job-seekers to the total number of employed urban workers. It ignores all rural workers and rural migrant workers, foreign workers, as well as those in insecure, part-time or casual work. The only real use of the official unemployment data is as a propaganda tool, which can at least give the illusion of stability in the employment market".

[44] Eaton based her calculation on the assumption that the Chinese economy grew by only 2% in 2016, considerably less than the official 6.9% figure. While other economists also doubt the official number, many other estimates on national GDP growth were around 4% or 5%.

estimates. However, it is clear that official statistics underreport the scale of the problem and the actual unemployment rate has been rising over the past few years.

The socio-economic gap between regions has been well documented and explained in the literature review. In 2016, the top ten provinces with the highest GDP per capita were mostly located along the East coast of China. In the context of identifying pattern of events, the question, however, is whether regions converge in terms of their economic status expressed in terms of per capita GDP, employment and household income such that the poorer regions are gradually catching up with the more affluent and advanced parts of the country (Zhang and Zou, 2012). Neoclassical growth theory asserts that poorer economies tend to develop faster than more affluent ones due to returns of investment decreasing with economic development. In the long run, economies are expected to converge with similar technologies, natural resources, institutional factors and government policies (Darity and Davis, 2005). The theory of economies converging over time is closely linked to the 'rising tide' hypothesis introduced in the introductory chapter to explore the ineffectiveness of past government initiatives to close the gap between regions.

This theory does not appear to be supported by empirical evidence in China. The gap in the level of living standards between the poor and the rich regions in China has remained persistent or has even been widening. In 2007 all of China's provinces were narrowing their income gap with the affluent cities of Shanghai and Beijing. As China's slowdown has been much sharper in poorer areas than the affluent regions, less than a third of provinces grew faster than the two coastal cities (The Economist, 2016).

Given the decline of the traditional industries, this trend is set to become more pronounced as millions of workers are facing redundancies, loss of earnings and lower standards of living. It is as difficult to ascertain actual unemployment at a regional level as it is at national level. News reports (Reuters, 2017b; Energy World, 2017; FT, 2016) as well as interviews (Interviews 6, 24, 70, 75, 76, 79) suggest that redundancies are increasingly becoming a social problem in the inner provinces, which are dominated by industries such as coal, steel and cement.

The slowdown observed in the energy intensive steel and cement industry is not confined to these sectors. The decline in manufacturing and construction output, past drivers of China's growth, has far wider implications. A slowing demand for electricity saw coal consumption drop for the first time since the start of post Mao reform (China Economic Net, 2015; 2016).[45] The fastest growing sectors of the economy are now services and

[45] Until 2013 the coal mining sector had been growing steadily for over a decade. In 2014 mining output fell by 2.9% (Sina Finance, 2016). 2015 saw an even greater decrease (by 3.7%), which was followed by a 3.3% reduction in the volume of coal produced by the mining sector (NBSC, 2016). In order to accelerate the transition of China's economy away from traditional industries the central government appears to actively support the decline of these industries. In February 2016, the State Council announced that China's coal production capacity is to be reduced by 500 million tonnes by 2020 (State Council, 2016a). Steel production, which has been a major coal consumer, is also to decrease by 100 to 150 million tonnes (State Council, 2016b; Bloomberg, 2016).

technology, which are gaining in importance and enjoy the support of the government (Eckhart, 2016). As with spatial differences in pollution, it appears to be linked to regional technology heterogeneity which is directly connected to China's development patterns. The positive differential in the pace of growth in China's coastal provinces compared to the national average is growing at an accelerated pace as the country undergoes the rebalancing of its economy.

The open door policies of the early reform years were instrumental in introducing advanced technologies to the coastal regions (Zheng and Chen, 2007; Wei, 1995). The current economic structure puts the Eastern metropolitan areas in an even more privileged position as technological innovation is a key driver for the economic reform. Experts (Interviews 4, 5, 19, 43, 46) interviewed highlighted the important role of technology to facilitate the reform of the energy sector. In the context of this study, this opens up the question of whether a carbon market, which in China is based on the idea of achieving emission reductions through the deployment of technology, could exacerbate existing regional disparity patters with living standards between the regions diverging even further.

5.3.3 Identifying Problem Drivers and Connecting Event Patterns

Problem Trees are used to illustrate how the cause and effect relationships explored in the preceding sections generate patterns. Each of the problem trees in Diagram 5.5 and Diagram 5.6 illustrates one pattern, which manifests itself in an observable event. The trees separately map out the anatomy of causes and effects around the issues of increased pollution and a slowing economy. The causes of the problem become the roots and the consequences of problems become the branches (Ericson, 1999; Ruijters and Stoelinga, 2015).

Despite their simple and linear nature, the problem trees provide useful insights. Firstly, the diagrams highlight the considerable overlap of several common variables. They appear on both the cause side and effect side of one tree. Secondly, they illustrate that overlap exists between trees, i.e. variables appear in both trees. It is important to note that a variable's strength and the direction of its effect on other variables is quite different, depending on which tree the variable is in.

Tree 1 in Diagram 5.5 describes the typical view of an individual who is affected by the economic downturn in the traditional industries. It is very likely that he lives in one of the inner provinces that depend on mining, energy generation, and heavy manufacturing for growth. This perspective on events was encountered during interviews in the Jingjinji Region (Interviews 72, 75, 76, 79). Tree 2 represents the view of the majority of people interviewed irrespective of their location. They were concerned about the impact of environmental pollution on their health and well-being. Levels of pollution vary widely in China. Therefore, the nature and severity of pollution events observed will be dependent on the location.

Problem trees are useful for identifying causal chains. They recognise that two variables are linked by "a chain of events each directly depending on its predecessor" (Halper and Perl, 2005a). However, they do not provide a meaningful way of showing how variables within a chain interact as the assumed process of causation is unidirectional. Causal connections do not just flow from the left to the right side of the tree. Factors influence one another and some even loop back. Feedback occurring between different trees is not considered at all.

For example, decisions affecting economic development, such as the approval of a new coal fired plant, have an effect on both the population that lives in the vicinity of the plant and the population that consumes the electricity generated in this plant. Given the regional patterns of energy generation and consumption, increased demand for electricity impacts the welfare and the material living standard of both populations, albeit in very different ways. An attempt was made to illustrate the feedback taking place between the different trees by adding the red arrows in Diagram 5.5.

The example above highlights that failing to recognise 'links between the tree' inevitably ignores socio-economic and environmental disparities. People tend to see only problems that affect themselves but fail to make connections to other events occurring in different parts of the system, outside of their view. Different views on events, which are generated within the system boundary, therefore need to be combined into a qualitative causal diagram. A causal loop diagram provides a more detailed picture of linkages, interdependencies and feedback mechanisms. The model illustrates the complex relationships between the drivers underlying the problems and their effect on people's quality of life (Section 5.5). The next section explores the causal chains captured by Problem Trees 1 and 2 in light of structural complexity. The objective is to learn how self-organising, co-evolutionary and path-dependent processes have led to the emergence of patterns.

Diagram 5.5 Cause and Effect Relationship between Energy, Pollution, Employment, Human Well Being and Material Standard of Living

Problem Tree 1 : Energy, Unemployment and the Material Standard of Living

Problem Tree 2 : Energy, Pollution and Human Wellbeing

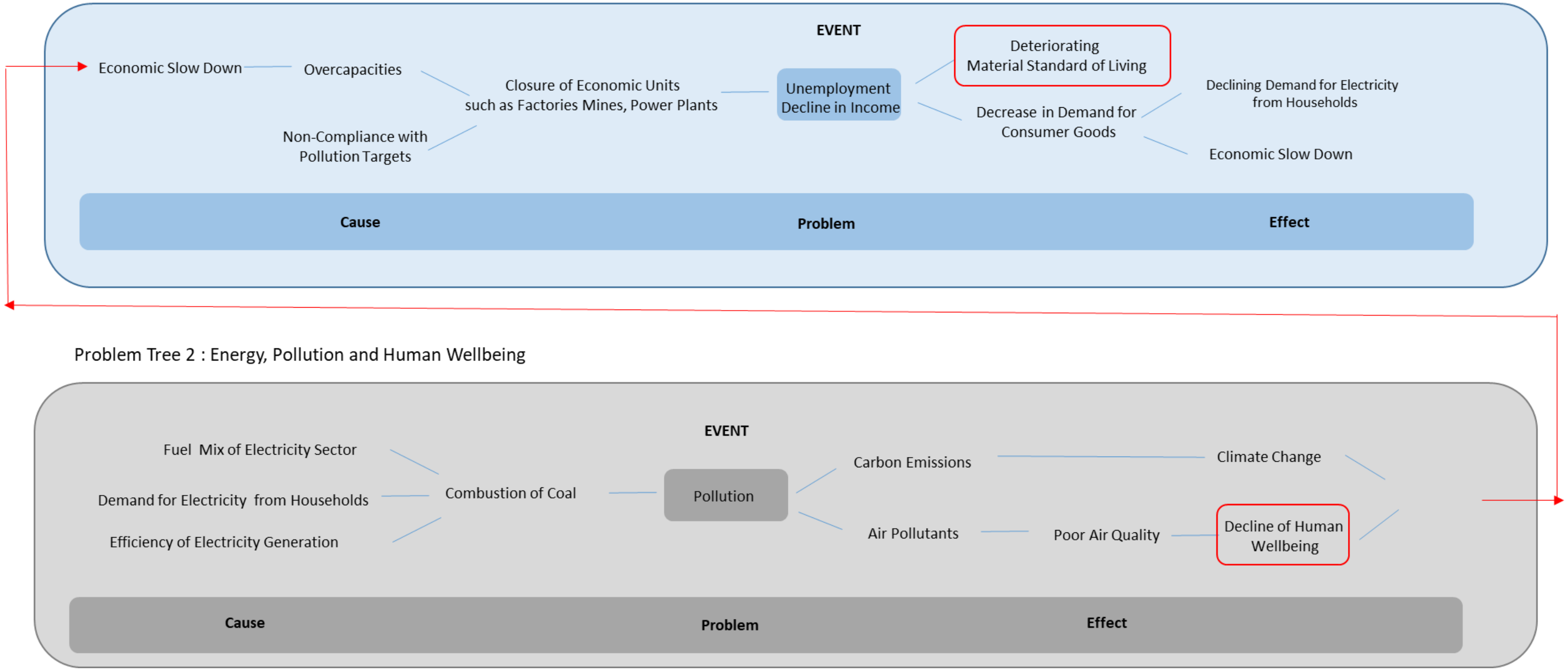
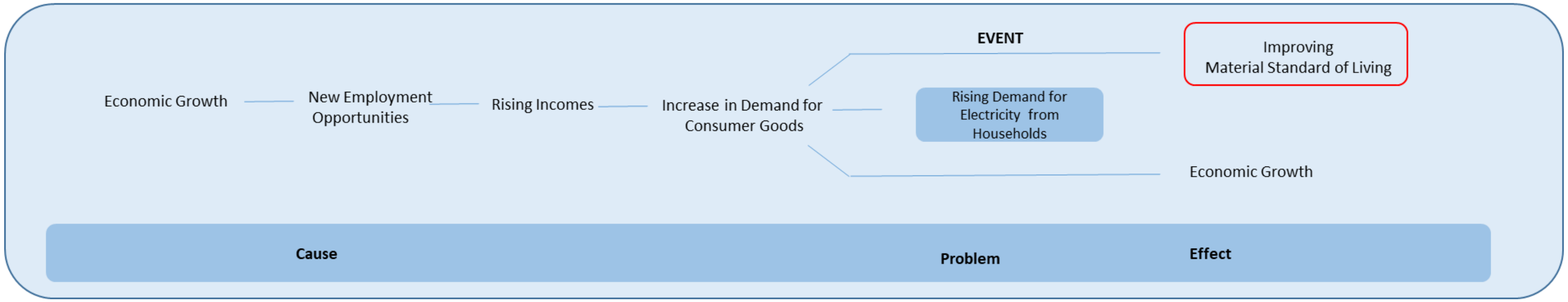


Diagram 5.6 Cause and Effect Relationship between Economic Development Energy, Consumption and Material Standard of Living

Problem Tree 3 : Energy, Consumption and the Material Standard of Living

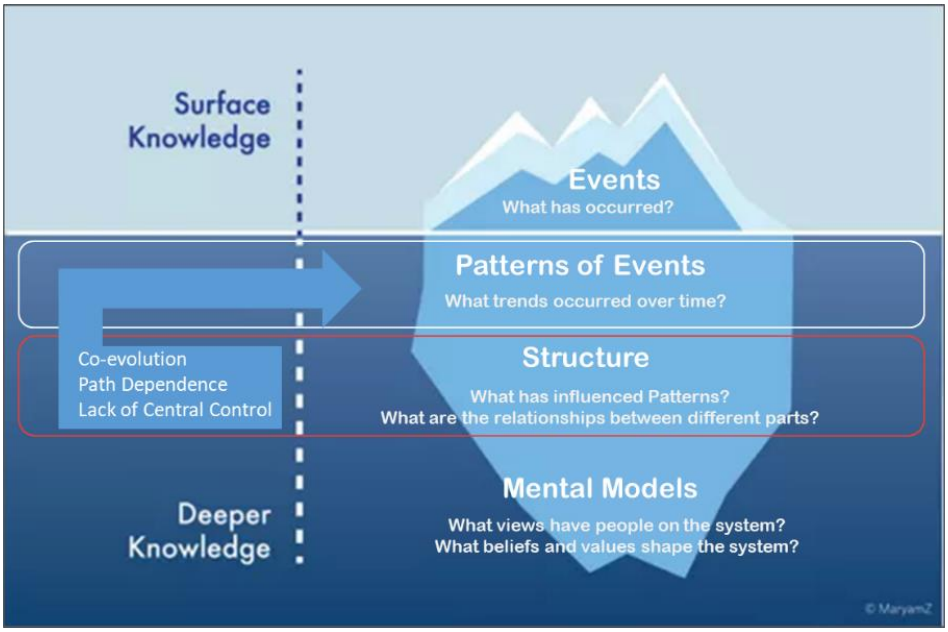


5.4 Explaining Patterns through Dimensions of Structural Complexity

Structure is mostly invisible. Structure is the result of formal and informal ways of 'how the world works' that have been tacitly accepted, such as power structures or the distribution of resources or explicitly institutionalised rules, norms and policies.

Understanding structure underlying a system helps explain why event patterns occur. System structure itself is shaped by complex system traits such as the lack of central control, co-evolutionary and path-dependent processes. As explained in the introduction of the theoretical framework awareness of these processes is a prerequisite for effective intervention design. Interventions purposely disrupt the status quo; they are deliberate attempts to end or alter current patterns of events or to create new ones. Interventions need to consider and address events, even seemingly unrelated ones, in an interconnected way to avoid a 'silo effect'. A silo effect occurs when each intervention sees and treats a situation as separate (Scharmer, 2008).   Diagram 5.7 illustrates how system structure influences patterns of events. The diagram also highlights how the analysis of problem drivers at structural level links to Systems Thinking, the overarching analytical framework of the study. The discussion in Chapter 3 explained in detail how Systems Thinking can help to elucidate issues caused by the structural make-up of a system.

Diagram 5.7 System Structure Driving Patterns of Events



5.4.1 Co-Evolutionary Processes

Co-evolutionary processes are frequently the by-product of transitions occurring in other parts of the system. Co-evolutionary processes can give rise to patterns, which generate new events or have an impact on existing ones. The structure of the system is the relationship between patterns. Co-evolutionary processes can exert a reinforcing or a balancing force on the process, which gave rise to it in the first place.

Increasing household consumption is a co-evolutionary process. It is occurring alongside the decline of traditional industries. The relationship between increasing consumption, energy demand and pollution has been emerging as a new pattern. This pattern has been created by deliberate government policy to shift away from traditional industries to a less energy intensive economy. The strategy of changing economic drivers has borne fruit in controlling electricity demand in the early years of the economic restructuring policy.

Over the years 2013 to 2015 electricity consumption remained stable (NSBC, 2016; WSJ, 2016). Across the country, industrial output grew at less than 6% in December 2015 according to data from the National Bureau of Statistics (2017). More recent electricity consumption figures published by the NDRC suggest that electricity usage has shifted from deceleration back to acceleration. The first quarter data of 2016 indicates an annual increase in consumption by 3.2 % for the period. As noted in the in the introductory section household electricity use and consumption by the service sector each rose by almost 11% year on year, while industry use almost stagnated at a growth rate of only 0.2% (Lockett, 2016; NSBC, 2016). Long-term impact of domestic consumption threatens to offset environmental gains achieved through scaling back combustion of coal for electricity generation. This finding is supported by other studies, which confirm that consumption from an emerging urban middle class has appeared as a main driver of energy demand as well as pollution (Miao, 2017; Huo et al., 2013; Peters et al., 2007).

Co-evolutionary processes are counter-productive to the government's efforts to reform the electricity sector, unless adequate measures are taken to control rising electricity usage from consumers. The cause and effect relationship between rising affluence, electricity consumption and people's material standard of living is illustrated in Problem Tree 3 (Diagram 5.6). The transition from heavy manufacturing to less pollution intensive forms of economic growth has unexpected side effects on the environment. The link between improving living standards and deteriorating environmental quality connects Problem Trees 2 and 3.

In addition to increasing household affluence, other co-evolutionary processes are expected to lead to a future rise in consumption and residential electricity usage. One such factor is falling saving rates. China has one of the world's highest household saving rates, which has depressed consumption in the past. The household saving rate surged from 5 % in the mid-1970s to almost 40 % in recent years[46]. The introduction of the one child family policy brought with it lower household expenditure and the requirement to save for old age (Modigliani and Cao, 2004; Choukhmane, 2013; Curtis, Lugauer and Mark, 2012). The reduction of social services such as healthcare and lower job security following the abandonment of guaranteed lifetime employment in state-owned enterprises contributed to the precautionary motive of saving a large part of the household income (Zhang, 2016).

[46] According to data gathered by the OECD (2017b) Chinese households saved 37.88% of their disposable income in 2014. Household savings rates recorded for Germany and the U.S. were 9.67% and 6.0% respectively in 2015. In the UK households saved on average 0.16% of their income in the same year.

Continuing urbanisation, the relaxation of the one child policy, the growth of e-commerce, the emergence of a new generation of sophisticated consumers, who unlike their frugal parents were raised in a period of relative abundance, are expected to become the main factors driving the expansion of China's consumer economy (Barton et al., 2013; Cheng, 2016). Research by the Boston Consulting Group (Kuo et al., 2015) forecasts that household consumption will grow by 50% from 2015 levels to 6.5 trillion US $ in 2020, even if GDP growth stays suppressed at under 6%. The estimated incremental growth over the next five years alone is equivalent to 1.3 times that of today's UK consumer market.

As illustrated in Diagram 5.6, household income is the main factor that influences the usage of electricity. A more complex picture of consumption patterns emerges in light of distinct regional economic structures. People are affected by the country's transition in different ways. Given distinct regional differences in household affluence in terms of income, consumption levels across regions are rising at a different pace. With the government promoting household consumption as new economic driver, the gap between regions in terms of local pollution and the population's standard of living is set to widen. Regional consumption patterns have far wider implications for equity than differences in the material standard of living. The high standard of living enjoyed by people in the richest provinces comes at the expense of energy related local pollution in less affluent regions. Feng et al. (2013) find that up to 80% of emissions embedded in goods consumed in the East are imported. This observation extends to electricity consumption. Electricity used by households in the East, as explained earlier, is to a varying degree imported from the inner provinces, where generation takes place in mostly obsolete coal fired plants.

5.4.2 Path Dependency of the Energy System

As explained previously, energy systems are subject to strong and long-lived path dependence, owing to technological, infrastructural, institutional and behavioural lock-ins (Simmie, 2012). Experts interviewed pointed out that innovation is required to transform China's coal based energy system into a clean, low-carbon system. The dominance of coal based power generation is the legacy of past investment decisions. Given their long life span, the large sums invested in coal-based generation threaten to crowd out the deployment of cleaner generation technology for many years to come.

The idea of a path dependent process as a self-reinforcing cycle has been employed in the analysis of the persisting regional disparities in economic development and the 'lock-in' of regions to a particular economic structure. Unlike the metropolitan areas on the coast that rely on innovative industries and services for economic growth the inner regions are locked into a coal-dependent energy infrastructure based on inferior technology. The retirement of power plants, as they approach the end of their life, could be an opportunity to end the lock-in effect of a coal based energy system. However, plans to construct more coal based power stations, most of them in the inner provinces, could start a new cycle of path dependence. In 2015 China's provincial governments issued environmental approvals for 155 new coal-fired power plants (Boren, 2015). Following an intervention of the central government, some of the planned projects appear to have been put on hold. The implications of devolution of power from national authorities to regional governments are discussed in the next section.

Path dependence is more than a lock-in to an emission intensive capital and physical infrastructure of the energy system. Along the establishment of an unsustainable energy sector, social and political processes have increasingly become locked-in. A shift away from a coal-based energy infrastructure, for example, requires a structural shift providing access to technology, finance and a labour force with a suitable skillset (Green and Stern, 2014). The consultation of stakeholders brought to light that potential social impacts of the reform have not been given much consideration. The topic remained absent from most of the discussions unless brought onto the agenda by myself, the researcher. Further questioning revealed that effects of de-carbonising the energy sector on employment opportunities were not thought to be relevant. A very insightful interview with the founder of a Beijing based ENGO was an exception (Interview 24). The discussion highlighted the challenge for provinces locked into a coal-based economic structure to facilitate the transition for its work force. A report by the Chinese Academy of Social Sciences (CASS, 2017) confirmed that the continuing decline of the coal sector will cause a range of social problems. The authors estimate that by 2020 approximately 2.3 million miners alone will require re-employment. Considering that the study does not consider employment in the coal power sector, the scale of the problem could be much wider.

What is encouraging for the mining regions is that the main sites for the generation of renewable energy, wind power in particular, are also concentrated in the Northern and Western part of China. According to the International Renewable Energy Agency (IRENA, 2017) currently 3.65 million people are employed by the renewable sector in China. It is widely accepted that renewable technology development, the production and deployment of equipment, creates more jobs per kWh generated than fossil fuel power generation. It is estimated that wind power creates almost a third more jobs than the same amount of energy generated by a coal fired plant (EWEA, 2009; Lewis, 2013). Less clear, however, is to which extent new jobs in the renewables sector[47] could replace employment in the traditional industries. The employment of the local workforce would require large-scale re-education initiatives (Joint, 2011). In the aforementioned interview, it was pointed out that there are plenty of obstacles to the re-employment of miners in the light of uncertainties over future funding and market prospects.

5.4.3 Lack of Central Control

Not all system aspects can be externally controlled. Most complex systems are to an extent self-organising, even in the presence of an authority with central control. Pattern formation

[47] It is not quite clear how much new employment will be created in the renewables sector. In January 2017 The National Energy Agency (NEA) of China forecast 13 million new jobs from 2016 to 2020. In an announcement made one month earlier the NDRC put forward a more cautious estimate of an additional 3 million jobs by 2020 (Reuters, 2015b).

occurs through interactions internal to the system, frequently without intervention by external directing influences (Yates, 2012).

Despite the powerful position of the central government, China's political system is de-facto functioning more like federalism (Zheng, 2006). Chinese regional decentralisation evolved during the post-Mao reform. Provincial governments were given control over a significant amount of resources including energy (Xu, 2006). The surge of plans for the construction of 155 new coal-based power plants appears to be the outcome of the central government’s decision to decentralise authority to approve coal-fired power plant projects to the province level in March 2015. Within a year provincial governments approved the construction of new coal-fired units with a total capacity of 169 GW. This is over three times more than the year before. As noted in the earlier discussion on regional differences that exist within the energy sector, the construction of new coal capacity is concentrated in a few central provinces. Permits for 55 of the plants with over 40% of the total capacity were issued in Shanxi, Inner Mongolia and Xinjiang. In these three provinces coal-related sectors such as mining and energy generation have the biggest share in GDP (Myllyvirta et al. 2016; Jakobowski, 2016).

The rationale behind the political decentralisation process was based on the idea that local knowledge and resources would respond more effectively and efficiently to local needs than interventions initiated by central authorities in Beijing (Landry, 2008). One of the consequences of delegating competences to provincial governments involves the central state losing control of the energy sector reform. Paradoxically, in the parts of the country which are the main target of reform the provincial governments were undermining national reform efforts the most. New investment in coal-fired energy generation was seen as a way to stimulate local economies and to fight rising unemployment by supporting coal related sectors (Jakobowski, 2016).

In light of the existing overcapacities in the region of 100 GW (estimated by Kahrl (2016) for the year 2014) and the environmental impact of the new plants, central government brought the approval process of new power plants back under its control. If constructed, the additional generation capacity could jeopardise carbon and air pollution targets[48]. In March 2016, the National Development and Reform Council announced its intention to end the construction of coal-fired units (NDRC, 2016b). The key element of the plan is to suspend the process of issuing permits for the construction of new power plants until the end of 2017, and to put all approved projects, whose construction has not yet been

[48] In line with emission limits given in the approval decisions or environmental impact assessments, air pollutants from the 155 power plants are estimated at 96,000 tonnes of SO_2, 124,000 tonnes of NOx and 29,000 tonnes of particulate matter emitted in one year. The yearly CO_2 emissions from the 155 projects would be equal to 6% of China’s current emissions, or to the total energy-related emissions of Brazil (Myllyvirta et al., 2016*)*.

launched, on hold. The restrictions cover 15 provinces[49], in which an oversupply of electricity has been observed.

Despite the benefits of local decision making, a lack of central control could be counter-productive in facilitating a major reform of the energy sector. Other conflicts of interest which have been documented are the reluctance of local officials to carry out orders by the central government (Kostka and Mol, 2013; Kostka and Hobbs, 2012), such as the shutdown of heavily polluting factories or power plants (Zhu, 2016; Interview 6). The example of the coal sector shows that the success of China's transition, including the market-led reform of the energy sector, depends on the central government's ability to control groups that seek to maintain the status quo, i.e. existing patterns of unsustainability.

This section illustrated how socio-economic and political structures of a country shapes current unsustainable and inequitable patterns of electricity generation and consumption. The discussion highlighted the importance of structural reform either facilitated by a market-based intervention or supplementary measures. Once linkages and interdependences between different system components are known, the effect of a deliberate change in the system structure, through an intervention, such as a carbon market, can be better understood. The first step is to construct a causal model of the Chinese energy sector.

5.5 Causal Model of the Chinese Energy System

Diagram 5.8 below depicts the basic structure of the Chinese energy system. The structure of a system provides linkages between patterns and the interrelationships among parts of a system. The model links problem drivers identified by the three problem trees in the previous section to the stakeholder areas of concern.

The main insight drawn from the diagram is that China's current growth pattern is close to having exhausted its potential. To ensure people's material living standards continue to improve, urgent measures are required to break the link between economic expansion and environmental degradation (Moomaw and Tullis, 1994; Panayotou, 2016). The important role of technology to decouple development from pollution in China has been explored. Access to technology plays an important role in decoupling growth from pollution as confirmed by a number of studies. For example, Yu et al. (2013) come to the conclusion that the effect of technology was the predominant positive factor in improving energy and resource efficiency of industrial processes in China from 1998-2010. Liu (2016) explained regional pollution patterns through uneven access to technological innovation at provincial level.

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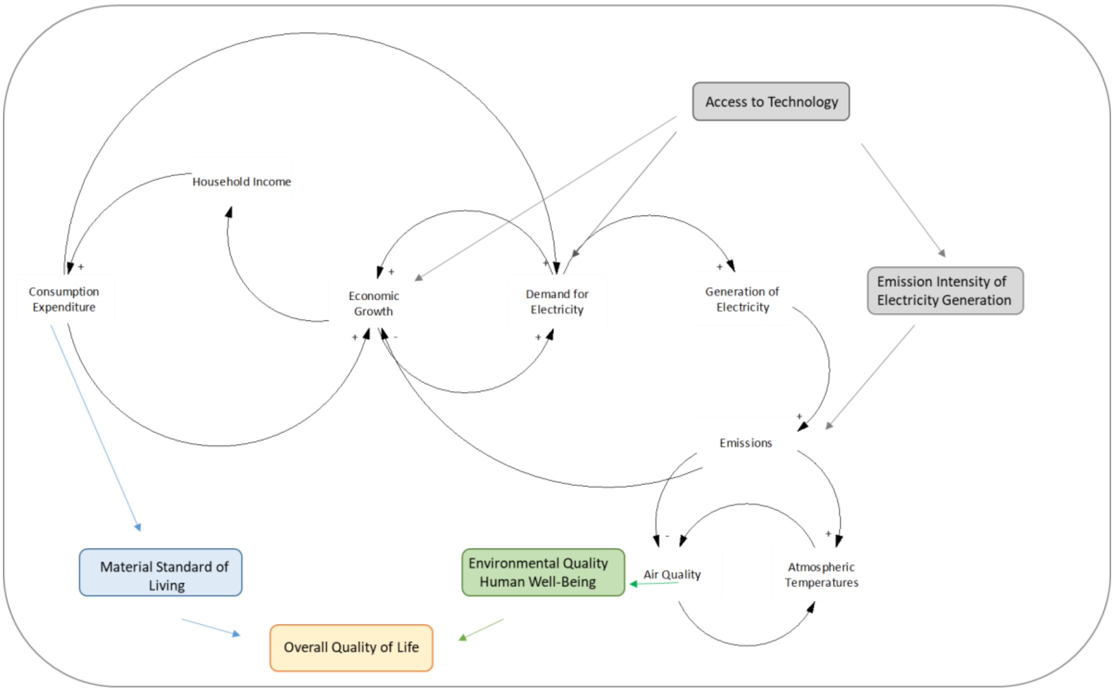
[49] Provinces which require central approval for new power plants are: Heilongjiang Province; Liaoning Province; Inner Mongolia; Shaanxi; Ningxia; Gansu; Hubei; Henan; Jiangsu; Guangdong; Guangxi; Guizhou; and Yunnan (NDRC, 2016b).

Diagram 5.8 Causal Loop Diagram of the Chinese Energy System



In their seminal treatise 'Limits to Growth' the authors (Meadows et al. 1972) emphasized that technology and innovation are not an environmental panacea. They argued that variables (such as population, industrialisation and pollution) driving resource depletion in an unsustainable growth model grow exponentially, while the ability of technology to increase resources is only linear. Through the causal relationship between technology, development and pollution, innovation itself becomes the source of environmental degradation. Diagram 5.8 captures the ambiguous effect of technology. On the one hand, technical solutions play an important role in the transition of the energy sector to a less emission intensive model. On the other hand, they emerge indirectly as drivers of unsustainable growth. An expanding innovation sector stimulates economic growth, rising living standards and consumption. The establishment of an innovative technology sector provides short term economic and environmental gains, in particular in the less developed regions relying on coal and mining sectors for growth. Altering current unsustainable patterns in the long term requires far deeper reaching structural changes, which take into account existing differences in the regional development models. The path to the 'New Normal' is region specific.

The starting point of intervention design requires a more comprehensive definition of development than the one offered by growth-based models that measure development simply by looking at the Gross Domestic Product (GDP). As countries develop, people increasingly come to the conclusion that quality of life or human well-being is not necessarily a function of material wealth alone. A similar view emerged in the stakeholder interviews. Diagram 5.8 acknowledges that development is a much broader concept. The vision of development, adopted by the study encompasses a wider range of factors relating to the general quality of life that encompasses the sustainability objectives of the 'New Normal'.

Research into quality of life recognises that it is the very personal relationship between people and their everyday experience that matters (Pacione, 1982; Hills, 1995; Benzeval et al., 1999). Understanding the nature of the human–environment relationship means understanding the values an individual places on consumption and environmental quality and the attitude towards foregoing one for the benefit of the other. This knowledge is essential for the formulation of acceptable and effective solutions for environmental problems. To better understand people's views, a questionnaire was administered in various study sites. The survey investigates public attitudes towards environmental and socio-economic trade-offs. The analysis of the survey responses is presented in Chapter 7.

5.6 Stakeholder-Led Case Identification

As explained in the methodological framework (Chapter 4), the research follows a case study approach. The determination of a case is derived from a multi-level definition. At the top level the case is the 'Reform of the residential electricity sector in China through a market-based intervention.' The study period covers the years 2015 to 2035.

Case definition at lower level is closely connected with the conceptual construct of event patterns and the factors driving them. The discussion in Section 5.4 found that problem drivers are deeply rooted in China's specific socio-economic and political structure. Over time they have manifested themselves in path dependent, co-evolutionary and self-organising processes. The observation that event patterns have evolved in different directions at regional level suggests the division of the overarching case into geographic units of enquiry.

Event patterns are embedded in a unique spatial context. The context is provided by a region's economic structure, which determines people's material standard of living. The context is also provided by the structure of a region's energy system. The capacity and the emission intensity of the generation base is a determinant of local environmental conditions. Both contextual factors are closely linked through the transfer of electricity from the less developed inner provinces to the affluent coastal regions. The transmission of electricity between provinces manifests itself in the inter-regional trade-off between the material standard of living and human well-being, which in sum determine an individual's quality of life. In addition to a region's development status and local air quality, the quota of electricity transfers from outside the region forms the third case criterion.

By combining the three criteria the following three regional cases have been identified[50]:

[50] It is understood that many more permutations of the case criteria exist. The three cases seem to be representative of the conditions affecting 80% of China's population (see Appendix Table 7.D).

Case 1: Dominant coal sector, low household incomes, high level of air pollution, electricity exporter.

Case 2: Dominant innovation and services sector, high household incomes, high level of air pollution from non-industrial sources, electricity importer - high proportion of electricity imported.

Case 3: Dominant innovation and service sector, high household incomes, low to medium levels of air pollution, electricity importer - moderate proportion of electricity imported

The next step is to identify provinces or cities that are representative of each case.
The province of Shanxi has been selected to represent Case 1. Beijing and Shanghai have been chosen to represent Case 2 and Case 3, respectively. The following sections provide the rationale for the selection of the three locations as case study sites.

Shanxi, along with other provinces in the region, is an electricity exporter. According to official data, over 90% of electricity is generated in coal fired plants (NSBC, 2015). 35% of electricity generated in the province is exported (Cui-Mei and Quan-Sheng, 2014).

Beijing and, to a lesser extent, Shanghai import a great part of electricity for consumption. Beijing imports most of its electricity. All coal-fired power plants have been moved out of the city. Only a small number of gas-fired power plants remain and supply Beijing with electricity. Most of the electricity consumed in Beijing is from Shanxi and Inner Mongolia. A smaller share of electricity is imported from the neighbouring province of Hebei. All three provinces have enormous coal-fired power generation capacity, so that most of Beijing's electricity consumption still comes from coal (NBSC, 2015; Feng, 2017; Cui-Mei and Quan-Sheng, 2014; Interviews 24, 30).

Shanghai's pollution profile is less emission intensive than Beijing's. About 60% of Shanghai's electricity is generated within the city, mainly in gas fired plants as well as in advanced supercritical and ultra-supercritical coal power stations (NBSC, 2015; Overton, 2015; Interview 32). Most of the imported power is from Hubei and Sichuan, for which the proportion of hydropower is much higher than the national average (Cui-Mei and Quan-Sheng, 2014).

Pollution from electricity generation, which occurs within the city, is negligible in the case of Beijing. Nevertheless, the city is plagued by poor air quality throughout the year. In 2016 the average density of $PM_{2.5}$ was around 73 $\mu g/m^3$, according to municipal government figures reported by state media. My own calculations based on measurements taken by the U.S. Embassy confirm this figure. In 2015 the average $PM_{2.5}$ level was calculated as 83 $\mu g/m^3$ (U.S. Embassy, 2017; Beijing Bureau of Municipal Statistics, 2016). In Shanghai the annual average $PM_{2.5}$ levels were calculated as 45 $\mu g/m^3$ for 2016 and 50 $\mu g/m^3$ for 2015 using data from the U.S. Consulate.

It proved more difficult to find historic air quality data for Shanxi. In 2013 average $PM_{2.5}$ measurements ranged from 80 µg/m^3 (Tan, 2014) to 255 µg/m^3 in Shanxi's capital city Taiyuan. Taiyuan is one of the major centres in China for energy production. About a quarter of China's coal is mined in the surrounding province and burnt in the city's factories and coal plants. According to official government statistics (NSBC, 2016), 1,120,643t of SO_2 and 930,750 t of NO_x were generated in Shanxi in 2015, an increase of about 10% compared to the previous year. In Shanghai the corresponding figures are 170,843t of SO_2 and 300, 621 t of NO_x. Both pollutants have been declining steadily year on year since 2006, the first year for which SO_2 was documented. Air pollution caused by processes within the city of Beijing has shown a similar downward trend.

The two developed cities of Shanghai and Beijing have fully fledged advanced economies increasingly relying on strategic innovation driven industries and services. In Shanghai companies involved in the development of green technology have a strong base (Shanghai Municipal Government, 2016). As financial centre of the country (Zhaojin, 2016) the introduction of a carbon market and the general adoption of market-based policies is set to provide additional opportunities in the city. Beijing as capital is home to many organisations that offer products and services relevant to the transition of China's economy. The current high development status of both cities is reflected in income levels that are well above the national average. Household energy consumption has been gradually increasing in Beijing and Shanghai. Electricity use at home and energy for electric vehicles are becoming more important with urbanisation and lifestyle changes (Wehrle, 2008).

The province of Shanxi follows the traditional economic model built on mining, heavy industry and coal based electricity generation. In 2015 the average disposable per capita income was 52,892 RMB in Beijing and 52,962 RMB in Shanghai. In Shanxi, the average disposable income was considerably lower at 26,420 RMB[51]. The potential implications of a carbon market on regional employment opportunities, household affluence and electricity consumption further justify a regional case study approach (NSBC, 2016).

5.7 Conclusion

This chapter presented a causal model of the Chinese energy system. It is based on three interconnected problems that in sum determine people's quality of life: A coal based energy system, poor local environmental quality and deteriorating human well-being; rising residential electricity consumption; a decline of the traditional (coal based) industrial sector and a stagnating or deteriorating material standard of living.

[51] According to the OECD (2017b) "household disposable income can be seen as the maximum amount that households can afford to spend on consumption goods or services without having to reduce their financial or non-financial assets or to increase their liabilities."

These problems have distinct spatial characteristics. A regional case study approach lends itself to the investigation of the spatial dislocation of household electricity consumption and electricity generation. The overarching research question, which is concerned with regional equity issues of a carbon market, also justifies the adoption of a regional case study. The cities of Beijing and Shanghai and the province of Shanxi were selected as case study regions. The three regions are representative of the different problem patterns that have emerged across China.

Patterns evolve as events interact over time. Patterns influence each other and should therefore not be analysed in isolation. The isolated cause and effects relationships occurring within patterns were connected to form a causal model of energy system. Awareness of causal structure is the basis for understanding the effectiveness of a market-based intervention to disrupt patterns of unsustainability over time. The Chinese leadership has selected a carbon market to address sustainability issues of the energy systems through the deployment of technical innovations. Expert consultation also highlighted the important role that is attributed to technology in solving environmental problems in China. Technology has the potential to improve environmental quality within a relatively short time span. However, once provinces have attained a high level of development, technology itself could become a driver of unsustainability. The system dynamic model developed in Chapter 6 will test the effect of an innovation driven approach facilitated by a carbon market on the three study regions.

The feedback mechanisms of the causal model constructed in Section 5.5 suggest that interventions at a deeper systemic level, additional to a market-based reform, could be required to deliver long lasting change. In line with the analogy offered by the iceberg model, measures need to target the mental models of people as consumption related pollution and deteriorating levels of human well-being threaten to off-set the benefits derived from a high material standard of living. Factors motivating environmentally friendly behaviour are explored in Chapter 7.

Stakeholder involvement is an integral part of this research. The engagement of experts and residential electricity users shaped the study in a number of ways. Their input located salient issues within a web of interrelated problems. Stakeholders were influential in changing the environmental focus of the study to local air pollution. The original research design envisaged the investigation of the carbon market's potential to mitigate global climate change impacts. Experts pointed out the relevance of a 'co-benefits' approach as climate change and air pollution are two major environmental issues connected in multiple ways. Stakeholder engagement in the study design also minimised research bias compared to a set-up, where the researcher alone defines the frame of the analysis.

The review of evaluation literature on the EU ETS highlighted the wide ranging problems associated with a market-based solution to environmental pollution. This chapter demonstrated that a number of challenges await the implementation of a national emissions trading scheme that are specific to the situation in China. In a systems-based framework three criteria define an effective intervention. Firstly, the extent to which the intervention disrupts the status quo and moves the system towards the desired state; secondly, the extent to which the intervention is based on a causal understanding of the intended outcome; thirdly and most importantly, the extent to which the intervention meets the requirements of those affected. The extent to which these three criteria are fulfilled by a national carbon market are explored in the following two chapters.

6 Opportunities for the Reform of the Residential Electricity Sector within a Market-based Setting

The reform of the electricity system is a key pillar of China's plan to transition its economy to a more sustainable model. This chapter tries to understand to what extent different market-based intervention scenarios can move the country closer towards the 'New Normal', whose goals broadly match the interests of residential electricity consumers interviewed during the fieldwork stage of this study (Chapter 5).

This chapter is divided into two main parts. The first part is concerned with developing a detailed understanding of the structural complexity inherent in the market-based reform of the Chinese electricity sector. A causal-loop diagram can explain what the problem is and what causes it. Based on the awareness of causal interdependences and feedback mechanisms potential barriers to the reform at structural system level are identified. The second part of the chapter is concerned with developing an approach to deal with the uncertainty of intervention outcomes. Uncertainty arises as system components are changed over time through external influences and interactions between them. A stock-and-flow model is a tool that is employed in system dynamics to solve complex problems with uncertain outcomes. Through the simulation of future conditions the effect of interventions to change the dynamics of the system can be tested. The execution of intervention scenarios at regional level simulates the effect of different market designs on the regional socio-economic and environmental disparities that exist between the three case study regions, Shanghai, Beijing and Shanxi.

The chapter is structured as follows. In the first section drivers of unsustainable patterns that were identified in Chapter 5 are analysed in detail. Processes and feedback loops, within which emission intensive energy generation and rising household electricity usage are embedded, are mapped in causal diagrams. Feedback mechanisms are explored to account for the consequences of carbon market-based interventions on the areas, which stakeholders were most concerned about: Local pollution and their material standard of living. The feedback models are then integrated in a comprehensive causal-loop diagram of the energy sector.

The second section identifies opportunities for a market-based reform within the specific setting of the highly regulated Chinese electricity system. The objective of the analysis is to identify opportunities for effective policy interventions. Points for interventions are located within the causal system structure. Their role in disrupting increasingly unsustainable developments within the residential electricity sector is explored. The section concludes with a discussion on the potential barriers for interventions at structural system level that are specific to the situation of the Chinese energy sector.

In the third section of the chapter a system dynamics model linked to an intervention scenario framework is developed. The effect of different market-based interventions on residential consumption behaviour is tested in a stock-and-flow-model. The chapter concludes with an evaluation of the simulation output. The effectiveness of a carbon market to induce electricity saving behaviour and its implications for regional equity at household level receive particular attention in the discussion.

6.1 Capturing Structural Complexity of the Electricity Market Reform in a Causal Systems Model

As explained in Chapter 3, which introduces the conceptual framework, energy transitions embody complex governance problems. Complexity derives from a multitude of different sources (Rittel and Weber, 1972; Dorner and Funke, 2017). The preceding empirical chapter dealt with complexity stemming from the lack of a clearly defined problem. A diverse set of people is affected by the reform of the residential electricity sector and many different views of the problem exist. The engagement of stakeholders was instrumental in identifying the scope and the multiple facets of the problem.

This section aims to develop a deeper understanding of structural complexity that is characterised by the existence of interdependencies between different components of the electricity sector[52] in the presence of a carbon market. The high level causal loop model of Chinese energy system developed in Chapter 5 illustrates the relationships between the system components linked to the generation and consumption of electricity. These components influence areas that were identified as important by stakeholders.

The model is enhanced to reflect more technical detail of electricity generation and consumption in the presence of a carbon market. The main objective of the causal analysis is to understand how drivers of unsustainable behaviour can be influenced through an effective market-based intervention in the system. 'Unsustainability' drivers were previously identified as unemployment and a decline of traditional industries, local pollution from a coal-based generation base and increasing residential demand for electricity. Awareness of interdependencies between system components pinpoints the places in the system that a carbon market needs to target in order to reverse or mitigate the effect of aforementioned drivers. Intervention points identified in the following are mechanisms that determine the cost of carbon and how the cost is divided between those who are responsible for pollution.

Another objective of causal modelling is to deepen the awareness of structural aspects of complexity, which pose barriers for the implementation of a carbon market. The discussion builds on the investigation of structural complexity in Chapter 5. The analysis recognises that the market-led reform of the electricity sector requires more than technological innovations as behaviours shaping both the generation and consumption of electricity are deeply rooted in the specific political, social and economic system of China.

[52] Structural complexity relates to complexity caused by interconnected and co-evolutionary processes as well as by a lack of central control (see Chapter 3).

6.1.1 Understanding the Potential of a Carbon Market to Influence Drivers of Unsustainability

Electricity is a vital resource in our society. Its use has far reaching implications for the environment, human well-being and people's standard of living. A coal-based generation base and rising electricity demand from consumers have been identified as causes for rising pollution from electricity generation in China. As discovered in the review of literature, a government has a number of different policy options at its disposal to improve environmental conditions. They fall into two broad categories: Command-and-control regulations and market-based interventions (Stavins, 1998). Command-and-control regulations force adherence to a certain standard or target. China relied on command-and-control measures with varying success in the past. Market-based interventions use an economic incentive to encourage electricity providers to adopt less pollution intensive forms of generation. Economic incentives in form of a price signal encourage consumers to use less of a resource.

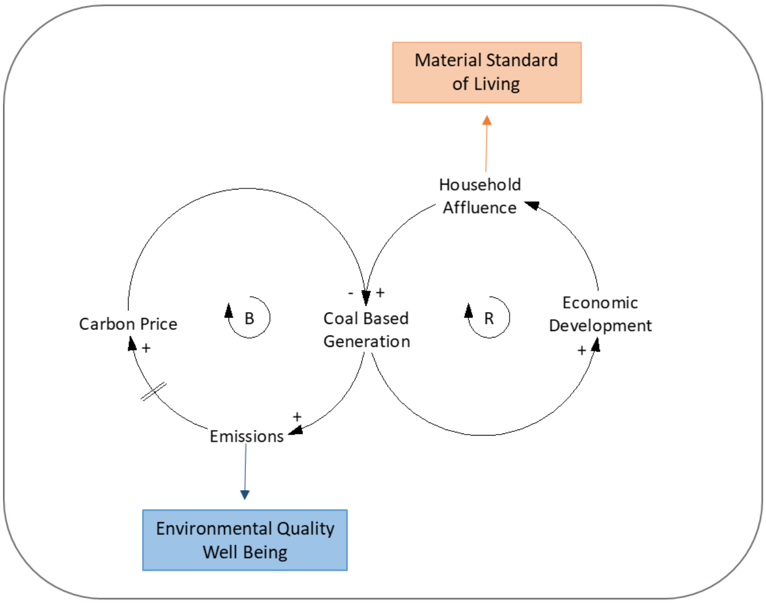
A pollution intensive generation base, economic restructuring and rising residential consumption were recognised as unsustainable developments linked to the Chinese electricity sector. The following explores the interdependencies between these key drivers that are behind unsustainable activities linked to the generation and consumption of electricity.

6.1.1.1 Unsustainability Driver 1: Emission Intensive Generation Base

Diagram 6.1. shows the basic balancing feedback that governs the long term development of a power sector that is regulated by a market-based approach. It links the intervention of a market generated price on carbon to the problem areas of concern; material standard of living and local environmental quality. Higher levels of emissions trigger a government intervention to introduce market-based incentives to conserve energy. The aim of a carbon price is to make emission intensive forms of electricity generation more expensive. The additional cost burden on the energy sector slows the economy with a negative effect on growth, which in then leads to a drop in demand for electricity. Over time emissions from electricity generation are reduced. There is a 'delay' between action and response that extends the time it takes to achieve a particular target (Maani, 2013).

The diagram illustrates the existence of two types of feedback loops, which influence the effectiveness of a carbon market to control residential electricity consumption: Reinforcing Feedback and Balancing Feedback. These two forms of feedback are typically depicted in the form of a loop where feedback flows back into the system forming 'Circles of Causality' (Senge, 1990). Reinforcing feedback accelerates change in a system. Economic growth and rising incomes lead to increased demand for electricity. Rising demand accelerates the expansion of generation capacity and degradation of the environment through the emission of carbon and air pollutants.

Diagram 6.1 Basic Feed Back Mechanisms in the Presence of a Carbon Market (adapted from Maani, 2013)



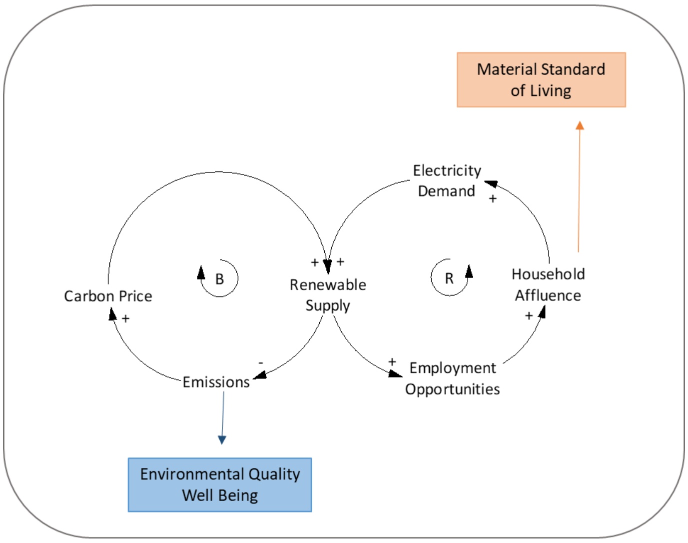
In the preceding chapter it was noted that environmental degradation acts as a limiting factor to growth. If pollution is left unchecked, the system reaches a tipping point where irreversible ecological damage has detrimental effects on economy and society. Balancing feedback through the introduction of a carbon price has the objective to bring the system back to a stable state by lowering the amount of energy generated in pollution intensive coal-based power plants.

Above diagram considers the effect of an emission intensive coal-based generation base on environmental quality and people's standard of living. One implication of limiting the direct effect of a carbon market to the supply side, i.e. generators, is to forego an immediate response to the price signal by electricity consumer on the demand side.

6.1.1.2 Unsustainability Driver 2: Rising Residential Consumption

The relationship between a growing innovation sector, an expanding economy and improving household affluence is depicted in Diagram 6.2. While a price on carbon has a balancing effect on emissions from energy generation, it simultaneously acts as stimulant for the economy as new industries offering employment are established. With household incomes rising, demand for electricity is on the increase. Which effect dominates, the de-carbonisation of the electricity supply or the adjustment in demand, depends on whether the substitution of emission intensive generation capacity with low carbon alternatives can grow at the same rate or faster than residential electricity usage.

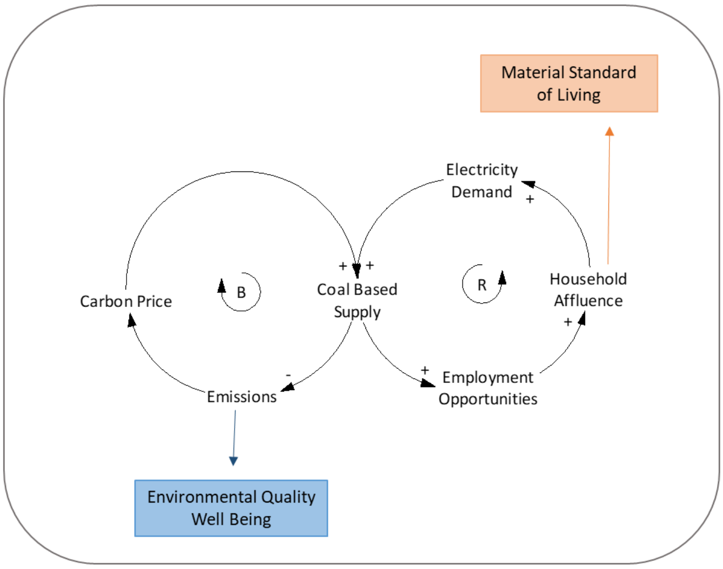
Diagram 6.2 Unsustainability Driver – Rising Residential Consumption



6.1.1.3 *Unsustainability Driver 3: Declining Traditional Sector*

The other side of the economic restructuring process accelerated by a carbon market is the decline of coal-based industries. Patterns associated with economic slowdown are implicitly represented in the generic Diagram 6.1. The model is based on the assumption that a carbon price has a negative effect on economic development as traditional forms of energy generation have to shoulder an additional cost burden for the environmental damage they cause. The cost burden puts pressure on coal related industries with unemployment expected to rise at an accelerated pace as the restructuring process gains momentum. Diagram 6.3. illustrates the relationship between a price on carbon, coal-based energy generation and household affluence.

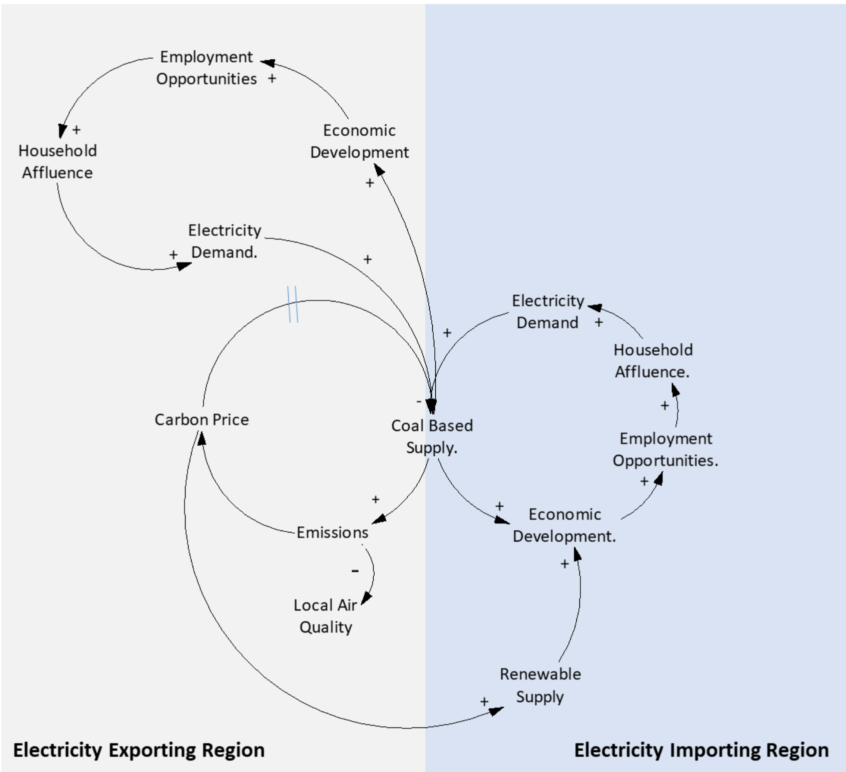
Diagram 6.3 Unsustainability Driver – Declining Traditional industries



A number of studies have highlighted that interventions supporting the replacement of traditional forms of energy generation with renewables could enable China to lead the world in low-carbon development and off-set the economic slowdown in traditional industries (Green and Stern, 2017; Wang, 2014b; Bowen at al., 2009). However, whether an expanding innovation sector (Diagram 6.2) can off-set the effect of rising unemployment in traditional industries on households' material well-being (Diagram 6.3) will dependent on a number of factors, first and foremost the current economic structure of a region

Regional electricity consumption and generation patterns further influence the effect of a carbon market on households. Diagram 6.4 illustrates how a carbon market influences the relationships in a system, where one province with an economy based on innovation imports electricity from another province with surplus coal-based electricity. The price on carbon has a direct effect on event patterns in both provinces. In Province A, the electricity exporting province, the price on carbon poses an economic burden with negative impacts on the average house household income and consequently people's standard of living. Falling demand for electricity from residential and industrial users within the province could free up additional electricity for export. Importing Province B, which is experiencing increasing demand from a growing economy, is not impacted by the local pollution caused by electricity generation in Province B. The diagram captures the ethical dilemma of assigning responsibility for the damage caused by pollution between producers and consumers. In the situation depicted in the diagram a carbon price is a burden for the coal-based traditional economy of the electricity exporting province, while the importing province benefits from the positive effect on its modern economy. The speed at which the gaps widens is determined by the price level.

Diagram 6.4 Integration of Regional Differences at Structural Level



In the following Diagrams 6.1. to 6.4. are integrated with the causal model of the energy system that was developed based on stakeholder input in the preceding chapter. The objective is to build a holistic causal-loop diagram of the Chinese energy system that qualitatively expresses the mutual interactions of a carbon market with the current drivers of unsustainable electricity sector. The model attempts to answer the following research questions:

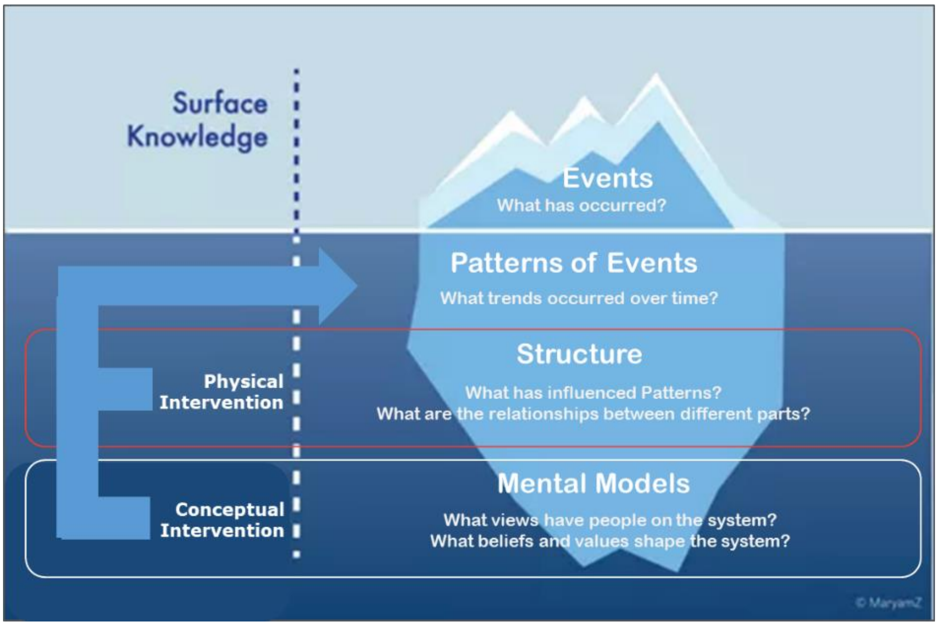
Firstly, how can a carbon market influence drivers of an unsustainable energy system and rising consumption from households in particular? (6.1.3.)
Secondly, where are the intervention points of a carbon market within the system to regulate the price signal? (6.1.2.)
Thirdly, what are the potential barriers to a market-based reform at structural level? (6.1.4.)

The following is concerned with determining how a market mechanism can interrupt the current functioning of the system and open up ways of change. Once intervention points have been established, a comprehensive causal model of the energy system with a carbon market at its centre is developed in Section 6.2. Based on cause-end effect relationships structural factors inhibiting and facilitating the reform are identified.

6.1.2 Locating Points for System Interventions

The causes of sustainability problems associated with the residential electricity sector have been explained through causal diagrams 6.1 to 6.4 In order to effectively deal with the factors contributing to problems of an unsustainable electricity sector, points of intervention are located within the system. Points of intervention are places in a physical system or in a conceptual system, where action can be taken to effectively intervene in system. Physical intervention occurs at structural level. Conceptual interventions target mental models. Diagram 6.5 illustrates how the two types of interventions influence patterns of events through deliberate action occurring at two different levels within the system. The diagram also highlights how the approach to intervention design links to Systems Thinking, the overall analytical framework of the study.

Diagram 6.5 Structural and Conceptual Intervention Points within the System



Whether the problem drivers can be effectively addressed, requires an understanding of how points of intervention are connected to other parts of the system. There are no rules or procedures that could be applied to find intervention points within the system structure. Intervention points are mainly located through intuition, once awareness of the causal relationship within the system has been created (Meadows and Wright, 2008; Forrester, 1997). The causal diagrams developed in the preceding section suggest that the carbon price signal has an effect on all three problem drivers. The review of the EU ETS and the U.S. SO_2 market highlighted that the carbon price level and the division of the carbon cost burden between consumers and producers has implications for the generators and users of residential electricity alike.

6.1.2.1 Putting a Price on Pollution

Factors that determine the carbon price level offer intervention points with direct effects on the environment and economy. The most important single concept in the economics of the pollution is the social cost of environmental degradation.[53] More specifically in the context of this study, the social cost of pollution represents the hidden costs from poor air quality such as the effects on people's health.

[53] As discovered as part of the literature review, a carbon market is an instrument, which puts a price on climate change related damage caused by CO_2 emissions. The fundamental concept is the social cost of carbon that measures the present discounted value of the additional social costs (or the marginal social damage) that an extra tonne of carbon released now would impose on the current and future society (Nordhaus, 2017; Chris and Newbery, 2007). As this study is concerned with the potential of a carbon market to address wider issues of local air pollution, the text adopts the term 'social cost of pollution' to describe this concept.

The environmental and social damage associated with poor air quality depends on the amount of air pollutants that are emitted during the generation of electricity. For the sake of clarity, it is re-iterated here that global climate change and local air pollution are both driven by the combustion of fossil fuel and result in two interrelated environmental policy problems. Putting a price on carbon therefore addresses both issues simultaneously.

Given that the Chinese government has set itself targets with regards to CO_2 emissions and air pollution, the most obvious way to identify the 'right' carbon price is to set it at a level consistent with meeting those targets. This approach might not necessarily result in a price that is reflective of the environmental damage caused by the combustion of coal. However, it is frequently adopted by developed economies such as the U.S. and UK, when valuing carbon emissions in policy appraisals (BEIS, 2017; EPA, 2017a; Nature, 2017).

The process of establishing an appropriate price on environmental destruction is difficult, particularly in light of the complex trade-offs, which have become salient during the discussion of problem drivers. The experience of the EU ETS has shown the operational difficulties of letting market forces determine a price level that incentivises the shift towards more environmentally friendly practices. The chronic oversupply of emission allowances has resulted in an ineffective price signal. The strong role of the government in the China could ensure a strong enough price signal is set by the market through the adjustment of the allowance supply. However, it is exactly the high degree of regulation of the Chinese electricity sector[54] that could inhibit the rebalancing effect of a carbon market on emissions. The opportunities and the barriers at structural level posed by the tightly state controlled electricity sectors are discussed in Section 6.2.

6.1.2.2 Dividing the Cost: Cost Pass-Through Mechanism

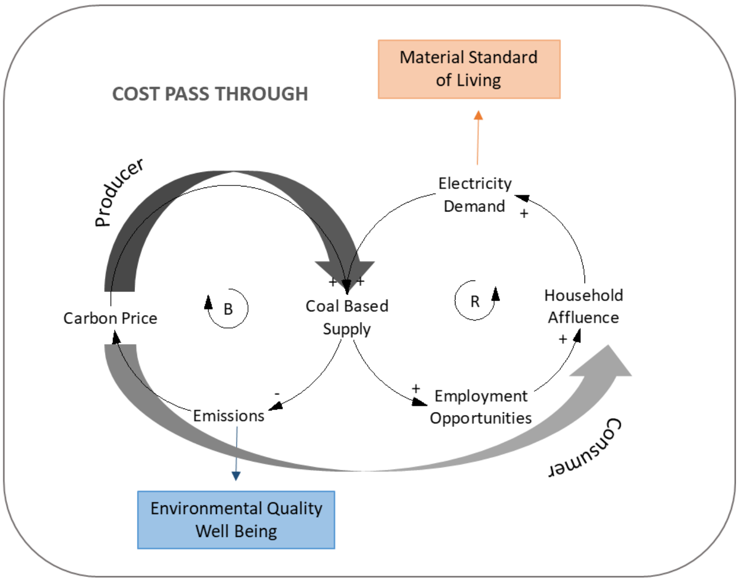
The national Chinese carbon market is production centred, which means that emission permits are allocated to large industrial and commercial polluters, including emission intensive electricity generation plants. It is the responsibility of industrial polluters to ensure they hold a sufficient number of permits to cover their emissions at the end of the trading period. They can achieve this by reducing their emissions or by obtaining additional permits from other market participants at a cost. Production based schemes do not require the direct participation of individual consumers.

[54] Key market players are state-owned or at least institutionally dependent on the state, significantly more so than in capitalist economies. The last major structural transformation occurred in 2002 with the dismantling of the State Power Corporation (Liu, 2013). However, competition in power generation is limited. Market concentration remains high as five state owned companies account for about 50 percent of the sector (Epikhina, 2015). According to Hubbard (2015) central and local state-owned enterprises control 83 percent of thermal, 84% of hydroelectric and 100% of nuclear power generation. The transmission and distribution systems is operated by a state owned monopoly. The State Grid and the South Grid buy under long-term contracts from generators and sell to residential consumers at government-controlled prices in their regional markets. NDRC also determines the maximum price that generators can charge (on-grid tariff caps) to cover their total costs, including fuel (Rioux et al., 2016).

As discovered during the review of literature the decision to base emissions trading on production or consumption based emissions accounting has equity implications at regional level. Production based emissions take place where the pollution is caused through processes of manufacturing or electricity generation. Consumption-based emission accounting places the responsibility for environmental degradation on households who use emission intensive goods and services. This includes responsibility for emissions caused by the production of imports. In the context of the Chinese production based carbon market, users of imported electricity do not have to cover any of the damage caused by emission intensive generation, irrespective of where generation takes place. This relationship is captured in Diagram 6.5 above.

However, a production based carbon market does not per se exclude the individual consumers from shouldering at least part of the cost burden as the experience of emissions trading in Western economies has demonstrated. Producers have the possibility to pass on some or all of the carbon cost to consumers. The effect of a cost pass-through to households is depicted in Diagram 6.6.

Diagram 6.6 Effect of a Cost Pass-Through on Residential Electricity Consumption



Transferring some of the carbon cost burden to residential users of electricity results in higher tariffs that in turn lower people' s consumption. Lower demand for electricity will decrease the supply of electricity generated in emission intensive plants.

The arrangement regarding cost pass-through from producer to consumer is a pivotal intervention point. The pass-through rate is the percentage of the price on carbon that is passed from the generator to the user of electricity (Solier and Jouvet, 2013; Sijm et al., 2006). The pass-through rate indicates how much of the responsibility for energy related pollution is put on residential users.

Attribution of responsibility between the two groups is not dichotomous. The obligation to reduce emissions is divided along a variable scale between power generators and electricity consumers. Given the spatial divide between electricity consumption and generation in China, the pass-through of cost transfers responsibility for pollution from the generators in inner regions to the users in the Eastern provinces. Expressed differently, the cost pass-through mechanism is a reflection of the extent to which the equity principles of 'consumer pays' and 'producer pays' have been implemented (Rose et al., 1998). Through the division of the cost burden between consumers and generators a carbon market could be turned into a re-distributive tool mitigating socio-economic disparities between regions.

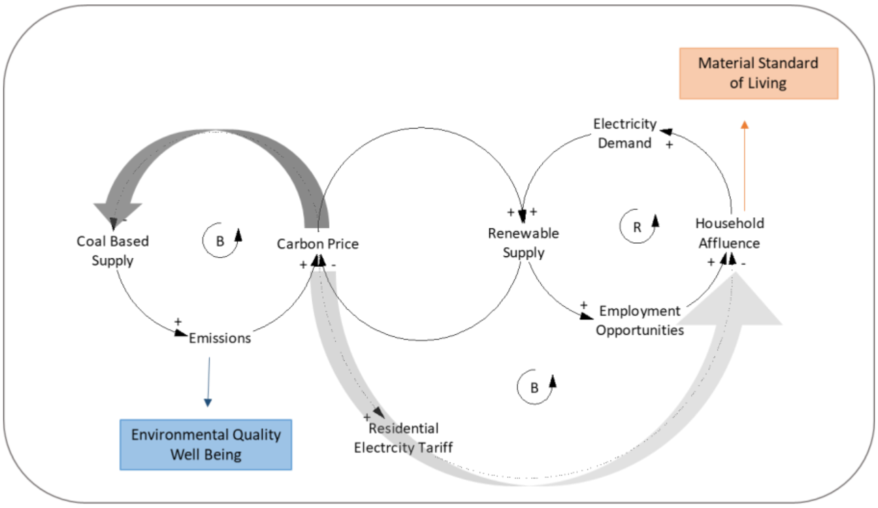
Dividing responsibility for electricity related pollution between households and generators, however, requires careful deliberation due to the uncertain effects of burden sharing polices on the people's quality of life in the environmental and material sense. Given the urgency to address China's sustainability problems, foregoing a demand site response altogether could jeopardise the reform. Changing consumptions behaviour is thought to deliver quicker results than the adoption of technological innovation on the supply side, which is likely to be prone to time delays (Dietz et al., 2009).

6.1.2.3 Investigating the Interplay between Carbon Price and Cost Pass-Through Mechanism

As indicated in Diagrams 6.1 to 6.3, processes which influence the carbon price play a pivotal role in interrupting current patterns of unsustainability. The arrangement selected regarding the division of the cost burdens between generators and consumers of electricity provides another point of intervention within the system to change feedback mechanisms within each problem area and between the problem areas. The potential of a carbon price to re-balance the coal-based electricity supply by encouraging the adoption of low carbon generation technology lies at hand (Driver 1). Moving some of the cost burden onto consumers, however, could dampen this effect. Sharing the cost burden between consumers and generators has a second effect. The deceleration of economic restructuring slows the growth of household affluence and consequently contains rising electricity demand in the more advanced parts of the country (Driver 2).

Splitting the cost burden is likely to delay carbon market induced impacts on employment in the coal regions. Lowering the impact on household affluence comes at a trade-off with improvements of environmental quality. As indicated in Diagram 6.7 below the carbon price in combination with the pass-through rate determines the overall effect of a carbon market on factors that in the past have led to an unsustainable electricity system. Variations of price level and cost-pass-through rate will be simulated in a system dynamic model to understand how the interplay between the two intervention strategies influences patterns of unsustainability. Particular attention will be paid to their combined effect on regional disparities.

Diagram 6.7 Effect of Cost-Pass-Through on Environmental Quality and Households' Material Standard of Living

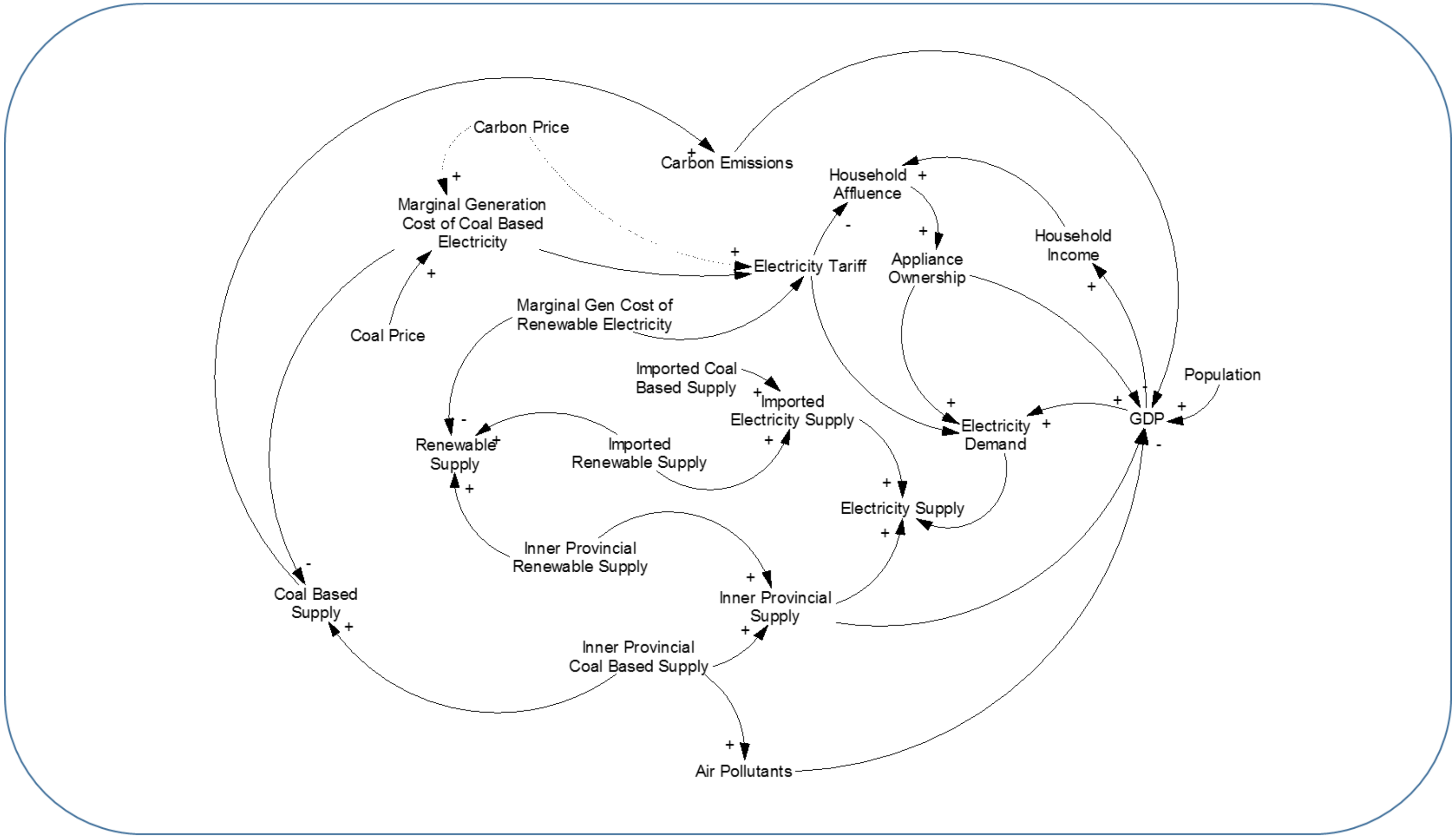


6.1.3 Causal Loop Diagram of the Chinese Electricity System with a Carbon Market

The emphasis of building a solid causal loop diagram is on structural content. The system dynamic model developed in Section 6.3. requires a detailed technical view of the Chinese energy sector. The scope of the system is defined by the stakeholders' areas of concerns. Diagrams 6.1. to 6.3. elaborate how key problem drivers are embedded in mechanisms governing the Chinese electricity system with a carbon market at its centre. Insights gained from the review of literature and the consultation of experts were also incorporated in the model to provide a representation of China's particular circumstances. By tracing cause and effect relationships between these variables across electricity importing and electricity exporting regions a comprehensive causal model of the Chinese electricity system is constructed (Diagram 6.8).

The causal diagram is used in the following to highlight differences between a liberalised electricity market, which can typically be found in most Western market economies, and the current set-up of China's electric-power sector characterised by the overarching control of the State. The potential effect of structural barriers linked to China's approach to environmental and economic governance to effectively support a market-based reform are explored further in Section 6.2. The discussion is preceded by an explanation of the assumptions underlying the model.

Diagram 6.8 Causal-Loop Model of the Chinese Electricity Sector



6.1.4 Limitations and Assumptions of the Causal Model

The causal loop model of the Chinese electricity system was constructed with the aim to closely reflect the setting in which the national carbon market will be embedded. However, as all models it is a simplified description of reality. Nevertheless, model simplification is a means of increasing understanding by identifying important feedback loops (Saysel and Barras, 2006). In order for the model to be a valid and a useful simplification of the original one, the assumptions that were made during the modelling process need to be understood. The assumptions underlying the model also determine the limitations of this study.

Generation Fuel Mix

The causal loop model only considers the impact of a carbon market on renewables and coal-based electricity. Other fuel types such as gas and nuclear are excluded from the analysis as they only constitute a small part of China's electricity mix[55].

Capacity Adjustment

The possibility of supply shortages as a reaction of the supply side to the carbon market-based reform is excluded from the model. It is assumed that increasing demand can be met through additional generation capacity at all times. A reduction in coal-based generation in response to the carbon price signal is met by additional renewable capacity.

Transmission

Grid companies involved in the distribution of electricity from generation plants to end consumers are not considered as a separate entity. Transmission costs are subsumed within generation costs. The model further assumes that no loss occurs during the transmission process.

Demand Side Behaviour

Only the usage patterns of residential electricity consumers and their determinants are modelled. The influence of industrial and other commercial users on electricity demand are neglected.

Market Participants

The electricity sector is the only sector participating in the national carbon market. Other polluting industries are excluded from the analysis. All coal-based generation capacity is included, irrespective of plant size or emission quantity. [56]

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[55] According to key statistics from China's 2015 Statistical Communique, coal and renewables made up almost 80% of the electricity generation (NBSC, 2016)

[56] On 19 December 2017 China launched the first phase of its carbon market. As an electricity-only scheme, China's ETS will cover around 3 $GtCO_2$ per year, about 8% of global CO_2 emissions (Jotzo et al., 2018). The market once fully implemented will cover emissions from firms in eight sectors: Petrochemicals, chemicals, building materials, steel, ferrous metals, papermaking, aviation as well as electricity generation. Any firm in these sectors using more than 10,000 tonnes of standard coal equivalent of energy annually, equivalent to 26,000 tons of CO_2, must participate in the market (Carbon Pulse, 2017a; Swartz, 2016; Jotzo et al.; 2018). This threshold implies that smaller installations often relying on obsolete and carbon intensive technology are excluded from participation.

Carbon Offsets

The model does not consider carbon offsets. Carbon-offsets are credits generated by non-participating entities that avoid an amount of CO_2 equal to an emission permit. These credits can be acquired by covered installations to meet their reduction commitments in lieu of purchasing tradeable permits or lowering emissions themselves. For the avoidance of doubt, it is mentioned here that financial products traded on a carbon exchange such as derivatives are also not included in this study.

Further caveats regarding the viability of the model exist within the specific setting of China. To which extent these factors pose limitations on a market-based reform are explored in the next section.

6.2 Understanding Barriers and Opportunities for a Market-based Reform within the Structure of China's Electricity System

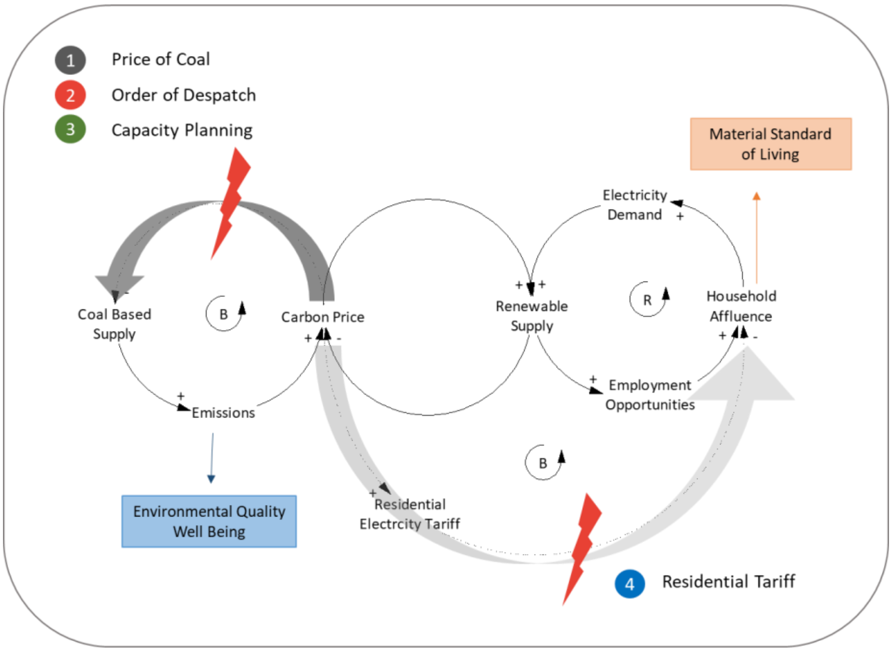
The premise of a functioning emissions trading scheme is a de-regulated electricity market, in which both generators and consumers adjust their behaviour in response to the carbon price signal. China's tightly state controlled electricity sector prevents the carbon price signal to fully reach generators and consumers alike, which puts into question the effectiveness of emission trading to incentivize the substitution of existing coal-based capacity with low emission forms of electricity generation. The currently state subsidised residential tariff structure limits the scope to control increases in household consumption through price induced behavioural change.

The strong role of the state appears to be an advantage for China in ensuring that the carbon market operates at an optimal level. The experience of emissions trading in liberal Western economies has highlighted that continuous intervention from a regulating authority is required to maintain a price level that contributes to the achievement of environmental and socio-economic objectives.

6.2.1 Structural Barriers to a Market-Based Electricity Reform

China's electricity system is highly regulated by the government. On-grid tariffs and end user tariffs are currently fixed, power plants run at the discretion of the government and investment in state-run enterprises are guided by central planners, whose decisions are typically not led by economic factors (Du et al., 2014; Lo, 2016). In China investment decisions in the energy sector are only in part determined by future assumptions on profitability. Under the current set up of the Chinese electricity sector the full strength of the carbon price signal would neither reach generators nor consumers as both supply side and demand side are shielded from the actual private and social costs of electricity production and usage. In the causal model of the Chinese energy system the links between carbon price, generation related emissions, residential consumption levels and economic development are weakened or even broken as illustrated in Diagram 6.9.

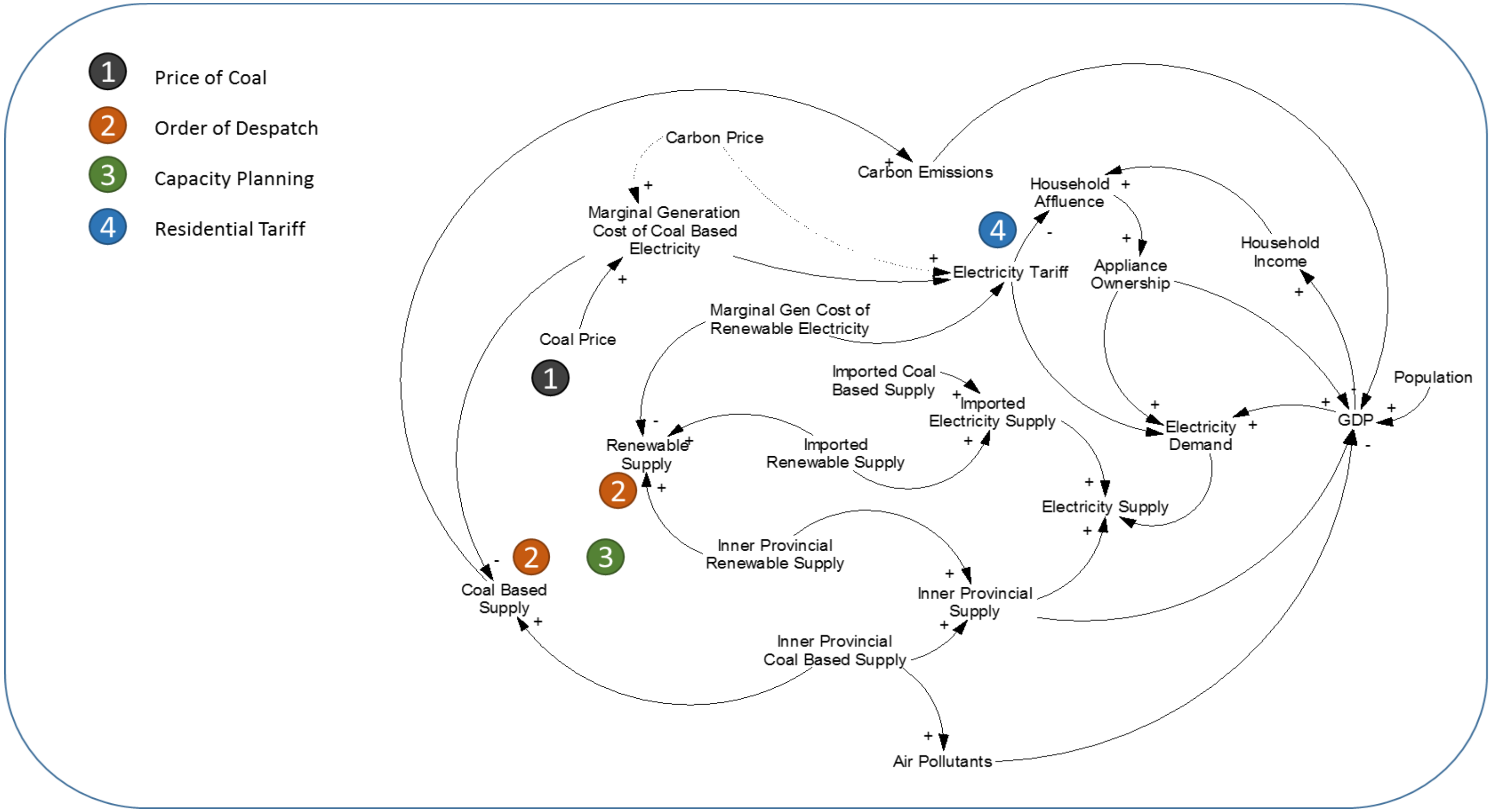
Diagram 6.9 Interruption of Feedback Mechanisms Through State Control - Barriers to a Market-based Reform.



In contrast to deregulated electricity market fuel costs, the despatch of electricity, investment planning of generation capacity, and the end user tariff structure are primarily determined and operated by the central and local governments. These findings have important implications for the effectiveness of a price led reform of the electricity sector in China.

In a competitive wholesale electricity market, demand and supply are balanced through the economic despatch of electricity, in so-called 'merit order'. Merit order is a way of ranking available sources of electrical generation, based on the ascending order of their short-run marginal costs of production, together with the amount of energy that will be generated. Irrespective of initial investment costs, plants with the lowest marginal generation costs thus operate most of the time while costlier plants are only fired up during a demand surge. Assuming dispatch in merit order electricity generated from renewables is given priority over coal-based electricity due to the advantage of lower marginal generation costs (determined by fuel costs). This effect is enhanced in the presence of an emissions trading scheme. A carbon price signal raises the variable generation costs of coal power plants, making those with the highest emissions less competitive than those which emit less. The level at which a carbon price can influence the merit order of thermal plants depends both on the efficiency of the plants (i.e. the fuel volume required to generate 1 kWh) and on the cost of fuel (i.e. coal) (RTE, 2016).

Diagram 6.10 Causal-Loop Model of the Chinese Electricity Sector – Barriers to a Market-based Reform



Currently China has a different approach to dispatch. The government annually assigns an equal number of operating hours to each coal-fired generator. The objective is to treat each generator equally in terms of cost recovery. This policy, however, largely ignores the fact that plants within the coal fleet vary greatly with regards to efficiency and emission intensity. As a result, the overall system has suffered significantly in terms of economic and environmental performance, ultimately undermining the achievement of pollution targets. The dependence of each coal generator on running a predetermined (similar) number of hours has emerged as a major barrier to the effectiveness of a carbon market to firstly prioritise renewable energy, and secondly to allocate more operating hours to cleaner coal-based plants than dirtier units (Kahrl et al., 2016).

The lack of merit order leads to distorted investment decisions as coal-based technology has a relative advantage over renewables. Base load technology of coal plants is regarded as a guarantee for a reliable supply of electricity in contrast to intermittent renewables. In regions with mining as the dominant economic sector officials at provincial level favour coal power as an easy way to generate economic activity at a time of reduced growth though the construction of coal plants. The current system leads to long term lock-in to emission intensive forms of electricity generation.

The experience of merit order based despatch systems in Western electricity markets has demonstrated that despatch of electricity could lead to lower household expenditure for electricity. Merit order generated cost savings offset the cost of funding renewables through feed-in tariffs or other consumer funded subsidy schemes. Whether or not the savings created on the wholesale market are passed on as tariff reductions to end users heavily depends on the competitiveness of the consumer market[57]. In the absence of despatch in merit order Chinese households do not benefit from these cost savings.

The lack of transmission capacity further weakens the positive effect of electricity despatch in merit order on the adoption low emission generation technology. China has installed more renewable capacity than any other country but not all of the power is used due to curtailment. According to the National Energy Administration (NEA, 2016), one fifth of wind power generated in the Western province of Inner Mongolia suffered curtailment, while one third of wind power generated in Gansu was lost due to a lack of transmission lines. Besides the financial loss impacting local economic development, the curtailment of renewable electricity undermines the replacement of heavily polluting coal-fired power plants with cleaner forms of electricity generation. Boren (2017) finds that in addition to an inflexible power grid designed for big power stations, ill-equipped cross-province transmission and fixed quotas allocated for coal power plants there is no formal means of punishing curtailment. An interview with a consultant in the renewable energy sector highlighted economic and political motivations of local governments to prevent the

[57] In Germany the dispatch in merit order let to substantial price decline of the power on the spot market. In 2013 the average wholesale price fell 11%from 42.60 Euro/MWh in 2012 to 37.78 Euro/MWh. In 2014, the average spot market price fell to an even lower 33 Euro/MWh (Appun, 2015). In the UK the value of the MOE in 2015 is estimated at £2 billion (Good Energy, 2015)

replacement of existing coal capacity with renewables by intentionally not making improvements to the grid (Interview 19). The central government, however, is trying to tackle the problem. It pledged to reduce wind power curtailment to 5% by 2020 in the 13th Five Year Plan (FYP).

In order for a carbon market to effectively lower electricity related emissions in China, the carbon price signal needs to be strong enough to offset demand growth resulting from higher incomes. In the 13th FYP the Chinese government released an annual 6.5% growth target for salaries matching the target for GDP development for the period from 2016 to 2020.

In a liberalised electricity system producers systematically pass through to consumers their expenditure for emission permits to offset increased costs by raising end user tariffs. So for example in a market with 80% pass through, a one dollar increase in emissions costs incurred for the generation of a certain number of kilowatt hours translates into an average tariff increase of 80 cents (Fabra and Reguat, 2014). In China tariffs have remained under the control of the central government despite years of gradually liberalising residential electricity pricing structure. Currently, electricity tariffs are subsidised and are much lower than the actual cost of generating and distributing electricity. In the current system of fixed residential tariffs carbon market consumers would be protected from a price increase triggered by the additional cost of a carbon market. In the absence of cost-reflective pricing coal-based generators shoulder the entire cost burden as they are held solely responsible for the damage caused by the combustion of coal.

6.2.2 Opportunities at Structural Level for a Market-based Electricity

Whether market-based environmental instruments bring about the desired results in the long run depends on public regulation (Baldwin, 2008). Unlike markets for goods or services, which have evolved over time, a carbon market comes into existence following a decision by one or a number of states to control environmental degradation. Right from the outset of the planning stage the government or a state affiliated regulating body determines how the market will operate. This involves making fundamental choices, which involve making a number of value judgements ex-ante.

Key decisions have to be made regarding the participating sectors, the overall cap (i.e. the emission target determined by the number of allowances) and the way the allowances are allocated (i.e. free or auctioned). These decisions determine to a great extent the effectiveness of the market to meet its objectives. In case of the EU ETS, its design has rendered the scheme ineffective to generate tangible emission reductions. The highly political nature of the decisions highlights the institutional underpinnings of an evolving carbon market (Lederer, 2012).

Short term fluctuations in the price are caused by the market participants' behaviour in response to changing economic conditions or by gaining access to new technology. However, de-facto the carbon price is to a great extent influenced by deliberate decisions made by the state as it creates the overall frame within which the market operates. State intervention is required so that a carbon price remains at an optimal level to meet desired targets. China's authoritarian approach to environmentalism and the country's approach to 'capitalism' which still bears the trademarks of a planned economy could prove an advantage.

The price is an indication of the government's commitment to lower emissions. The carbon price level is effectively a political decision, and frequently the reflection of different interests. In the EU ETS, sustained lobbying by individual market participants, in particular from the emission intensive energy sector, led to the issuance of additional permits. The oversupply of permits led to a long term slump of the carbon price, rendering the ETS ineffective to lower emissions (Hanoteau, 2014). A lack of interventions to correct the issue during the first two trading periods cast doubt on the free-market approach. The UK's Climate Change Committee agreed that in the presence of laissez-faire liberalism, the EU ETS is failing to deliver the desired results (Cambridge Econometrics, 2009).

The carbon price and the cost pass-through rate have been identified as intervention points that act as levers for the transition of the electricity sector. Like the carbon price, the decision regarding the division of the carbon cost burden between generators and residential users lies with the government as it controls residential electricity tariffs. The strong role of the state within a centrally planned economy appears to be an advantage for China. By limiting the influence of non-state actors on important decisions such as cap setting, the permit allocation method as well as the arrangement of cost-pass-through the government is instrumental in ensuring that the approach to benefit and burden sharing is conducive in meeting its sustainability objectives.

6.2.3 Equity Implications of Market-Based Electricity Sector Reform

The EU ETS provides a wealth of material to illustrate the effects of a market-based approach to emission control on equity, in the sense of burden sharing between generators and residential consumers. In a de-regulated electricity market power companies set end user tariffs without much interference from the state. As explained in Chapter 2, power companies participating in the EU ETS realised substantial windfall profits as they passed on fictional CO_2 costs to households even though allowances were handed out for free (Sijm et al., 2006). Residential electricity prices increased significantly leading to alarming rates of fuel poverty amongst poorer households.

In light of the experience in the European Union the market oriented reform of the residential electricity sector will have to be handled carefully in China. A high pass-through rate could inadvertently affect the living standard of millions of low income households. Despite their relatively low usage levels, households in the inner part of the country could inadvertently be affected to a greater degree by a carbon cost burden than more affluent consumers in the East.

Foregoing a demand side response entirely would jeopardise the effectiveness of emissions trading to address rising household consumption, a major driver of an unsustainable electricity sector. Given that the majority of new coal capacity is planned in the inner provinces top consuming households in the urban centres along the coast would remain unaffected by the additional pollution caused by their increased consumption. In China the pass-through rate not just allocates carbon reduction responsibility between electricity generators and end users, but also between regions due to distinct spatial patterns of consumption and production. The carbon price level determines the speed of the transition. The cost pass-through rate attributes responsibility for making these changes. The combination of the two variables, price level and pass-through rate, determines the strength of the price signal on the supply side and on the demand side. The Chinese government is faced with the difficult task of allocating the benefits and burdens of a carbon market equitably between electricity exporting regions and electricity importing regions.

By detangling the many complex cause and effect relationships a causal loop diagram of the Chinese electricity sector (Diagram 6.8) has highlighted the key patterns of unsustainable behaviours. It also guided the identification of two policy levers, which have potential to disrupt these patterns. These insights, however, open up new questions, which are concerned with determining the ‘optimal’ combination of the carbon price level and cost-pass-through rate. The next section attempts to find answers by testing the effect of alternative intervention scenarios on households located in the three case study regions of Shanghai, Beijing and Shanxi Province. To this end, a system dynamic model is developed based on the qualitative causal model constructed in Section 6.1. A stock-and-flow model quantifies relationships between system variables and simulates the effect of system interventions on behavioural patterns that are tracked over time.

6.3 Understanding Barriers and Opportunities for a Market-based Reform within the Dynamics of China’s Electricity System

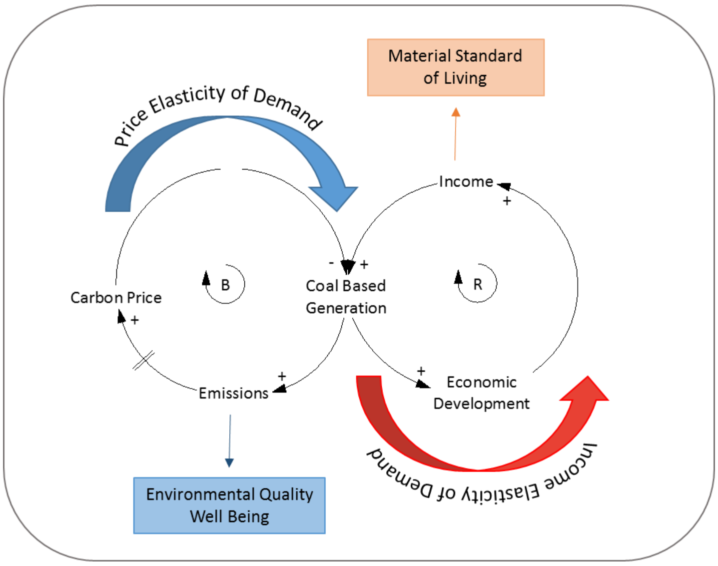
This section is concerned with modelling the impact of different electricity price policies on consumers located in different parts of China. More specifically the objective is to ascertain the impact of a national carbon market on people’s material standard of living and local air quality, areas of concern elicited from residential users of electricity. A number of scenarios under different policy foci and economic growth assumptions are formulated against the particular socio-economic settings of Shanghai, Beijing and Shanxi over the period from 2015 to 2035. These intervention based scenarios are a reflection of the government’s level of ambition to transform the electricity sector and its approach to attributing responsibility for electricity related pollution.

Variations in the carbon price level are simulated to ascertain the effect of a price signal on changing behaviour on the supply side and the demand side. Scenarios also test the effects of different approaches of burden sharing between generators and consumers by varying the rate of cost pass-through. Scenario simulation requires the causal systems model to be translated into a stock-and-flow model, which quantifies relationships between the system variables. The simulation of the scenarios is carried out in the systems modelling software package Vensim. The chapter concludes with a discussion of the simulation results. Equity implications of the different carbon price scenarios on residential electricity consumers receive particular attention in the analysis.

6.3.1 Modelling System Dynamic Behaviour of Electricity Consumption

Causal modelling has demonstrated that the extent to which people's material standard of living and the level of environmental degradation they are exposed to depends on the interplay of the price effect and the income effect that make up the two main feedback mechanism. The price level and pass-through rate determine the strength of the signal. Whether households react to the signal depends on their sensitivity to the price change. The same idea applies to a change in income. Rising incomes signal households that they can 'afford' extra expenditure on consumer goods such as electric appliances or longer operating hours of appliances (Jones and Lomas, 2016; Huang, 2015; Liu et al., 2016).

Diagram 6.11 Basic Feed Back Mechanisms - Consumer Responsiveness to Price and Income Changes



Responsiveness to a carbon price signal and changes in the economy are determined by the so-called elasticities of demand for electricity. Economic theory suggests that demand for a good depends on two variables: its price and the income of potential consumers. Several studies (Hondroyiannis, 2004; Holtedahl and Joultz, 2004; Bose and Shukla, 1999; Filippini, 2011; Narayan et al., 2007) analysed the effect of demand elasticities on the consumption of electricity. The elasticity of electricity demand measures the percentage change in electricity consumption resulting from the percentage change in a factor influencing demand (GDP (income), price of electricity (tariff) and price of substitute or complementary goods (gas for example) (Bose and Shukla, 1999). Diagram 6.11 illustrates how demand elasticities influence the relative strength of the feedback loops that make up the causal linkages of an energy system.

Although estimating demand elasticities has attracted much research effort since the energy crisis of the 1970s, most of the focus remains on Western countries (Fouquet, 2014; Ros, 2015; Schulte and Heindl, 2017). Despite its considerable relevance, the issue of residential electricity demand in China as such has not received much attention in the literature. Research on electricity demand elasticities is particularly rare. The review of research estimating demand elasticities for the country reveals that there is much heterogeneity in the results.

Using provincial level data between 2005 and 2007, Qi et al. (2008) estimated the price elasticity of residential electricity demand to be −0.15 [58]. Lin et al. (2014) calculated elasticities for 29 provinces from 1998 to 2011. They found that households appear not to adjust their electricity usage in response to changing tariffs. At national level price elasticity is -0.4, -0.3 in urban areas, and -0.522 in rural areas. He at al. (2011) examined the demand price elasticity for several sectors including residential electricity consumers. Their study is based on data from 2007. They found that the price elasticity in the residential sector is –0.3.

Despite the variability of results, the vast majority of studies on China suggest that price elasticity is significantly below unity, which implies that residents appear not to be sensitive to changes in electricity prices.

6.3.1.1 Exploring the Role of Demand Elasticities

Huang (1993) examined the electricity–economic growth nexus for China for the 1950–1980 period. He found income elasticity of electricity consumption to be greater than unity, which suggests that consumers increase electricity usage faster than their income increases[59]. A number of more recent studies suggest significant variability in results. The Economic Research Institute for ASEAN and East Asia (ERIA), for example, found that long term income elasticity hovered around the +0.7 mark from 1990 to 2010. Based on micro-level household data from the China Residential Energy Consumption Survey (CRECS) which covered 26 provinces in 2012 Guo et al.(2016) found that a 1% increase in a household's disposable income would result in only a 0.145% increase in electricity demand.

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[58] If a demand is price elastic, then small changes in price will cause large changes in the quantity of a commodity consumed. If demand is less elastic, then it will take large changes in price to effect a change in quantity consumed. A price elasticity of -0.15 means that in response to a price change of 1% demand falls by 0.15%.

[59] If demand is income inelastic, then even significant changes in income will cause very small changes in the quantity consumed. An income elasticity of 0.7 means that in response to a price change of 1% demand increases by 0.7%.

Shi et al.'s study (2012) suggests that consumption is unresponsive to the level of income with an income elasticity of 0.058. Household level data collected in the Eastern cities of Beijing, Shanghai, and Guangdong were used as basis for the estimate. Qi et al. (2008) calculate income elasticities of residential electricity demand at 1.06 using provincial level data between 2005 and 2007. Luo and Song (2012) also show that income elasticity of consumer demand in the rural areas is high and greater than unity. Lin et al. (2014) found that income elasticities for households is 1.476 at the national level, 1.550 in urban areas, and 1.093 in rural areas.

My own calculations based on year-on-year changes in national income levels and residential electricity usage found that between 1990 and 2014 the elasticity of demand was +0.9. The calculation did not test for any causal relationships. Data underlying the calculation was obtained from the China Energy Yearbook.

6.3.1.2 Implications for Modelling Data

Households' responsiveness of demand to changes in income and price are key input variables for the simulation of intervention scenarios in a system dynamic stock-and-flow model. The studies discussed in the two preceding sections seem to agree in terms of the very low responsiveness of consumers to changes in electricity tariffs. Research on income elasticity comes to different conclusions. The divergence of estimates is astounding. Differences appear to be mainly caused by different calculation methods, some of which take into account factors other than income determining the demand for electricity. Some studies include cross elasticities of other forms of energy such as gas, which could substitute electricity. Other studies consider additional factors such as supply shortages.

Some shortcomings seem to stem from the data applied in the estimating equations. National level data appears not suitable to understand demand for electricity by households of different income and consumption categories. Even though there is agreement that significant wealth disparities exist between regions and between rural and urban areas, only one study by Lin et al. (2014) was located which considers the effect of varying levels of household income.

The review of official income data and residential electricity usage highlighted the correlation between a household's income and electricity consumption. It is understood that correlation does not necessarily imply causality. However, the positive relationship between household affluence, appliance ownership and electricity usage is intuitive and is supported by a number of studies (Jones and Lomas, 2016; Huang, 2015; Liu et al., 2016). As incomes increase, households tend to live in larger dwellings and purchase more electric appliances, which leads to higher electricity usage.

Income elasticity, which is one of the inputs to the simulation of different market reform options, is set at a value greater than unity. This means that an increase in income leads to a rise in electricity consumption at a greater rate than the change in income. Income levels also appear to influence households' reaction to tariff changes. Poorer households are more responsive to price changes. In light of significant differences in household affluence across regions the study needs to gauge the impact of carbon pricing on consumers living in different parts of the country. This is achieved through accounting for regional differences in income when determining households' sensitivity to a price adjustment.

The above discussion on demand elasticities improves the understanding of how the two dominant feedback mechanisms, the reinforcing relationship between electricity demand and household affluence and the balancing relationship between demand for electricity and price, influence the outcome of interventions targeting the demand side. The carbon price and the cost-pass-through-rate are two intervention variables that can be controlled by deliberate government policies. Demand elasticities are intrinsic to the system and cannot directly be influenced by a carbon market generated price signal as such. However, awareness of price and income sensitivities is important as policy design might need to compensate consumers' failure to adjust their consumption in reaction to a tariff increase.

6.3.2 Developing a Stock-and-Flow Model of the Residential Electricity Sector

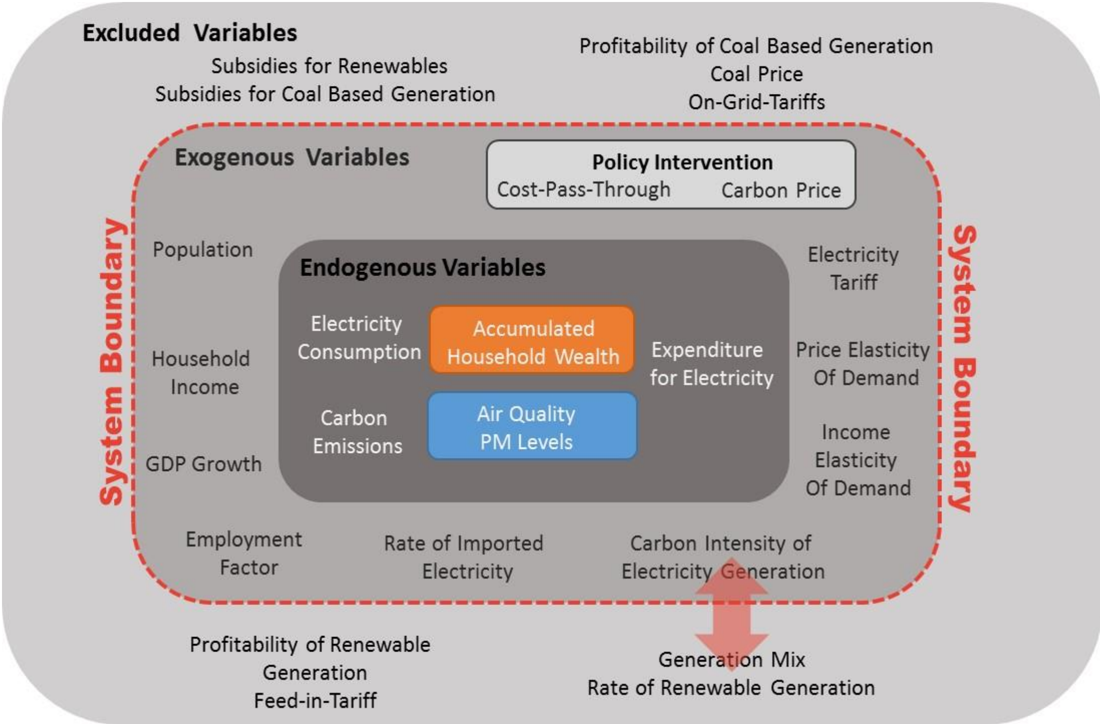
The construction of the system dynamic model involves the following steps. First, the model's structural relationships identified in the qualitative causal loop diagram of the Chinese electricity sector (Diagram 6.8) are translated into a stock-and-flow diagram. The definition of the system's boundary provides a clear picture of the scope of the study. Awareness of which variables are 'in' and which variables are 'out' also clarifies the requirements for the data underlying the simulation equations. Second, the simulation equations are formulated. These equations allow the modeller to quantitatively analyse system behaviour over time. Lastly, assumptions and limitations of the model are explained.

6.3.2.1 Defining the Systems Boundary

The boundary of the model is illustrated in a bull's eye diagram (Diagram 6.12), which is adapted from Kilanc and Or (2008). The diagram makes visible the endogenous and exogenous variables that define the stock-and-flow model. It also shows variables that have been excluded from the model.

Prior to constructing a systems model it is vital to explicitly define the system boundary. The system modeller needs to be aware of which system parts can be observed when studying the effect of an intervention. Subsystems or interactions outside the system under investigation could influence the effect of an intervention or may be affected themselves. Even though excluded from the analysis awareness of these interdependencies can add to the holistic understanding of a problem and draw the modeller's attention to potentially unintended intervention outcomes.

Diagram 6.12 Bull's Eye Diagram of variables describing the residential electricity sector



The system under study, which forms the basis of the stock-and-flow-model, focuses on investigating the effect of a carbon price signal on demand side behaviour. In order to keep the scope of the study manageable, a number of variables linked to the supply side of the electricity system were excluded from the stock-and-flow model. However, through an interface the effect of interventions targeting electricity generators move along linkages between the system (i.e. demand side) and its environment (i.e. supply side). Supply related factors, which drive or inhibit the decarbonisation of electricity sector or impact the socio-economic development of a region, are included as a proxy variable, the carbon intensity parameter.

The carbon intensity parameter captures the extent to which the obstacles to de-regulation of the electricity supply (discussed in 6.2) have been removed. Carbon intensity of electricity is a region specific parameter. Its initial value is determined by the amount of CO_2 produced for a unit of electricity. The value takes into account the carbon intensity of the electricity generated within the region and the carbon intensity of electricity imported from other regions. Relevant data was retrieved from various studies and the China Energy Yearbook as well as Provincial Yearbooks. Over time, the carbon intensity changes in line with the cost-pass-through rate and the carbon price (i.e. the carbon cost burden borne by generators). A higher cost burden puts more pressure on generators to adopt low carbon technology and thus accelerates the decline in carbon intensity. Carbon intensity, along with the amount of electricity supplied (in terms of Wh), determines pollution levels.

In order to provide the basis for realistic modelling within the setting of regions, specific socio-demographic variables such as fluctuations of the population size are included in the model. The impact of region specific economic growth forecasts is taken into account to estimate the development of household incomes over time. In the context of income changes the model takes into account that demand for electricity changes in response to a carbon price induced tariff increase. People's responsiveness to a price adjustment varies with levels of household affluence, which in turn is to a large extent influenced by locality. Average household incomes in Beijing are more than three times higher than in Shanxi, the province that produces a large part of the electricity consumed in the capital. The effect of demand elasticities on consumption is discussed in more detail above.

The employment factor accounts for changing employment opportunities in electricity related sectors such as mining, renewable energy technology and innovation industries in the presence of a carbon market. This indictor is also region specific in order to reflect that the effects of the economic transition are dependent on a province's economic structure. Its value is dependent on the cost burden put on the supply side. A higher cost burden incentivises emission intensive generators to adopt low carbon technology, which spurs the expansion of the innovation sector. Dependent on the scenario the value is fixed or variable with regards to time. The scenarios with variable rates simulate the effects of a changing economy over the course of the market-based electricity reform as well as the effect of supplementary government measures to support the development of the innovation sector in a specific region.

The bull's eye diagram also shows the balance between required inputs, i.e. exogenous variables, and endogenous variables. The latter are determined by the system behaviour itself. In the centre of the diagram are the two measures of stakeholder concerns, people's material standard of living and local air quality. Household wealth represents the material standard of living in each of the case study areas. Household wealth is derived by subtracting a household's expenditure for electricity from its income accumulated over the study period. Other household expenses are excluded from the analysis. Electricity expenditure is dependent on a province specific block tariff structure, the passed through portion of the carbon price as well as electricity usage, which is adjusted over time dependent on price and income elasticities. Block tariffs charge a higher tariff per kWh at higher levels of electricity usage, and a lower tariff at lower usage levels. The market generated carbon price varies with the intervention scenario. The cost of carbon for 1 KWh in a specific region[60] is added to the appropriate tariff rate.

The effect of carbon trading on local air pollution from the generation of coal-based electricity is used to assess the well-being of the population. The model differentiates between emissions from locally generated electricity and emissions from imported electricity. The carbon intensity of the electricity consumed within a region provides the

[60] The calculation of the cost of carbon takes into account regional differences in the carbon intensity of the generation capacity.

basis to calculate NO_x emissions[61]. NO_x is used as a proxy to measure changes to air pollution over the simulation period.

6.3.2.2 Constructing a System Dynamic Stock-and-Flow-Model

In line with the boundary definition and the causal relationships between variables the stock-and-flow diagram is constructed in Vensim. System dynamic stock-and-flow models are predictive in nature as cause-effect relationships are quantified. As explained in the methodology chapter the constituent elements of such a model are 'stocks' and 'flows' (or 'levels' and 'rates'). Changes in systems occur over time when levels in the stocks create changes in the flows and vice versa (Meadows and Wright, 2008; Sterman, 2000).

By changing the input variables, identified as exogenous variables, it is possible to study the effect of various factors (such as population growth, changing economic climate, the tariff structure, the influence of electricity demand elasticities, and certain supply side related issues) as well as the effect of different interventions (the carbon price level and the cost-pass-through rate) on household electricity consumption over time. The stock-and-flow model constructed for the purpose of the study is presented in Diagram 6.13. An overview of the system variables including their description can be found in the Appendix along with a table listing the simulation equations behind each variable. Simulation equations are expressed in the Vensim modelling language.

6.3.2.3 Testing the Validity of the Model

In order to ensure the model generates meaningful results, its validity needs to be confirmed prior to the execution of simulation scenarios. There are two main aspects of validation of system dynamics models: structure validity and behaviour validity (Saysel and Barlas, 2006; Özbaş et al., 2014; Barlas, 1996). Structure validity is assuring that the model structure reflects the cause-and-effect relationships existing in real life. Behaviour based validity tests demonstrate that the model generates output reflecting the 'real life' behaviour of the system in terms of observable event patterns.

To ensure structure validity, causal relationships have been verified against concepts presented in the literature. The causal structure of the model is explained in Section 6.2. Following its completion the model was checked by experts, who were consulted during the fieldwork stage (see Chapter 5), to make certain that it represents the situation in China as accurately as possible.

To prove behavioural validity, the modelling output should be consistent with real data. To this end, a historical simulation was executed for the whole of China from 2005 to 2015.

[61] Nitrogen dioxide NOx stems from the combustion of fossil fuel and is one of the main air pollutants realised by coal-based electricity generation. It is a toxic gas that can form ozone and particulate matter (SEPA, 2017).

The objective of the test was to verify the accuracy of key output variables such as CO_2 emissions from electricity generation and residential electricity consumption. Proving the behavioural validity of the model output turned out to be difficult as there was considerable variability in the historical data depending on source (even between official yearbooks). A comparison between real data and simulated data produced an error margin of around 12 percent. This should be considered acceptable since the study is not concerned with accurate forecasting. It rather seeks to understand behavioural system patterns and the impact of interventions on them. The results of the behavioural validity test can be found in the Appendix.

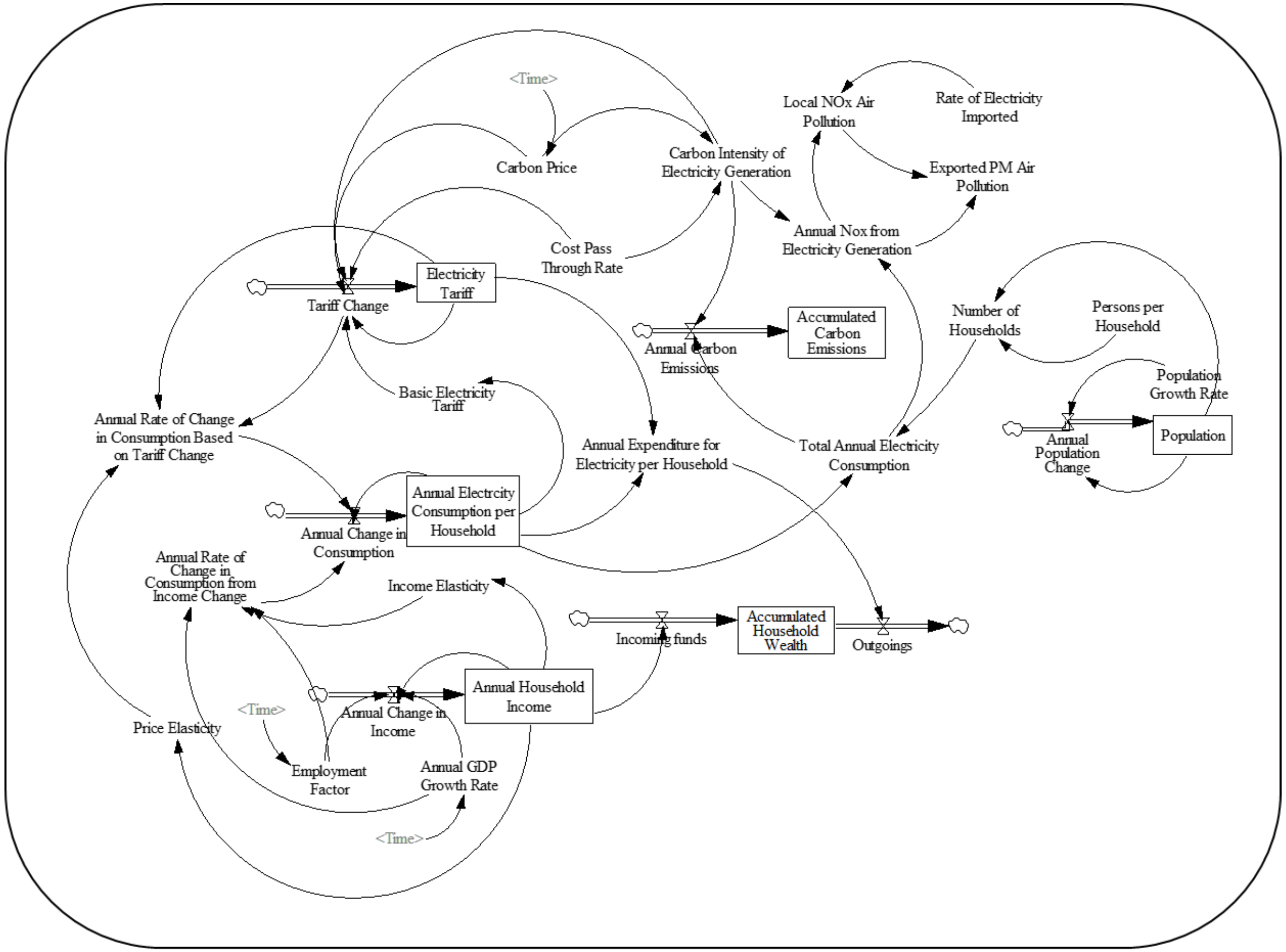
6.3.2.4 Limitations and Assumptions of the Model

The stock-and-flow model was constructed with the aim to enhance the understanding of how a market-based intervention affects current patterns of electricity consumption and electricity generation. The model is a simplified description of reality, designed to yield hypotheses about interactions between system components (Ouliaris, 2012). As was the case for the causal model simplification was deemed necessary to contain complexity. The variables that have been explicitly excluded are listed in Diagram 6.12.

The validity test has demonstrated that the stock-and-flow-model delivers reliable results and mirrors past developments even though several assumptions have been made to formulate the simulation equations. The estimation of the region specific carbon intensity indicator is based on past developments in other countries in line with their reduction ambition (legislations, targets etc. in lieu of a carbon market price signal). The same approach was taken with the estimation of employment impacts of a carbon market, which are quantified by the region specific employment factor.

A considerable number of variables influence future residential electricity usage patterns. The predictive nature of the model requires estimates for future developments such as economic growth and changes in the population. A number of input variables have been derived from secondary literature and studies that in turn rely on models that estimate certain variables. In a number of cases it was difficult to gauge their validity, particularly in the context of China as the country has not had much experience with a deregulated electricity market. The current non-cost reflective tariff system makes it difficult to gauge people’s responsiveness to a carbon price (see discussion on demand elasticities).

Diagram 6.13 Stock-and-Flow-Diagram – Systems Dynamic Model of Residential Electricity Consumption Behaviour



Data is derived from a number of sources. This might affect data compatibility. The majority of data, in particular socio-economic data, was retrieved from official yearbooks and government publications to limit variation of source. Technical information regarding emission factors, for example, was retrieved from studies in peer-reviewed journals or publications of international organisations such as the IPCC. The assumptions underlying these studies have been checked to see whether they are commensurate with the requirements of the scenario analysis. Data sources and how the data is used as input are made explicit in Appendix Tables 6.A to 6.C.

Despite these limitations the stock-and-flow-model meets the study's overall objective, which is to understand the linkages between different parts of the system as well as the influence of exogenous variables and interventions on the two main electricity demand feedback mechanisms in the presence of a carbon market.

6.3.3 Simulating the Effect of Price Interventions on Electricity Consumption

The system dynamic toolset is employed as a learning device to extend the knowledge gained from the qualitative and quantitative system modelling exercise. As stated above, the study does not intend to accurately predict the future or to prescribe what should happen as part of an electricity sector reform. Scenario simulation in Vensim offers laboratory conditions to test how the system responds to market related interventions by varying socio-economic and political circumstances of a region (Hoffmann and Mc Innis, 2004).

The scenarios executed in Vensim test the combined effect of carbon price and cost-pass-through rates on households in the three regions of Shanghai, Beijing and Shanxi over the period from 2015 to 2035. Each location has distinct electricity consumption and generation patterns that are reflections of the region's current development status.

Estimating the cost of carbon is a profoundly difficult exercise (Robins, 2012). As explained before difficulty arises because there are several deep uncertainties in estimating the loss caused by emissions (Bowen, 2011). In light of China's regional differences, estimates for one national carbon price become even more complex. Price targets are typically based on production emissions, which do not take into account the emissions that are indirectly caused by electricity consumers, who are removed from the site of generation. In order to design realistic scenario conditions, numerous studies were consulted to understand what price level would incentivise the effective reduction in emissions. Most studies appear to be based on the experience of carbon markets operating in Europe and North America. General estimates of the 'optimal carbon price' range from \$32/t CO_2 to \$220/t CO_2 (220RMB/t CO_2 to 1515 RMB/Mt CO_2) (Yeo, 2014; Lontzek et al., 2015).

Only a few China specific studies could be located. In an interview (Interview 20) a recognised Chinese academic expert in the field of energy transitions suggested an optimal carbon price between 150RMB/t CO_2 and 300 RMB/t CO_2. A study by de Boer and Roaldo (2015), which elicited views on the future of China's carbon price from professional stakeholders in emissions trading, anticipates a price for national Chinese ETS of around 35 RMB/t CO_2. According to a news report (Chun, 2016) Jiang Zhaoli, deputy head of the NDRC's climate change department, revealed that the launch price is expected to be set as the average of the prices on China's pilot carbon markets. The trials have highlighted significant differences in performance across regions. The carbon price in the pilot ETS was generally very low. In the Shanghai pilot it fluctuated around the 11RMB/t CO_2 mark in 2016. Prices amongst all pilots were the highest in Beijing, about 50 RMB/t $CO_{2,}$ in 2015. The price of one ton of carbon dropped to 30 RMB in the following year (Carbon Pulse, 2015-2016).

The intervention scenarios test the effect of a carbon price ranging from 0 RMB/tCO_2 to 300 RMB/tCO_2 based on expert advice and the conditions encountered in the pilot ETS. The cost-pass-through rate indicating to which extent the carbon cost burden is split between generators and consumers is varied from 0% to 100%. For all three locations a Business-as-Usual (BAU) scenario is simulated. The BAU scenario is a reference point to compare the effect of any of the carbon market scenarios against a scenario with no market. Two baseline carbon market scenarios (BL) are executed to estimate the effect of conditions, which according to experts are likely to reflect the first few trading periods of a national market. Baseline Scenario 1 (BL1) tests the situation of a very low carbon price, 11 RMB/tCO_2, and zero cost-pass-through, currently found in most of the pilot ETS. Baseline Scenario 2 (BL2) simulates the effect of a slightly higher carbon price of 35 RMB/tCO_2. Both BL1 and BL2 provide points of reference for scenarios that examine the effect of more ambitious carbon price levels, 150 RMB/tCO_2 and 300 RMB/t$CO_{2,}$ combined with different variations of cost-pass-through.

Tables 6.1 and 6.3 provide an overview of the intervention specific input parameters for each of the scenarios executed. The carbon price is stated in RMB/t CO_2, the Cost-Pass-Through rate is a percentage and the employment factor is dimensionless. General and region specific input variables are explained in Appendix Tables 6.A and 6.C.

Table 6.1 Intervention Scenario Input Parameters for Shanghai

	SHGBAU	SHGBL1	SHGBL2	SHGSC1	SHGSC2	SHGSC3	SHGSC4	SHGSC5	SHGSC6	SHGSC7	SHGSC8
Carbon Price (in RMB)	0	11	35	150	150	150	150	300	300	300	300
Cost Pass-Through Rate (in %)	0	0	0	0	25	50	100	0	25	50	100
Employment Factor	1.1	1.1	1.1	1.4	1.3	1.2	1.1	1.5	1.4	1.3	1.1

Table 6.2 Intervention Scenario Input Parameters for Beijing

	BJGBAU	BJGBL1	BJGBL2	BJGSC1	BJGSC2	BJGSC3	BJGSC4	BJGSC5	BJGSC6	BJGSC7	BJGSC8
Carbon Price (in RMB)	0	11	35	150	150	150	150	300	300	300	300
Cost Pass-Through Rate (in %)	0	0	0	0	25	50	100	0	25	50	100
Employment Factor	1.1	1.1	1.1	1.4	1.3	1.2	1.1	1.5	1.4	1.3	1.1

Table 6.3 Intervention Scenario Input Parameters for Shanxi

	SHXBAU	SHXBL1	SHXBL2	SHXSC1	SHXSC2	SHXSC3	SHXSC4	SHXSC5	SHXSC6	SHXSC7	SHXSC8	SHXSC9	SHXSC10	SHXSC11	SHXSC12
Carbon Price (in RMB)	0	11	35	150	150	150	150	150	150	300	300	300	300	300	300
Cost Pass-Through Rate (in %)	0	0	0	0	25	50	100	100	0	0	25	50	100	100	0
Employment Factor	1.1	1.1	1.1	0.5	0.6	0.7	0.7	0.5-1.5	0.5-1.5	0.5	0.6	0.7	1.1	0.5-1.5	0.5-1.5

In the systems simulation software Vensim it is the formulae and relationships that make up the model. Formulae are captured by simulation equations (Appendix Table 6.B) and relationships are represented by the stock-and-flow model (Diagram 6.13). Intervention specific data is entered directly into the model. The numbers generated by the execution are treated as experiments. They are stored as datasets separate from the model. These datasets can be downloaded into spreadsheet applications such as Excel for further analysis. Data sheets of the simulation output can be found in the Appendix (Appendix Tables 6.D1 to 6.D3).

6.4 Exploring Implications of a Market-Based Approach on the Residential Electricity Reform

The simulation of intervention scenarios has the objective firstly to enhance the understanding of the interplay between the balancing effect of a carbon price (CP) signal and the reinforcing effect of higher household incomes on residential electricity demand. The second objective is to quantify the effect of a price signal on household wealth and air quality in the three study locations. This information is required to evaluate the potential of alternative market-based interventions firstly to control residential consumption and secondly to close the gap between regions that exists in terms of household affluence and local air quality.

6.4.1 Limitations of a Price Signal to Regulate Electricity Consumption

This section explores the effectiveness of a price signal to limit electricity demand growth. The intention of a carbon market aiming to reform the demand side of the electricity system is to induce consumers to use less in response to higher tariffs. The saving needs to be sufficient to offset the effect of other factors that lead to increased consumption such as rising incomes. The effect of a price signal was tested in various economic growth scenarios tailored to the specific settings of the three study sides. In order to isolate the price effect from interactions occurring on the supply side only scenarios with a cost-pass-through rate (CPR) of 100% are considered in this analysis. This situation is also reflective of conditions encountered in the EU, where almost the entire carbon cost burden is borne by electricity consumers.

Across all scenarios the effect of a price signal on demand was found to be limited. For example, in Shanghai the most ambitious scenario in terms of demand reduction (SHGSC 8: CP = 300RMB/tCO_2, CPR=100%) delivered only a moderate annual savings for the average household (5381.01 kWh vs. 5878.83 kWh) compared to Business-as-Usual scenario (no carbon market; CP =0) in 2035, the final year of the simulation. Scenario output confirms the correlation between the price level and usage levels, which suggests that consumers do adjust their usage as tariffs change. The scenario that tested a less aggressive price policy (SHG SC4: CP = 150RMB/tCO_2, CPR=100%) led to a lower reduction in annual demand (5664.72 kWh in 2035). Annual expenditure for electricity develops in line with consumption levels: 5390.89 RMB (BAU), 6225.83 RMB (SHG SC8) and 5664.72 RMB (SHG SC4). Despite the average price paid for 1 kWh (from 0.617 RMB/kWh to 1.157RMB/kWh) almost doubling over the period from 2015 to 2035, in Shanghai demand almost trebled in the aggressive price scenario (SHG SC8) over the simulation period. The effect of an electricity price increase on usage levels was entirely offset by the effect of a growing economy as the average annual income increased by a factor of 2.7 from 65,417 RMB to 179,148.55 RMB. A very similar observation was made for the consumption patterns of Beijing households.

Only in scenarios with low economic growth expectations and pessimistic forecasts regarding the development of household incomes combined with unrealistically high carbon price levels borne entirely by consumers could an increase of electricity usage be effectively contained. Poor households with low income are more likely to react to higher tariffs. This is reflected by higher demand elasticities at lower income levels. At the start of the simulation in 2015 household incomes in Shanxi were only about a third of the levels encountered in Beijing and Shanghai. In the high price scenario SHX SC10 (CP = 300RMB/tCO_2, CPR=100%) annual electricity consumption at household level increased only slightly from 980.35 kWh to 1071.73 kWh over the 20 year period from 2015 to 2035, while average household income grew by 50% from 23,876 RMB to 36,428.52 RMB.

Despite limiting the increase of usage to a greater extent (and therefore expenditure for electricity) compared to more affluent households in the East, the wealth of poorer households in Shanxi did not accumulate as quickly. Households spent a greater percentage of income on expenditure for electricity following the introduction of a carbon market. The share of electricity expenditure increased from 1.89% in 2015 to 2.22% in 2035, even in a moderate price scenario (SHX SC4: CP = 150 RMB/tCO_2, CPR = 100%). This observation matches the effect of the EU ETS on the affluence of poorer households

The insights suggest that disparities in the material standard of living between regions are increasing in the presence of an ETS. The following investigates the fundamental question of whether a market-based solution could under any circumstances mitigate current disparities between regions.

6.4.2 Understanding Regional Equity Implications of a Tariff Reform

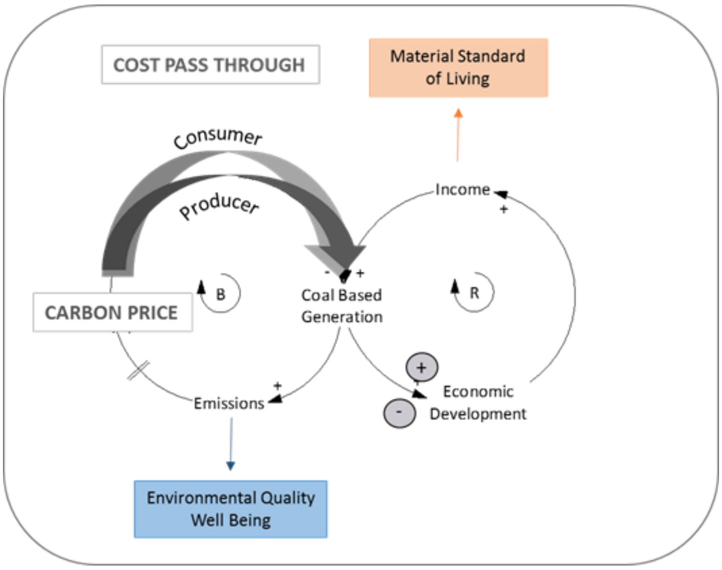
The analysis has highlighted the limited effect of a price signal to constrain demand. The carbon price signal was found to be least effective in the affluent regions, even though coastal households shoulder most of the cost burden (in absolute terms) due to their high consumption levels. The output of scenario simulations testing the effect of different burden sharing arrangements between generators and consumers on regional disparities are explored in the following. Different burden sharing arrangements are simulated through variations in the cost pass-through rate (CPR). The CPR determines how the carbon reduction responsibility is divided between consumers and generators.

In all scenarios with a low CPR the introduction of a carbon market slowed increases in emissions faster than under scenario conditions that test the effect of a higher cost burden on households (i.e. a high cost-pass-through rate). The carbon price has a greater impact on the supply side than on the demand side as generators are more responsive to the price signal than consumers. In order to trigger meaningful reductions of emission intensity on the supply side, the carbon price has to reach significantly high levels. In Shanghai the scenario that placed the greatest burden on generators (SHG SC5: CP = 300 RMB, CPR = 0%) resulted in local NO_x emissions to drop by almost a half (99981.59 t NOx) compared to BAU (187,855.73t NO_x). Passing on the cost to consumers (SHG SC8: CP = 300 RMB, CPR = 100%) led to a much smaller improvement in local air quality (difference BAU- SHG SC8: 15,907.80 tNO_x).

The effect of the burden sharing arrangement between consumers and producers has significant regional implications, if the province under investigation imports most of its energy from coal-fired plants in other provinces. Placing the cost burden on generators in other regions diminishes the effect of a carbon price on the energy importing province. However, shielding consumers in Beijing from a cost on environmental pollution accelerates the improvement of environmental conditions in the exporting provinces, such as Shanxi. This is because emission intensity of energy generation decreases as coal-based plants in the exporting provinces shoulder more of the cost burden. As in the case of Shanghai, de-carbonisation of the supply side has a greater effect on emissions than lowering consumption at the same carbon price level. In scenario BJG SC5 (CP = 300 RMB, CPR = 0%), where electricity exporters are responsible for most of the cost burden, a total of 229,714.97 tNO_x are transferred out of the capital from 2015 to 2035. Under scenario conditions of consumers shouldering more of the cost burden more air pollutants are transferred out of Beijing (BJG SC7: 32,6311.56 $tNO_{x,,}$ CP = 300 RMB, CPR =50%; BJG SC8: 531,128.45 $tNO_{x,}$ CP = 300 RMB, CPR =100%). The notion that the greater the share of consumers paying for the environmental damage of electricity generation, the smaller the positive effect of a carbon market on the improvement of air quality and other forms of environmental degradation might appear counter-intuitive. It highlights the complex and often unforeseen equity trade-offs that exist within the Chinese energy sector, in particular when electricity generation and consumption take place in different geographies.

The effects of decarbonising the supply side extend beyond improving the environment. Previously it was assumed that coal-based generation capacity, economic development and incomes move in the same direction. This relationship is denoted by the plus sign in the feedback loop on the right hand side in Diagram 6.1. The basic causal model developed at the outset of the causal analysis has been amended to incorporate the region specific effects of the carbon market, one of the lessons learnt from scenario execution in the stock-and-flow model.

Diagram 6.14 Basic Feed Back Mechanisms - Region Specific Effects



The positive and negative signs in Diagram 6.14 describe the ambiguous relationship between supply side changes and households' material standard of living as regions undergo different structural change in the response to a carbon market. Cost pressures on generators to lower their reliance on coal power affect regional economies differently. An electricity sector reform benefits regions with a developed innovative sector, which can supply products and service supporting the transition. The market driven decarbonisation of the generation base has a reinforcing effect on incomes and people's standard of living in the advanced economies of Shanghai and Beijing.

The economies of provinces such as Shanxi, whose growth model is built traditional industries, are likely to be impacted negatively by a high carbon cost burden. The growth of the average household income is likely to be suppressed in the presence of a strong price signal and a low pass-through rate. Scenario output confirms that the greater the cost burden on generators, the more pronounced the effect on employment and income. Shanghai and Beijing residents benefit from improved employment opportunities and higher salaries following the carbon market induced boost of the cities' innovation sector. In a moderate cost pass through scenario (BJG SC2: CP = 150, CPR =25%) the carbon market adds almost 270,000 RMB to the wealth of households in Beijing over the simulation period. In scenario BJG SC6 with a higher carbon price (CP = 300, CPR =0%) average household affluence increased by 414,897 RMB compared to BAU.

The same scenario conditions executed against the economic setting found in Shanxi suggests that the departure from coal-based forms of generation is likely to exacerbate the situation for households. The population is likely to be faced with wage cuts and unemployment in the presence of a carbon market forcing electricity generators and other coal related industries to lower their output. The gap in the material standard of living between regions appears to widen at an accelerated pace as the pressure of de-carbonisation on coal-based energy generation increases. In the BAU scenario annual income is estimated to be 36,428.52RMB in 2035. Under conditions of zero cost-pass-through (SHX SC7, CP = 300 RMB/tCO_2, CPR = 0%) a carbon market appears to suppress an increase in salaries by almost over 4,000 RMB (SHX SC7: average annual income 32,315.84 RMB).

Scenarios testing the effect of supplementary policies supporting the transition paint an entirely different picture. Thanks to its geographical and topographical characteristics Shanxi was identified as site for the installation of wind turbines and solar plants. As noted before, renewable forms of energy are more 'job intensive' than fossil fuel based energy sector. According to a study by Lewis (2013) wind power is estimated to create 27% more jobs than the same amount of electricity generated by a coal-fired plant. In order to achieve the creation of job opportunities on this scale a substantial part of the value chain would have to be located within the province. The manufacturing of wind power equipment contributes two thirds to the labour requirements while the installation and maintenance account for the remaining one third. The exploitation of these opportunities requires a specialised skill-set. The government plays a vital role to help workers and employers make transitions in the labour market by offering retraining programmes to upgrade workers' skills and employability. Assuming the availability of government support the average annual household incomes could increase by almost 7,000 RMB to 43,409.99 RMB (SHX SC12, max CP =300 RMB/tCO_2, CPR = 0%) by 2035 compared to the BAU scenario.

Better employment opportunities and higher income are per se positive. However, improved household affluence translates into higher electricity consumption and deteriorating environmental quality in the proximity of coal plants, if the demand cannot be met by additional renewable capacity. Shifting most of the responsibility of electricity related pollution in form of a cost burden on households delivers sub-optimal results in terms of environmental performance. Despite consumption levels being the lowest in scenarios with 100% cost-pass-through, the effect on emissions appears to be the weakest compared to situations where electricity demand is higher. This can be explained by lacking incentives for generators to switch to greener forms of electricity generation when cost-pass-through is low. As already explained, the decarbonisation of the supply side can be expected to lead to quick wins in the short run. However, once the 'low hanging fruit' of efficiency improvements have been picked in the provinces that currently rely on obsolete generation technology, supply side changes will become more costly.

The implication for a carbon market is that in order to effectively lower pollution in the longer run, households and generators need to share the cost. In an aggressive price scenario (SHG SC8: Max CP = 300RMB/tCO_2, CPR=100%) with 100 % cost-pass-through annual emissions from electricity generated for the consumption of Shanghai amounted to 42.99 Mt CO_2 whilst in an equal burden sharing scenario (SHG SC 7: CP = 300RMB/tCO_2, CPR=50%) 32.63 Mt of carbon were emitted. A similar pattern can be observed for air pollution approximated by NO_x emissions (SHG SC7: 130,517.61 t NO_x vs. SHG SC 8: 171, 947.94 NO_x) 35% of which are exported to other provinces. In shared responsibility scenarios it is not the effect of higher expenditure on electricity that leads to better emission abatement, but the weaker reinforcing effect of economic development on household income and demand. Burden sharing between consumers and generators simultaneously has a positive impact on electricity exporting economies such as Shanxi, which are to a lesser extent exposed to the cost burden of emission intensive electricity generation.

6.5 Conclusion

The protection of the environment and economic development are often seen as competing aims. Causal modelling, however, demonstrates that whether improving environmental quality and promoting economic development through a carbon market is a trade-off or a growth enhancing structural adjustment is dependent on the design of the intervention. Awareness of complex causal relationships and how they are shaped by local circumstances is a prerequisite for effective government interventions to change patterns of unsustainability. The main insights gained from dynamic system modelling for intervention design are summarised in the following.

The analysis of different intervention scenarios firstly found that under no realistic conditions can the presence of a carbon market significantly limit increasing demand from residential electricity consumption, particularly from top consuming households in the affluent urban centres along the East coast. The limited effect of a price signal to induce energy saving behaviour hampered the effectiveness of recent efforts to reform the residential electricity sector. In 2012 the Chinese government introduced an increasing block tariff structure for electricity. The departure from a flat rate was mainly driven by the desire to control rising electricity demand from affluent households. It was designed with the objective to freeze the tariffs of the first block in order to target only high consumers by the new price structure (He and Reiner, 2016; Zhang and Qin, 2015). Even though it is difficult to ascertain how electricity consumption would have developed without the price reform, the majority of studies on the subject found that the price rise did not sufficiently incentivise high consumers to adopt energy saving behaviour.

Secondly, burden sharing between consumers and generators delivers the most promising results for cutting emissions and improving local environmental quality. The cost-pass-through rate provides a powerful tool to affect environmental conditions and economic development. Focusing market-based intervention design solely on achieving an ‘optimal’ price level could lead to unintended and unforeseen impacts. The role of the government to define the interaction between carbon price and cost-pass-through rate is vital.

The third insight delivered by the study is the important yet ambiguous role of the state to facilitate the transition of the electricity sector through a market-based reform. In order for a carbon market to establish a functioning balancing feedback loop, the structural barriers to a market-based reform, which weaken the effect of a price signal both on the supply and demand side of the system, need to be removed. The deregulation of on-grid tariffs is required to ensure that the despatch of electricity in merit order provides low carbon generation technology with a cost advantage over emission intensive forms of generation. The deregulation of currently subsidised end-user tariff is required to ensure the carbon price signal reaches consumers despite its limited ability to induce energy saving behaviour.

The discussion on the deregulation of electricity prices might suggest that the state should withdraw entirely from controlling the electricity sector in the presence of a carbon market. State intervention is firstly desirable to ensure the price signal is set an appropriate level. The two baseline scenarios demonstrated that a low carbon price is not capable of facilitating an effective sustainability transition to the 'New Normal'. Secondly, by adjusting the cost-pass-through rate targeted government intervention can direct the effect of a carbon market between generators and consumers, and subsequently between highly developed electricity importing regions and less affluent regions reliant on electricity exports. The cost-pass-through rate appears to have a far greater effect than anticipated. It is not just a mechanism to shift the cost burden from generators to consumers. It has the potential to trigger significant changes to a region's economic situation. Contrary to the idea that higher tariffs impact higher consuming households most, scenarios testing the effect of moderate to high cost-pass-through illustrated that the populations of well-developed regions are likely to benefit under such conditions in terms of improved employment opportunities. The opposite appears to be the case for less developed provinces such as Shanxi, whose economy model is reliant on coal related industries. A high cost-pass-through rate suppressed the increase in household income due to deteriorating employment opportunities. Scenarios simulating conditions in the presence of policies actively supporting gradual restructuring of the economy away from coal, suggest that Shanxi could in the long term benefit from the 'spill-over effect' of China's economic transition. As observed in developed Western economies, state intervention in the form of re-training initiatives or subsidies has an important role to play in facilitating an equitable transition.

The observation made as part of the review of the EU ETS that no policy instrument can be more effective than policymakers allow it to be has been confirmed by the systems based study of the Chinese electricity sector. The potential to achieve significant emission reductions with a well-functioning carbon market underpinning the structural economic reform is enormous. If China is to achieve the sustainability targets of the 'New Normal', it needs to strike a balance between 'control' and 'laissez-faire' by retreating from some areas and reasserting its authority in others.

The remainder of the thesis seeks to find answers to the following questions, which the tools of hard systems analysis employed in this chapter were not able to address. In light of the ambiguous relationship between environment (local air quality) and economy (household's material standard of living) and the many different options for intervention design, the next chapter attempts to shed light on the preferences of households for the outcome of a residential electricity reform. It seeks to find answers to the following questions. What are their priorities for the outcome of the reform? What is the preferred market-based intervention scenario in each of the study regions?

The limited effectiveness of a price signal to control the consumption of top users suggests that implementation of complementary interventions might be helpful to weaken the reinforcing effect of rising incomes on electricity demand. The next chapter is therefore also concerned with answering the research questions that revolve around interventions improving electricity saving behaviour. What are behavioural barriers to the reform? What non-price incentives determine consumption behaviour? How does the propensity to react to price and non-price incentives vary across regions?

A survey conducted in various locations around China forms the basis of the next chapter concluding the empirical analysis. The questionnaire assesses consumers' preferences for the outcome of an electricity sector reform. It also elicits their attitudes towards clean electricity to identify the characteristics and potential driving forces of environmentally friendly behaviour.

7 Stakeholder Related Constraints and Opportunities for a Market-Based Reform of the Residential Electricity Sector

The simulation of market based intervention alternatives (Chapter 6) demonstrated that economic, environmental and social outcomes vary greatly between intervention scenarios. Outcomes differed significantly across the study regions of Shanghai, Beijing and Shanxi. During the problem articulation stage of this study (Chapter 5) it became apparent that stakeholders have conflicting interests regarding the outcome of residential electricity sector reform. Some stakeholders appeared to value environmental quality more than others, who were more concerned about the potential impacts of the reform on affordability. Some interventions would therefore be regarded as desirable by some stakeholders and undesirable by others. In order to identify which interventions enjoy the highest approval across the study population, preferences for intervention outcomes need to be established.

The first objective of this chapter is to identify the market based intervention which receives the highest acceptance across stakeholders by region and nationwide. Analytical Hierarchy Processing (AHP), a form of Multi-Criteria Decision Analysis (MCDA), is used to evaluate the intervention alternatives in light of stakeholder preferences for environmental quality, economic development and an equitable society. As explained in Chapter 4, which describes the methodological approach underlying this study, MCDA accounts for conflicting stakeholder objectives through a participatory decision framework. MCDA complements scenario-based research. It applies an algorithm, which systematically aggregates preferences for multi-dimensional decision criteria for each intervention scenario. Aggregated preference scores identify the scenarios that are the most accepted and contested in light of people's priorities for a clean environment, material standard of living and an equitable and fair society. Stakeholder priorities for these decision criteria were elicited in a close-ended questionnaire, which was presented to the public in various locations across China.

The second objective of this chapter is to understand determinants of energy conserving behaviour. Policy testing in a system dynamic model demonstrated that a carbon market can be a useful instrument to support the transition of the residential electricity sector. Market based interventions appeared to be most successful in transforming the supply side. Scenarios testing the effect of a price on carbon demonstrated the limitations of a market based approach to control increasing household consumption. Price based measures appear insufficient by themselves. Particularly top consuming households located in the developed Eastern region did not adjust their consumption to the level required to avoid the construction of coal based generation capacity to satisfy their demand for electricity in the future. The simulation of various price scenarios tested the effect on household electricity usage in Shanghai. The analysis of simulation output data highlighted that the magnitude of a tariff increase required would not be accepted by the majority of study participants in Shanghai who indicated their willingness to pay for green energy in a questionnaire.

Preferences for the outcome of a reform established by MCDA provides a starting point for the further study of factors, other than price determining the adoption of energy conservation behaviour. The analysis is based on a survey that gathered comprehensive information about people's views on wider issues relating to electricity usage and pricing. Insights gained from the survey are supplemented by interviews conducted during the fieldwork stage of this study and lessons drawn from relevant research on the determinants of environmentally friendly behaviour.

One key finding of this chapter is that the unique cultural and political setting of China, where the State dominates the political process, appears to be a barrier to a reform of the residential electricity sector. Current policies that focus on economic signals pay very little attention to behavioural factors. Another insight gained is that public participation in decision making is crucial to the planning and implementation of initiatives which aim to transform fundamental ways a society functions. The lack of participatory features in the Chinese environmental governance system seems to have contributed to the so-called 'action-value gap'. In general, people seem to place great value on a clean environment. Their concerns for the environment, however, are not followed by actions as responsibility for pollution reduction is abdicated to the State.

The chapter is structured as follows. The first part of the chapter seeks to establish which carbon market intervention scenario is the scenario preferred by electricity consuming households in China. Preferences for intervention design are calculated by employing tools borrowed from AHP based on stakeholder priorities for environmental quality, economic development and an equitable society. Stakeholder preferences are derived from a questionnaire administered to the public in several locations across China. A discussion on the implications of stakeholder preferences for a market based reform concludes the first part of the analysis.

The second part of the chapter is concerned with the investigation of measures supporting the effectiveness of a carbon market to control residential electricity consumption. Insights gained from understanding stakeholder priorities are enhanced by identifying determinants of energy conserving behaviour. To this end stakeholder views on price-based and non-priced based incentives are examined. The investigation is based on information elicited from responses to a survey, which captured people's views on wider issues related to the reform of the electricity sector. China's approach to environmental governance is explored to provide context for the so-called 'action-value gap' which was found to be a major barrier to the adoption of electricity saving behaviour.

The chapter ends with a discussion exploring the potential of a carbon market to remove behavioural barriers to a reform. Wider issues such as distributive implications of a market based reform and the role of the government conclude the analysis.

7.1 Analysing Stakeholder Preferences for the Reform Outcome

Multi-Criteria Decision Analysis (MCDA) completes the scenario analysis of Chapter 6 by providing a framework to systematically structure and aggregate scenario output data according to stakeholder priorities. MCDA is particularly useful in situations which involve multiple competing criteria. Analytical Hierarchy Process (AHP), a method of MCDA, uses measurable criteria generated for each scenario by systems dynamic intervention modelling to assess the extent to which objectives have been achieved. A set of decision criteria which were earlier identified in interviews with stakeholders (Chapter 5) forms the basis of the analysis.

The objective of this section is to build a ranking of intervention scenarios by aggregating individual stakeholder preferences for each of the study areas. Shanghai, Beijing and Shanxi are representative of the regional patterns of electricity generation and electricity consumption. More specifically provinces are categorised by their status of socio-economic development, exposure to environmental degradation (air pollution serves a proxy) and their position as electricity importer or exporter. Shanghai represents the first group of provinces, typically affluent net-electricity importing provinces with a low to medium level of air pollution. Beijing is characteristic for group 2, China's net-electricity importing provinces with a high level of air pollution. The province of Shanxi represents less developed net-electricity exporting regions with a high level of air pollution. Such provinces fall into group 3. Provinces exporting electricity generated from renewables as well as provinces with a balanced energy balance are subsumed into the fourth group. Categorisation is based on official data published in the National Statistical Yearbook and the Energy Statistical Yearbook. An overview of the categorisation of provinces by their energy and pollution profile can be found in the Appendix. Scenario rankings of the regional groups are aggregated in Section 7.1.5 to establish preferences for a market based reform at national level.

The ranking of stakeholder preferences by region for a specific intervention scenario involves the three steps carried out in in the first three sections. Section 7.1.4 interprets the results of the analysis. Over the past decades a plethora of methodologies and tools were devised to perform AHP, each suiting a different purpose (Cinelli et al., 2014). Past applications of AHP provided the basis to understand the different steps involved in the analysis. As no methodology fitted the exact requirements of this study, an approach tailored to the decision making situation of this research is developed. AHP is carried out in the spreadsheet application Excel. The methodological framework (Chapter 4) describes the application of AHP in this study. For the sake of clarity, the approach is re-iterated here and explained in more detail through the analysis of the empirical data in the latter part of this chapter.

The first step of AHP is to form a decomposition of the objectives to be achieved by an intervention into hierarchies. Three main objectives or criteria, economic development, environmental quality and an equitable society, have been elicited from stakeholders who were interviewed in the initial stage of the study (Chapter 5). A performance matrix is put together based on the output of scenario simulation performed in Chapter 6. Each column describes an intervention alternative and each row describes the performance of each alternative against each criterion.

The second step is concerned with determining the relative importance stakeholders attach to these criteria. Based on survey responses to a questionnaire the relative weightings of the three decision criteria are calculated.

The third step is concerned with the assignment of a rating to each of the intervention scenarios. The rating quantifies the effect of a particular intervention on each of the decision criteria at regional level (as per the performance matrix).

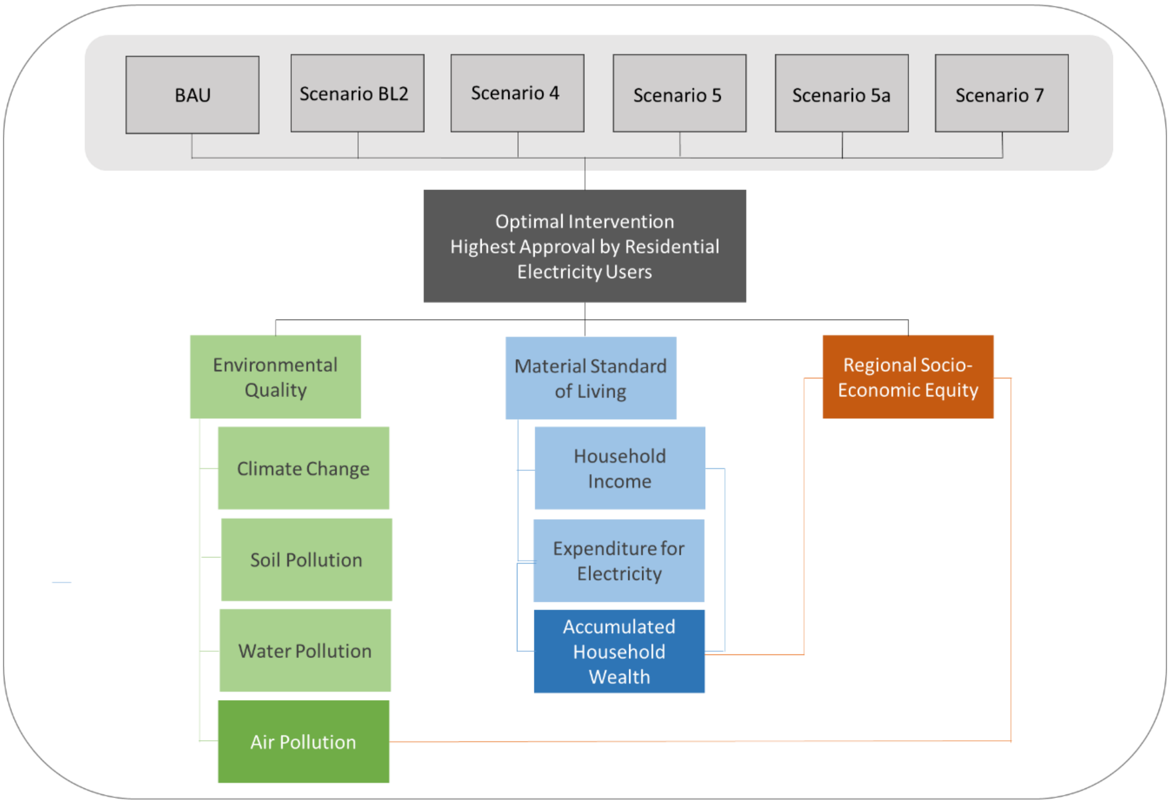
In the fourth step scenario ratings (Step 3) are weighted by the stakeholder preferences (Step 2) to produce an overall score for each intervention scenario. The score indicates the extent to which the criteria have been achieved by a particular intervention. To establish intervention preferences for each region Interventions are then ranked according to this score. Scenario preferences at national level are calculated by applying weighted population proportions by region to the scenario scores.

7.1.1 Structuring the Intervention Decision Problem

The first step of AHP is to decompose the overall objective to be achieved by the market-led reform of the residential electricity sector into hierarchies of sub-criteria. As discussed in Chapter 5, residential electricity users were interviewed during the initial stage of the research. They highlighted environmental quality and material standard of living as key areas of concern. Air pollution was cited as the most pressing environmental issue. Accumulated household wealth over the study period from 2015 to 2035 was adopted as proxy for material well-being. Household wealth is derived from average income levels adjusted by the average expenditure for electricity. The effect of various carbon market scenarios on air pollution levels and household affluence were tested in a system dynamic model (Chapter 6 included an evaluation of the different intervention scenarios).

During stakeholder interviews the widening divide between the provinces located on the East coast and the inner regions of the country was raised as another area of concern. The relevance of this issue in the context of a carbon market was demonstrated by the scenario simulation. Regions were affected differently by the reform. Depending on the intervention design a market based reform could exacerbate or mitigate spatial differences in average household wealth. Regional disparities extend to the environment as a result of existing regional electricity production and consumption patterns. Depending on scenario parameters these patterns could be influenced by a carbon market. The effect on local air pollution varied with the intervention scenario.

Diagram 7.1 Structure of the Decision Problem



The structure of the decision problem is illustrated in Diagram 7.1. The overarching goal is to find the 'optimal' intervention, i.e. the market based intervention scenario that meets the highest approval across all households in China. The objectives of environmental quality, material standard of living and regional equity are broken into lower level criteria, which were derived from the stakeholder areas of concern (Chapter 5).

In order to contain complexity a subset of intervention alternatives was selected from all the scenarios tested in the system dynamic model. The approach applied to intervention scenario selection is critical to the outcome of the process. It is important to choose scenarios that are realistic and not skewed towards the preferences of one particular type of stakeholder (Hiltunen et al., 2009).

Scenario 4 tests the effect of medium carbon price of 150 RMB/tCO_2, which is fully passed on to consumers. Scenario 5 simulates conditions of a high price of 300 RMB/tCO_2, which is entirely borne by coal based generation plants. This scenario is divided into two sub scenarios. SC5a models the effects of extra measures supporting the transition of the electricity exporting province of Shanxi. SC5 tests the same market design without the provision of additional support for Shanxi. The effect of a cost burden (300 RMB/tCO_2). shared equally by generators and consumers is tested by Scenario 7. To serve as benchmark the BAU scenario and Baseline Scenario BL2 (carbon price = 35 RMB; cost-pass-through rate = 0) are included in the analysis. CO_2 permits in China's national emissions trading scheme are expected to trade at 35RMB initially. The other scenarios included in the AHP analysis are more ambitious. Scenario simulation found that a carbon price exceeding 150RMB/tCO_2 is required to incentivise generators to switch from carbon intensive technologies to renewables. This finding is supported by other studies carried out in the context of a Chinese emissions trading scheme (see discussion in Chapter 6).

Intervention scenarios, which are assessed as part of the AHP analysis were selected based on their potential to produce different outcomes for different regions (Table 7.1).

Table 7.1 Overview of Intervention Scenarios with Policy Input Parameters

	BAU	**BL2**	**SC4**	**SC5**	**SC5a**	**SC7**
Carbon Price (RMB/tCO2)	0	35	150	300	300	300
Cost Pass Through Rate (%)	0	0	100	0	0	50
Employment Factor						
Shanghai	1.1	1.1	1.1	1.5	1.5	1.3
Beijing	1.1	1.1	1.1	1.5	1.5	1.3
Shanxi	0.7	0.7	0.7	0.5	0.5-1.5	0.7

One of the key findings of scenario simulation was that the consequences of a carbon market on economic development and environmental conditions are multiple and compete which each other. These trade-offs played out differently in different regions leading, under certain scenario conditions, to the amplification of existing disparities. This situation is often referred to as a 'cloud of consequences' (Bisdorff, 2001) expressing the dilemma of decision making in the face of complex issues and competing stakeholder interests.

The effect of intervention alternatives BL2, SC4, SC5, SC5a and SC7 on air quality and household wealth are listed for each of the study areas in the Appendix (Table 7.B). The performance matrices highlight the trade-off between the stakeholder criteria across the study regions. The matrix records to which extent each of the stakeholder criteria is met by a particular intervention scenario.

Scenario 5 maximises household wealth in the cities of Shanghai and Beijing, but delivers suboptimal outcome for the electricity exporting region of Shanxi. Scenario 5a is an attempt to promote fair burden sharing between regions. This intervention scenario produces the best result for households living in Shanxi due to the positive impact of additional measures on employment opportunities in the province. Households in the East experience a drop in income as they fund these measures. Selecting the optimal solution is further complicated by a second decision criterion, the effect of an intervention on air pollution from the combustion of coal for electricity generation. The intervention tested in scenario 5 achieves the highest reduction of air pollution in Shanxi. As Beijing imports most of its electricity from the region North West of the city, provinces such as Shanxi would benefit most from this intervention. As virtually all coal-fired capacity was moved out of Beijing, the effect of a carbon market on energy related emissions is negligible. The population, however, could benefit from the positive effect of a carbon market on regulating pollution from electricity generation taking place in neighbouring provinces. Scenario 7 spreads the burden of a carbon market between consumers and generators. This intervention scenario results in the increase of the cost burden for electricity users, particularly of the top consumers in the East. Households in Shanxi are 'compensated' by improved economic conditions translating into improved average household incomes as the impact on the coal related industries is mitigated.

The following section describes the second step in the AHP process, which is concerned with gaining an understanding of the relative importance stakeholders attach to the three decision criteria.

7.1.2 Calculating Stakeholder Intervention Preferences

In order to derive the optimal solution in terms of stakeholder preferences, intervention alternatives need to be evaluated against individual preference judgments (Sanders et al., 2008). As basis for the analysis a survey was conducted to understand the importance residential electricity users in the three study locations place on the environment, economic development and an equitable society. Preferences were first weighted for each survey respondent and then aggregated by study area.

7.1.2.1 Eliciting Stakeholder Preferences

Preferences are subjective judgements made by individual stakeholders who place a value on a good for the achievement of a desired outcome.[62] In order to understand the priorities individual electricity users place on environment, economy and equitable burden sharing, a questionnaire was administered in the three study locations. A paper version of the questionnaire was presented to the public in the study locations of Shanghai and Beijing. An online version accessible to respondents across China was created to reach more potential study participants. In order to increase the response rate from Shanxi a national market research company was tasked with inviting internet users living in the province to complete the survey.

The survey was designed to firstly collect information on stakeholder priorities, which would allow the application of MCDA (Multi-Criteria Decision Analysis). The second objective of the questionnaire was to gather comprehensive information on wider issues relating to electricity usage, and pricing. It comprised 22 questions and covered six main parts: the respondent's demographic characteristics; general areas of concern; priorities regarding environmental quality, economic development and perceptions on equity and poverty reduction; views on responsibility for environmental degradation; preferred forms

[62] The subjective theory of value puts forward the idea that the value of a good is neither depended on any inherent property of the good nor by the effort necessary to produce it. Instead, its value is determined by the importance an individual places on the good to achieve his personal objectives. The theory was developed by Jevons, Walras and Menger in the late 19th century (Aziz, 2013).

of energy generation; willingness to pay for clean electricity. The survey forms the basis of the analysis carried out in this section that is concerned with understanding stakeholder priorities. It also provides input for the second part of this chapter that investigates views of households on electricity pricing policies and wider topics related to the reform of the residential electricity sector. Details on the sampling approach, the survey design and survey analysis are provided in Chapter 4, which explains the methodological framework of this study.

Table 7.2 Sample Size by Region

	GROUP1: Shanghai	GROUP2: Beijing	GROUP3: Shanxi	GROUP4: Rest of China	Total	%
Paper Questionnaire	196	54	2	28	280	27.32%
Internet Survey	132	76	478	59	745	72.68%
Total	328	130	480	87	1025	100.00%

Table 7.2 provides an overview of the number of surveys completed by study location. Tables 7.A1 to 7.A5 in the Appendix provide information on the sample's profile in terms of gender, age, educational background and income.

The sample data was compared against the demographic make-up in the study areas. With regards to gender the sample was considered representative of the general population. The web based version of the survey was completed predominately by individuals under the age of 35, who obtained a high level of education. In most regions, apart from Shanghai, the majority of questionnaires were submitted online. The samples in these locations were found to be skewed towards the young and well educated. In Shanxi where almost all surveys were submitted online only 7% of respondents were over the age of 35. According to official data (NSBC, 2016) income distribution was generally representative of the study areas. The high level of education appeared to compensate lower income levels, which are typically associated with a younger workforce. These issues regarding the demographic profile of study participants need to be considered, if sound conclusions are to be drawn from the survey results.

7.1.2.2 Ranking Stakeholder Preferences

Once stakeholder preferences have been established, AHP (Analytical Hierarchy Process) calculates the relative weightings of the importance attached to the decision criteria. Survey responses regarding the relative importance placed by an individual survey respondent on environmental quality, material wealth and equity were used to perform paired comparisons of each criterion with respect to each other. The spreadsheet application Excel was used to execute an algorithm, which generated a comparison matrix with calculated weights and consistency measures.

Survey responses were translated into an AHP preference scale from 1 to 9 to form the basis for an individual's preference matrix. Individual ratings captured in the preference matrix were synthesised at regional level to calculate the weightings of decision criteria for each study area.

Table 7.3 Weighted Stakeholder Preferences by Region

	Shanghai	Beijing	Shanxi	Rest of China[63]
Environment	0.34	0.38	0.26	0.32
Local Air Quality				
Economy	0.35	0.27	0.37	0.35
Household Wealth				
Equity	0.31	0.35	0.37	0.33
Burden Sharing				

Across the regions all three decision criteria were given almost the same weighting (Table 7.3.). A clean environment, material standard of living and equity related issues are seen as nearly equally important. Despite similar values placed on environment, economy and equity, a closer look at the AHP results reveal regional differences do exist regarding the trade-off between environmental quality and material wealth. Survey respondents living in Beijing seem to prioritise environmental quality over an expanding economy and rising incomes. The results of criteria ranking suggest that study participants in less affluent regions appear to value material wealth more than environmentally quality. In Shanxi this effect is more pronounced than in other provinces. Even though Shanxi is located in a region severely affected by air pollution and other forms of ecological problems, the survey data suggests that economic growth and a better standard of living are valued higher than a clean environment. Most survey respondents from the province did not appear to be affected personally by recent increase in redundancies as they were in employment or in higher education. In conversations with individuals from less affluent regions, most showed concern about the situation (Interviews 69, 70, 75, 76, 79). The high importance placed on economic development is in line with conclusions drawn from the review of literature. Citizens of Shanghai, a city with high income levels and (for Chinese standards) moderate pollution levels, place about equal importance on the environment and economic opportunities. Beijing residents appear to be more aware of socio-economic inequality compared to their counter parts in Shanghai. This might be explained by the capital's relative proximity to the less developed and highly polluted provinces of Hebei, Shanxi and Inner Mongolia.

[63] Rest of China subsumes all survey submissions from participants living in provinces other than Shanghai, Beijing and Shanxi.

7.1.3 Ranking Interventions According to Stakeholder Preferences

This stage in the AHP process determines which intervention scenario is most preferred by the population in a particular location. It consists of two steps. Firstly, a rating indicating the extent to which an intervention meets a particular decision criterion is assigned to each scenario. Secondly, the scenario score is calculated based on stakeholder criteria preferences and the scenario rating.

7.1.3.1 Intervention Scenario Rating

A rating is assigned to each of the intervention scenarios. The rating quantifies the effect of a particular intervention on each decision criterion at regional level. Scenario ratings are based on the performance of scenarios regarding the three decision criteria: Environment (accumulated air pollution in terms of NO_x) economy (accumulated household income) and equity overall burden sharing (in form of transfer payments (Scenario 5a), pass through rate and carbon price (all scenarios). This data was generated through the simulation of intervention scenarios in a systems dynamic model (Chapter 6). Each of the criteria is assigned a ranking between 1 and 5, dependent on the degree an intervention changed the parameter compared to Business-as-Usual (BAU), i.e. in the presence of no carbon market.

For example, Scenario SC5 (CP = 300 RMB/tCO_2, CPR = 0, Shanxi Employment Factor = 0.7) achieves the best improvement of air quality in Shanxi. The decision criterion Environment is therefore rated 5 under the conditions of interventions taking place in SC5. The criterion Economy is rated 4 as household incomes are lower than in Scenario 5a. Scenario 5a achieves the best rating in terms of Equity as Shanxi's low carbon transition is supported by supplementary interventions to mitigate the impact of a cost of carbon on the province's economy.

As almost all electricity consumed in Beijing is imported, the ability of any intervention to lower generation related pollution locally is limited in the city. The decision criterion Environment is 3 across all scenarios. As a significant amount of the electricity used in Shanghai is generated within the city, the effect of interventions on the environment varies greatly with carbon price and cost-pass-through rate. Scenario 5, the most ambitious intervention scenario in terms of carbon price level (300 RMB/tCO_2) delivers the highest reductions in local air pollution related to the generation of electricity. 'Environment' is rated 5. Equity is considered low in Scenario 4 (CP = 150 RMB/tCO_2, CPR =100%) as the entire cost burden is shouldered by consumers. This decision criterion is rated 2 for Shanghai and Beijing. Top users, mostly affluent households in the Eastern part of the country, are affected by a significant rise in expenditure for electricity. As a result of a slower growing innovative industry household income of Shanghai and Beijing residents increases at a slower rate than in all other scenarios which target the decarbonisation of the supply side (i.e. CPR <100%). Scenario ratings are shown in Appendix Table 7.C.

7.1.3.2 Intervention Scenario Scoring

Now that scenario ratings have been established, scenario scores are calculated for each of the criteria. The total score of a scenario indicates its relative preference by the study participant (over the other scenarios). To calculate the score two inputs are required, the weighted stakeholder preferences for each criterion and the scenario ratings for each criterion. Table 7.4 provides an overview of the scenario scores for Shanxi, Shanghai, Beijing and the rest of China.

Scenario scores are calculated by multiplying the aggregated stakeholder preference weights by the corresponding rating assigned to a decision criterion. Despite similar preferences for the three decision criteria, intervention scenarios are rated differently across the regions. This can be explained by the significant regional variations regarding the effect of the interventions on air quality, household wealth and equitable burden sharing. Diagram 7.2 visualises the information captured in Table 7.4 in the form of a bar chart.

The following section interprets the results of the AHP and explains their implication for a market based reform of the residential electricity sector in China.

Table 7.4 Scenario scores for Shanxi, Shanghai, Beijing and the Rest of China

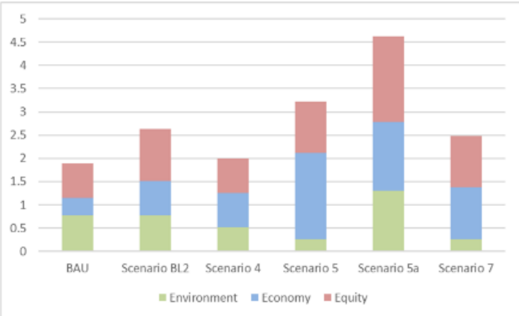
SHANGHAI	Scenario Score					
Decision Criterion	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7
Environmental Quality	0.68	1.02	0.68	1.7	1.7	1.02
Household Wealth	1.05	1.05	1.05	1.75	0.7	1.4
Equity	0.93	0.93	0.62	0.93	0.62	1.24
TOTAL SCORE	2.66	3	2.35	4.38	3.02	3.66

BEIJING	Scenario Score					
Decision Criterion	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7
Environmental Quality	1.14	1.14	1.14	1.14	1.14	1.14
Household Wealth	0.81	0.81	0.81	1.35	0.54	1.08
Equity	1.05	1.05	0.7	1.05	0.7	1.4
TOTAL SCORE	3	3	2.65	3.54	2.38	3.62

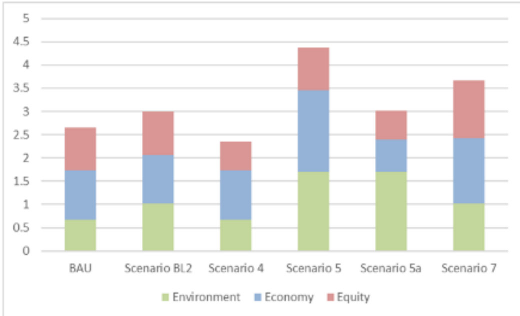
SHANXI	Scenario Score					
Decision Criterion	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7
Environmental Quality	0.78	0.78	0.52	0.26	1.3	0.26
Household Wealth	1.11	0.74	0.74	1.85	1.48	1.11
Equity	0.74	1.11	0.74	0.74	1.85	1.48
TOTAL SCORE	2.63	2.63	2	2.85	4.63	2.85

REST OF CHINA	Scenario Score					
Decision Criterion	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7
Environmental Quality	0.64	0.96	0.96	1.6	1.6	0.96
Household Wealth	1.05	1.05	1.05	1.4	1.05	1.4
Equity	0.99	0.99	0.66	0.99	0.99	0.99
TOTAL SCORE	2.68	3	2.67	3.99	3.64	3.35

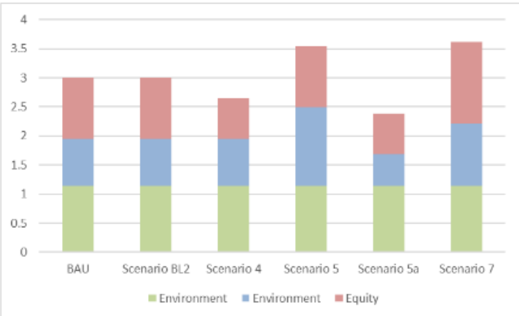
Diagram 7.2 Scenario Scores by Region



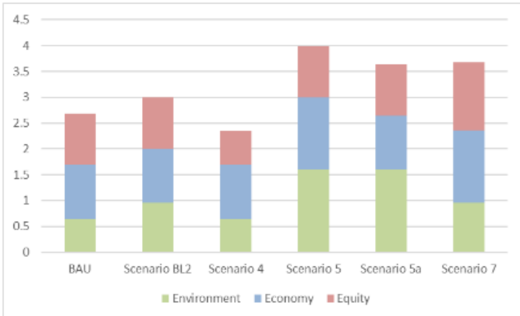
Shanxi Intervention Scenario Scores



Shanghai Intervention Scenario Scores



Beijing Intervention Scenario Scores



Rest of China Intervention Scenario Scores

7.1.4 Interpreting of Regional Preferences for a Market Based Reform

Irrespective of the study location survey respondents favour all scenarios with a market based reform and an element of burden sharing between consumers and generators over a business- as-usual situation. The least preferred carbon market scenario is SC4. Of all the market based intervention scenarios SC4 is the scenario with the lowest score. The low approval of SC4 (Carbon Price = 150 RMB/tCO_2, Cost-Pass-Through-Rate =100%) is not surprising as electricity consumers bear the entire cost burden. The cost burden is not high enough to trigger significantly lower consumption levels, which translate into significantly better environmental conditions compared to the BAU scenario. As generally people do not value a clean environment more than material wealth, the improvement in air quality is not sufficient to compensate households for the increased expenditure.

The discovery that the introduction of a carbon market is generally preferred to the BAU scenario appears counter-intuitive. A price on carbon, either in the form of a tax or as the result of an emissions trading scheme, is commonly considered undesirable from a consumer's point of view. Despite the additional cost burden society benefits overall from the introduction of a carbon market. The gradual transition away from traditional industries to an open economy offers highly paid job opportunities in the innovative sector. New employment opportunities mean higher incomes and thus a better material standard of living for most.

As demonstrated in Chapter 6, increasing household affluence has the downside of higher electricity consumption. Higher electricity usage in turn leads to more pollution from an expanding coal generation base as additional renewable capacity alone is not expected to cover additional demand. Overall, the majority of study participants appear to place greater importance on their material standard of living than on improved environmental conditions. Consequently, interventions which stimulate the economy and boost household wealth are favoured over situations in which environmental action inhibits economic expansion. Responses received from study participants in Beijing, however, cast doubts on this conclusion. Citizens in the capital seem to be willing to trade additional income for improved air quality.

In light of the preferences for environmental quality, economic development and equitable burden sharing, all regions apart from Shanxi favour intervention scenario 5. Scenario 5 tested an intervention where the significant cost burden of 300RMB/tCO_2 is borne entirely by coal based power generators (Cost-Pass-Through Rate = 0). The advanced regions of Shanghai and Beijing can expect to benefit from the drive for green innovations through new employment opportunities for a highly skilled work force. Shanxi, whose economy relies on the export of coal generated electricity, is set to lose under a scenario where most of the cost burden is shifted from the affluent electricity users on the East coast to power providers in the inner regions. Scenario 5a, in which Shanxi receives financial support from affluent parts of the country to support the market-led transition to a low carbon economy, is the most preferred amongst the province's population. In light of the additional cost burden for households in the affluent provinces Scenario 5a is less favoured in the wealthy cities of Shanghai and Beijing.

7.1.5 Interpreting National Preferences for a Market Based Reform

The regional priorities for each decision criterion now need to be synthesised into national preferences. The carbon market is anticipated to cover emissions from all regions with impacts on residential electricity users across the country.

In order to make study results transferable to the country as a whole, preference weights for the decision criteria calculated for each of the four regions are weighted according to regional population size. Stakeholders living in the provinces of Group 1 represent 35% of China's overall population. Their preferences for a particular intervention should therefore 'carry more weight' than the preferences of people living in regions belonging to Groups 2, 3 and 4 which each represent less than a fourth of the country's population.

Table 7.5 Stakeholder Preference Weighted by Population Proportions

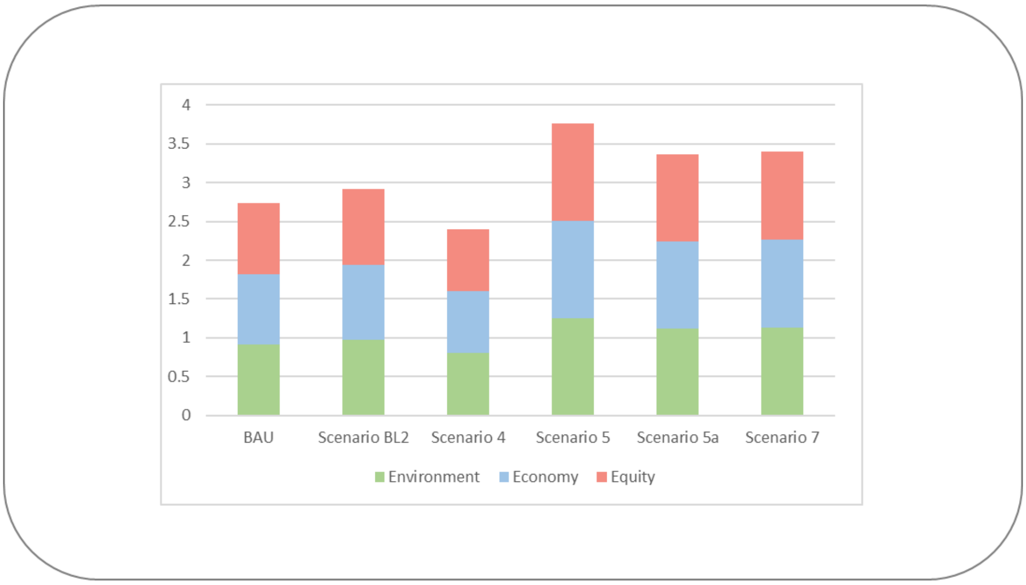
	Group 1	Group 2	Group 3	Group 4	Weighted Average
Study Site	Shanghai	Beijing	Shanxi	Rest of China	
Population (%)	0.35	0.23	0.23	0.18	
Environment	0.34	0.38	0.26	0.32	0.33
Economic Development	0.35	0.27	0.37	0.35	0.34
Equity	0.31	0.35	0.37	0.33	0.34

Stakeholder preferences by regional group and the population proportion of each group (Table 7.5) determine the weighted average of stakeholder preferences at national level. Across China people appear to equally value a clean environment, material wealth and equitable burden sharing. The weighted average of the regional intervention scores from the basis of the calculation to establish national preferences for interventions.

Table 7.6 Nationwide Scenario Scores

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Weighted Average**
Study Site	Shanghai	Beijing	Shanxi	Rest of China	
BAU	2.66	3	2.63	2.68	2.74
Scenario BL2	3	3	2.63	3	2.91
Scenario 4	2.35	2.65	2	2.67	2.40
Scenario 5	4.38	3.54	2.85	3.99	3.76
Scenario 5a	3.02	2.38	4.63	3.64	3.36
Scenario 7	3.66	3.62	2.85	3.35	3.41

Diagram 7.3 Nationwide Scenario Scores



Scenario scores calculated for the country as a whole are presented in Table 7.6 and Diagram 7.3. Scenario 5 is the intervention scenario preferred at national level followed by Scenario 7. One explanation for this choice might be that the majority of China's population (60%) live in electricity importing provinces belonging to Group 1 and Group 2. The interests of less developed regions such as Shanxi, which rely on coal fired electricity generation and other coal related industry for growth, are underrepresented. Only 23% of China's population live in Group 4 provinces. Scenario 5a requires affluent and mostly electricity importing regions to support Group 4 provinces. This could explain the scenario's lower popularity. Nationwide households prefer a carbon market compared to the BAU situation, but only if they are not expected to shoulder a significant part of the burden.

7.1.6 Implications of Stakeholder Preferences for a Market Based Reform

This section concludes with an analysis of the implications of stakeholder priorities for clean air, people's material standard of living and a fair burden sharing on the market based reform of the residential electricity sector.

The importance attached to environmental quality, economic development and an equitable society did not vary greatly across regions. However, slight variations in the importance attached to the three decision criteria could be observed. People in Beijing valued a clean environment most. Households in Shanxi appeared to prioritise economic growth and rising incomes over environmental quality. Residents of Shanghai placed about equal importance on economic development and environmental conditions. Ideally the survey sample should have been a miniature of the population. As noted before, the young and the well-educated were overrepresented. In particular, the online version of the questionnaire was answered mostly by under 35s with a university degree. Despite the underrepresentation of the older population, AHP analysis based on the survey responses from a predominantly young demographic provides valid insights for the future development of electricity consumption. Despite the younger generation becoming increasingly responsible for a significant proportion of electricity usage, there is scope for future study to encompass a wider demographic.

One important insight of stakeholder priorities for an electricity reform is the high acceptance of a carbon market as a tool to transition the energy sector to a less carbon intensive model. Irrespective of location, households appear hesitant to shoulder the majority of the cost burden of a carbon market. People's reluctance to support a reform by trading off material wealth with a cleaner environment appears counter-intuitive. The equal distribution of preferences for environment, economic and society suggests that energy sector related pollution is a concern amongst people. Concern for the environment should therefore translate into the willingness to contribute to the transition of the energy sector.

The preference of scenarios with zero-cost-pass-through highlights households' resistance to a cost-reflective tariff. The same observation was made following the introduction of increasing block tariffs in 2012. Opposition to tariff adjustments led to the wide spread disapproval of the reform, which failed to slow down household consumption. The relatively high score of Scenario 7, however, sheds new light on people's attitude towards the introduction of cost-reflective tariffs. Scenario 7 divides the burden equally between generators and consumers. The relatively high approval of this intervention alternative, in particular by the population in top consuming regions such as Beijing and Shanghai, could signal that households accept their responsibility to contribute to the transition of the electricity system. To explain the apparent gap between people's positive attitude towards the environment and their motivation to actively support the reform is explored in the next section (7.2).

Nationwide, Scenario 5 is the most preferred intervention alternative. To illustrate the implications of this scenario on regional disparities, the insights gained in Chapter 6 are re-iterated. Scenario 5 shifts the responsibility for decarbonising the residential electricity sector entirely to power generators. This scenario delivers the accelerated transition of the electricity supply side towards less pollution intensive forms of electricity generation. The implications of this intervention are twofold. Firstly, the accelerated decarbonisation of the supply side results in the quickest improvement of local environmental quality, relative to the other scenarios tested. Secondly, the economic gap between provinces is set to widen under interventions with zero-cost-pass-through. Affluent regions benefit from the economic boost associated with the accelerated adoption of innovative and renewable forms of energy generation. Shifting most of the cost burden to carbon intensive coal plants puts the central electricity exporting regions at a disadvantage. Slowing economic growth, diminished employment opportunities and stagnant household incomes further aggravate the economic situation of many households in the region, who have already been negatively affected by the transition of China's economy.

The democratic principle of every person having one 'vote' and every vote having equal weight was adopted to calculate nationwide and regional intervention preferences. Scenario

5 emerged as the most preferred intervention alternative as this intervention delivers the best result for more than three quarters of China's population who live outside the highly polluted electricity exporting provinces. The finding that Scenario 5 is ranked the highest in terms of the relative importance China's population attaches to the environment, economy and equity, opens the ethical question of whether a fair solution is a solution that delivers the results preferred by a majority whilst making an already disadvantaged part of society worse off. How the Chinese leadership addresses this dilemma will be reflected in the design of a market-led reform of the residential electricity sector.

The wide acceptance of a carbon market is certainly reassuring for environmental policymaking in China. In particular encouraging is that ambitious scenarios are favoured over business-as usual or scenarios with rather modest goals. However, as demonstrated by intervention simulation, no scenario was able to contain the growth of electricity usage by households to an extent that realistically could stop the construction of additional coal capacity. The limited ability of a price-based approach to control residential electricity demand could jeopardise the reform of the sector. The divide between people's high concern for the environment and their relatively low level of willingness to contribute to the reform could be one factor explaining the limitations of a carbon market to change people's consumption habits.

This finding highlights the need for further investigation into which factors influence people's behaviour towards electricity usage and the environment. The following section explores determinants of environmental behaviour. Particular attention is paid to the influence of cultural and political factors unique to China. The basis of the analysis is the questionnaire, which, in addition to gathering information of intervention preferences, captured wider views on the reform of the residential electricity sector.

7.2 Exploring Determinants of Environmental Behaviour

With the emergence of a consumer society in China behaviour of individuals is increasingly becoming a source of environmental problems and a key component of efficient and long-lasting solutions. Price policy has a particular role to play in energy conservation. Policy testing in a systems dynamic model illustrated that a carbon market is an effective tool to reform the supply side of the electricity sector. By adding to the cost of carbon intensive forms of generation, electricity providers are incentivised to replace coal based plants with renewables. The effect of a carbon price on inducing electricity saving behaviour amongst households, however, was found to be limited in all the scenarios simulated.[64]

[64] The effect of a tariff increase on consumption was off-set by growing demand from higher incomes. Most households do not appear to reduce electricity consumption in line with an increase in price. Reasons for the low price elasticity of demand for electricity observed in China are explained in detail in Chapter 6. Implications of people's low responsiveness to tariff changes are demonstrated through simulation in a system dynamic model in the same chapter.

As price based interventions are at the centre of a market-led reform of the demand side, the next section sets out to determine the magnitude of the tariff increase required to limit electricity demand growth to not exceed current Western European levels. The result is compared to people's willingness to pay extra for clean electricity. The objective is to gauge whether the increase in expenditure would be acceptable to residential consumers in return for clean electricity.

The system dynamic simulation of intervention scenarios is based on the concept of traditional economic theory, which assumes that a consumer would reduce energy consumption in response to a higher price. The model calculated the magnitude of the demand adjustment based on the carbon price and demand elasticities. Traditional economic theory assumes that individuals rationally evaluate the costs and benefits of their decisions (Kishtainy, 2017). Various empirical studies illustrate that the assumption of rational choice might be a poor guide for economics in general, and for environmental economics in particular. Practical experience with environmental policy making has demonstrated that human behaviour is often irrational und uncontrolled (Frederiks et al., 2015; Urban and Ščasny, 2012; Newton and Meyer, 2012; Kranz and Picot, 2011; Engel and Pötschke, 1995).

The understanding of behavioural aspects of electricity consumption could offer important lessons in designing new strategies complementary to a carbon market. The same survey, which was used to elicit preferences of residential electricity users (Section 7.1), gathered public views on wider issues related to the reform of the residential electricity sector including views on electricity pricing. The survey provides clues towards factors explaining the attitudes towards green energy and views on the pricing of green energy. A number of interviews were conducted during the fieldwork stage to provide context for the responses to the questionnaire. The insights gained from the review of relevant literature on the cultural and political situation in China provide the foundation for the discussion on the external context within which behaviours occur.

The remainder of this section is organised as follows. Survey data provides information on people's willingness to pay extra in return for clean electricity. Stakeholder views on a tariff reform are described and then compared to the results of price based intervention simulations in a system dynamic model. The aim is to establish the magnitude of a tariff increase required to contain residential consumption. This is followed by an analysis of non-price factors which influence energy conserving behaviour. Survey data and interviews are reviewed to understand which internal factors shape people's decisions to act in a pro-environmental way. The section concludes with a discussion on the external factors unique to the cultural and political setting of China which give meaning to the empirical study.

7.2.1 Internal Determinants of Electricity Saving Behaviour

Electricity pricing in China is a highly political topic. Following years of high subsidies cheap electricity is considered a prerogative by most. Given the relevance of the topic in light of the national carbon market and the lack of studies investigating opinions of residential users on electricity pricing, a survey was conducted. The survey elicits views on a market-led reform of the residential power sector. More detail regarding survey design and the sampling approach can be found in the methodological chapter and in Section 7.1.2 above.

7.2.1.1 Stakeholder Attitudes towards Green Energy

Many of the survey results reflect a positive outlook on the prospects for public support of an electricity sector reform in China. The majority of respondents regard the power sector along with heavy industry as the main source of pollution. The generation technology favoured by most was renewables (55%), followed by nuclear power and gas (about 20%). Less than 4 % of all respondents favoured the combustion of coal despite the perceived low generation cost (Q14). In Shanghai and Beijing over 50% (Shanghai: 51.2%; Beijing: 53.5%) of study participants thought clean power was more important than affordable electricity and a secure supply (Q10). In Shanxi the preference for clean electricity was strong (46%), albeit slightly lower than in Shanghai and Beijing Across all study areas the security of supply ranked second above affordability.

The general approval of a departure from a coal based energy system warrants further investigation into the willingness of China's electricity users to contribute to the transition. The survey found that the majority of respondents were willing to pay in return for green electricity (Q15). Across all study areas only very few respondents (10%) indicated that they would not be prepared to accept higher electricity bills in exchange for energy generated from non-fossil fuels. The great majority of study participants (59%) signalled that they would accept a rise of electricity tariffs between 10% and 50% of their current rate.

Overall, the survey response to Q15 seems to be supported by the AHP analysis in the preceding section. People favoured intervention alternatives with low to medium cost-pass-through. Scenarios with a moderate carbon price (Scenario 7) and 50% cost-pass-through appeared to be accepted by the majority albeit ranking behind interventions that place the entire cost burden on electricity providers.

7.2.1.2 Stakeholder Perspectives on Price-Based Incentives

At first glance most of the respondents to the survey appear to be willing to shoulder a substantial burden of the reform. However, as discussed at great length in the previous chapter, none of the market based intervention scenarios was able to stabilise consumption levels. The following analysis tests the effect of various electricity pricing scenarios on consumption behaviour to gauge the magnitude of the tariff change required to control electricity usage levels. The calculated tariff adjustment is then compared to the tariff increase people are willing to accept in return for clean energy.

Out of the three study regions Shanghai was selected to investigate the effect of residential electricity pricing on usage levels. Per capita electricity consumption is currently amongst the highest in the country. The affluent metropolis on the East coast embodies the leadership's visions for a future China with an innovative and affluent economic base. In Shanghai the most ambitious scenario with a carbon price of 300 RMB/tCO_2 and a cost pass-through rate (CPR) of 100% resulted in an average annual household consumption of 5606.16 kWh, which is 273 kWh less than in the BAU Scenario without a carbon market. As noted in analysis of the simulation output, a much higher carbon price, which is absorbed fully into higher residential electricity rates, would be required to bring about reductions in consumption sufficiently high to offset rising demand as a result of increasing household incomes.

In order to estimate the magnitude of a tariff adjustment required to limit the growth of residential electricity usage to not exceed Western European levels, the effect of three alternative block tariff structures on consumption levels were simulated in Vensim. The same systems dynamic model used to test the carbon market intervention alternatives in Chapter 6 was employed. Average household electricity consumption in the UK and Germany are 4,600 kWh p.a. and 3,514 kWh p.a. respectively (Eurostat, 2017a).

The effect of two Increasing Block Tariff (IBT) scenarios on electricity consumption levels, expenditure for electricity, accumulated household wealth and local air pollution are compared with conditions under the current IBT tariff structure. An overview of the three different price scenarios is provided in Table 7.7. IBT1 tests the effect of a medium price spectrum ranging from 1 RMB/kWh to 2RMB/kWh depending on consumption levels. IBT2 simulates a more ambitious pricing policy. Block tariffs range from 1.25 RMB/kWh to 3 RMB/kWh. In order to put the pricing scenarios in an international context, average residential electricity prices were obtained for the European Union. In the European Union the average residential electricity price per kWh was 0.21 Euros (1.5 RMB/kWh). In 2016 Danish and German households faced the highest tariffs at 0.31 Euros/kWh (2.28 RMB/kWh) (Eurostat, 2017c). Residential users in the United States pay on average considerably less than their European counterparts. In 2016 the average kWh cost 0.12 US $ (0.83 RMB/kWh; 0.11 Euro/kWh), which is lower than the top tariff currently charged in Shanghai.

Table 7.7 IBT Scenarios for Shanghai

	Block 1 Tariff RMB/kWh	Block 2 Tariff RMB/kWh	Block 3 Tariff RMB/kWh
Consumption			
Scenario			
Current IBT	0.617	0.667	0.917
IBT 1 Medium	1	1.5	2
IBT 2 High	1.25	2	3

Table 7.8 Effect of Different IBT Levels on Electricity Consumption, Expenditure, Accumulated Household Wealth and Air Pollution Levels in Shanghai

	2015	2020	2025	2030	2035
Electricity Consumption (kWh)					
Current IBT	1935.55	2857.731	3885.386	4684.345	5878.832
IBT 1 Medium	1935.55	2255.829	3138.632	2492.971	3037.267
IBT 2 High	1935.55	1862.943	2591.992	2117.579	3212.088
Expenditure for Electricity (RMB)					
Current IBT	1194.234	1763.22	2591.552	4295.544	5390.889
IBT 1 Medium	1194.234	2255.829	3138.632	4985.942	3037.267
IBT 2 High	1194.234	2328.678	3239.99	6352.736	4015.11
Accumulated Household Wealth (RMB)					
Current IBT	0	367,697.80	856,150.6	1,479,592	2,252,360
IBT 1 Medium	0	366,056.8	851,931.5	1,472,845	2,249,215
IBT 2 High	0	365,814.1	851,270.3	1,471,035	2,245,775
Annual Local Nox from Electricity Generation					
Current IBT	55644.75	84356.7	117763.5	145782	187855.7
IBT 1 Medium	55644.75	66589.29	95129.89	77584.02	97054.66
IBT 2 High	55644.75	54991.76	78561.58	65901.39	102641

Simulations were run with a carbon price of zero in order to be able to isolate the effect of different block tariffs. The initial tariff was 0.617 RMB/kWh in 2015 as average household consumption fell into the first usage block. Under conditions of IBT2 and IBT3 the tariff was increased to 1 RMB/kWh and to 1.25 RMB/kWh respectively in the following year. The tariff change led to a drop in consumption by 10% (273.21 kWh) under IBT1 conditions. A 100% price increase induced savings of just over 25% (562.731 Kwh) in scenario IBT2 in the same year as the price increased. Table 7.8 lists the output of the price scenario simulations which span the period from 2015 to 2035.

At the end of the simulation period Scenario IBT1 testing a medium price increase delivers better results in terms of consumption reduction than the more ambitious pricing scenario IBT2. This is counter-intuitive as higher prices are typically associated with lower demand. A look at the year-on-year- output data reveals that the price increase is so substantial that average consumption drops back as soon as electricity falls into the top price block of IBT1. This drop in demand translates into lower expenditure for electricity and ultimately higher wealth levels amongst households when faced with the tariff structure of IBT1 compared to IBT2. Average electricity usage in Scenario IBT2 never reaches block 3 levels. Therefore, no sharp decline in consumption was triggered in this pricing scenario. The results of the simulation illustrate that under the current IBT structure consumption increases to 5,878.83 kWh, which is almost 50% higher than in scenario IBT1. Under current IBT conditions average consumption levels reach the threshold of Block 2 in 2023 and Block 3 in 2030. Average household usage continues to rise almost unchecked thereafter despite being charged at the top tariff.

A higher tariff leading to the reduction in residential electricity demand had positive benefits on the environment. In the medium price scenario IBT1 NO_x from electricity generated for residential usage in Shanghai was calculated as almost half of the quantity released compared to conditions of the current tariff structure.

The simulation of different tariff scenarios demonstrates that an electricity rate increase would need to be substantial to induce savings to effectively offset demand growth from increasing household affluence in the city of Shanghai. In the most ambitious carbon market scenario which tested a carbon price of 300 RMB/tCO2 borne entirely by households (CPR = 100%), the tariff (including the carbon cost) at the end of the simulation period was 1.145 RMB/kWh. The average annual consumption per household reached 5606.16 kWh in 2035, which is substantially higher compared to IBT1, where the tariff reached 2 RMB/kWh. IBT1 contained household consumption to a level comparable to the current German average of 3,514 kWh/p.a. (Eurostat, 2017a).

In light of the simulation results, the public's willingness to generally accept a tariff increase of up to 50% appears insufficient to induce the significant levels of demand reduction which are required to prevent the expansion of coal based generation capacity. A tariff increase to 2 RMB/kWh is unlikely to be accepted by electricity users. In the city of Shanghai, where the average household currently pays 0.617 RMB/kWh, a 50% increase would take the rate to 1 RMB/kWh, which is considerably lower than 2 RMB/kWh, the rate required to effectively limit average consumption in the affluent Eastern region to European levels. Only a minority of mainly high income households in Shanghai and Beijing (around 25%) were prepared to accept an increase of their expenditure for electricity between 50% and 100%. Residents of Shanxi were less willing to pay more for electricity. Nevertheless, responses received from the central province indicated that a third of the population would be prepared to accept a tariff increase of up to 50%. Only a negligible number of study participants across all regions were willing to accept a rate rise of over 100%.

7.2.1.3 Implications of Stakeholders' Willingness to Pay for Green Electricity

Awareness of environmental pollution and concern for environmental issues was found to be high across all socio-demographic groups and all study locations. However, survey responses highlighted that awareness does not automatically translate into the willingness to conserve electricity or to adopt other forms of environmentally friendly behaviour. Even high income households sampled were typically not prepared to pay substantially more for clean energy even though a low to moderate increase would not noticeably impact the household's life style.

Literature refers to the divide between personal values and attitudes of an individual and his actions as the 'Awareness-Action-Gap' (Tiller and Schott, 2013; Garrard, 2007) or the 'Value-Action Gap' (Hori etal. 2013; Barr, 2006; Kollmuss and Agyeman, 2002). The disparity between what people say and do is often observed as a reluctance to adopt pro-environmental behaviour despite people's high regard for environmental issues (Frederiks et al., 2015). As all models, the stock-and-flow model used to gauge the magnitude of a tariff increase required to create a financial incentive to conserve a certain amount of energy is a simplification of the real world. The assumptions made regarding human behaviour require scrutiny. The model is built around the view of traditional economics, which sees humans as rational actors (Sterman, 2000).

Environmental and social psychology as well as behavioural economics question the picture of the human decision maker as a rational agent (Pollitt and Shaorshadze, 2013; Pesendorfer, 2006; Camerer et al., 2004; Kahneman, 2003). The idea that people maximise utility by weighing the price for a good against affordability is far removed from everyday life. Pro-environmental behaviour in particular appears to be shaped by factors other than cost. Knowledge about individual, social and situational factors that influence human motivations to engage in certain behaviours can explain far better the attitude-behaviour gap than a model quantifying consumption decisions through mathematical equations, which do not take into account human habits and emotions.

The overall objective of the next section is to identify the reasons for the observed action-value gap. More specifically, the following is concerned with developing an understanding as to how knowledgeable and aware the Chinese people are of environmental degradation caused by the electricity sector, the factors that influence their awareness (i.e., who thinks what and where), their views on who is responsible for the situation and, very importantly, their willingness to adjust electricity consumption in ways that are ultimately less harmful to the environment.

7.2.1.4 Stakeholder Perspectives on Non-Price Based Incentives

Many factors influence energy saving behaviour. Response to a price signal is just one. Awareness of pollution related to the electricity sector and the understanding of its effect on human wellbeing and socio-economic development are prerequisites for the adoption of pro-environmental action. The analysis also explores the role of personal exposure to pollution and the importance of an individual's sense of responsibility for a clean environment. Issues around people's empowerment to take action are explored in the context of the Chinese environmental governance system.

Responses to the questionnaire suggest that awareness of poor environmental conditions is high (Q1 and Q3). As most of survey respondents were highly educated this finding was expected. Other research conducted to understand the public's awareness of pollution related issues also found that the majority of China's population is well informed. Most studies observed socio-economic differences, in particular with regards to knowledge on the detrimental effect of pollution on health and human wellbeing (Gu et al., 2015). Across all studies, age and occupation were the main factors associated with the level of knowledge about pollution. City dwellers under 40 years old with higher education levels appear to have the highest level of awareness of environmental degradation and its consequences for human wellbeing (Wang et al., 2016; Liao et al., 2015). Other studies (Liu, 2014; Qian et al., 2016; Liu et al., 2016) found that less educated individuals, the elderly and people in rural locations typically have less knowledge on poor environmental conditions and their effects on human health and wellbeing than their university educated counterparts living in urban areas.

The analysis of responses to Q5 in the survey suggests that concern for a particular environmental problem varies across regions. Poor air quality tops the list of public concern across all three study sites. In Shanghai just over 50% of respondents were most worried about local air pollution. 68% of people questioned in Beijing thought toxic air was the most pressing environmental issue. In Shanxi about 62% ranked poor air quality above water pollution (30%) as the most severe pollution related problem. Soil contamination was thought to be the second most important environmental issue to be solved in Shanghai and Beijing. Climate change impacts were generally of lesser concern. Climate change topped the list of concerns of only one in ten respondents from Shanghai and Beijing. In Shanxi, worry over rising global temperatures was particularly low (2%).

Research suggests that personal experience of environmental degradation is often seen as a factor shaping people's attitude towards the adoption of pro-environmental behaviour. People, irrespectively of their income, are more inclined to make financial and other sacrifices when they have personal experience of high levels of pollution and poor environmental quality (Chen et al., 2015). Interviews with members of the public were carried out in the highly industrialised Beijing-Tianjin-Hebei region, one of most polluted areas in the world. Interview partners highlighted that experience of poor air quality alone is not necessarily a determinant of pro-environmental behaviour. Low income households indicated that they prioritise activities improving their standard of living over pro-environmental action. This observation is in line with responses to the questionnaire completed in Shanxi. Despite being exposed to toxic levels of air pollution, low income households are generally more concerned about the economy than the environment (Q4). Of the households earning less than the provincial average of about 25,000 RMB/p.a., only 18% thought environmental problems should be prioritised over economic development. As the region has recently witnessed rising unemployment due to overcapacities in coal related industries, the high concern placed on economic growth even at the expense of the environment is not surprising.

A positive relationship between personal experience of pollution and the awareness of its detrimental effects on society appears to emerge once a household has reached a certain standard of living supported by an annual household income above the national average which is around 45,000 RMB (NSBC, 2016). In Beijing people place a higher value on the environment than any other part of the country. This could be explained by the combination of the country's highest average household income and people's exposure to severe air pollution levels. This observed relationship between people's income and pro-environmental behaviour is often explained by treating environmental quality as a luxury good. A number of studies suggest that people have more freedom to devote time and resources to improving environmental quality once their basic material needs are satisfied (Van Liere and Dunlap, 1980; Scott and Willits, 1994).

A number of studies in the area of environmental psychology (Cornelissen et al. 2008; Feinberg and Willer, 2013; Klöckner, 2013) found that the moral obligation felt by an individual to protect the environment is one of the main motivators for pro-environmental behaviour change. In light of this suggestion the survey included a question to gauge people's sense of responsibility to behave in an environmentally friendly way and to conserve electricity. Responses to Q6 suggest that overall people's sense of environmental responsibility appears to be low. Survey respondents indicated that they do not feel personally accountable for harming the environment through their actions. The great majority of study participants (86%) thought that heavy industry and the energy sector were responsible for pollution. One in ten people believed that traffic and transport were the reason for poor environmental conditions. Less than three percent of respondents thought that personal consumption contributed most to environmental problems. Responses did not vary significantly across locations. Therefore, no inference regarding the influence of demographic factors or of a region's economic development status on people's perception of responsibility could be made.

The survey did not indicate a correlation between educational level, income or any other socio-demographic characteristics and people's sense of responsibility. Other research was reviewed to understand the influence of demographic factors on the extent to which people feel personal accountability for poor environmental conditions. These studies suggest that individuals with higher education levels and higher household incomes appear to be more likely to agree that personal consumption habits are responsible for environmental harm (Harris, 2012; Hori et al., 2013).

In addition to abdicating responsibility for environmental degradation to heavy industrial polluters, the majority of people questioned expected others, particularly the government, to take care of environmental protection (Q16). People generally perceived that their actions would only have low or no impact. A recurring theme in discussions with members of the Chinese public was the tendency to place responsibility for environmental protection and social issues on the government. It appeared that people who achieved a higher socio-economic status in terms of education level and income were more likely to use their own initiative to engage in energy conserving behaviour than those who received less schooling. This may reflect the fact that Chinese people in less influential positions tend to place responsibility for environmental action on 'powerful' people who they believe can make a difference (Harris, 2006). The relationship between an individual's tendency to adopt proactive behaviour and the distribution of power within the Chinese society will be explored in more detail in the context of external factors influencing pro-environmental action.

To fully understand which determinants shape behaviour, the next section sets out to integrate both internally and externally driven factors (Menguc et al., 2009), in parallel to exploring ways to close the value-action-gap.

7.2.2 External Barriers to Electricity Saving Behaviour

The previous section was concerned with the analysis of internal factors shaping people's attitude towards the environment and their motivations to act in an environmentally friendly way. Considerable research aimed at understanding the internally driven perspective of pro-environmental behaviour has been conducted. However, most studies on the subject appear to have been carried out within a Western context. Not much research has been conducted on linking internal determinants to external factors that are unique to the cultural, social and political setting of China. Externally driven factors influence internally driven perspectives. They are the result of cultural and social norms as well as political and institutional pressures such as government regulation (Hart, 1995; Suchman, 1995). Gaining an understanding of the interplay between both internal and external behavioural determinants is crucial for intervention design. The following discussion highlights that internal or external barriers to pro-environmental action in China are the result of deeply engrained social and political structures and processes. These processes need to undergo transformational system change in order to instil people with responsibility for proactive action and encourage energy conservation to effectively support a market-based reform of the electricity sector.

Different environmental policy measures provide different incentives for 'environmentally responsive' consumer choices and behavioural responses (OECD, 2012). In addition to economic instruments, the provision of information to consumers is a common form of government intervention. The dissemination of information on pollution related issues is thought to raise public awareness of environmental problems. Information campaigns are a powerful mechanism to encourage citizens to voluntarily change their behaviour (Wood and Newborough, 2003). In the past the Chinese State relied on work units and neighbourhood committees to disseminate information. In today's diverse society with different working and living arrangements the one-way communication structure has broken down.

The government's increasing presence on social media and blogging sites is a first step for officials to understand and consider the needs and wants of the population. Most communication, however, still appears not to foster the engagement of citizens. The message of China's ambitions to create an 'Ecological Society' is omnipresent in the form of posters, leaflets and media campaigns. In order to gain attention and to increase public support for adopting pro-environmental behaviour the selection of an appropriate communication frame is needed (Druckman, 2004; Chong and Druckman, 2007; Chen, 2016; Steinhorst et al., 2015). Survey data indicated that study participants were mostly concerned about local issues. People typically think in terms of themes that are close to their lives such as health or employment. Domestic and local issues such as air and water pollution are most important to most people. National issues such as acid rain or deforestation are much less important to people. Global issues such as ozone depletion and climate change are beyond most people's concerns (Harris, 2006).

In a departure from past practices to cover up pollution related issues the government has now openly admitted that China's model of economic development has led to unprecedented levels of pollution. The improvement of environmental conditions was made a cornerstone of China's national policy programme.[65] Despite increased transparency the state is still in control of which information is made accessible to the public. Following an episode of particularly bad air quality in parts of the country in early 2017, officials decided to disclose only limited information on pollution levels in an attempt to hide the scale of the problem[66]. Appeasing public concerns through non-disclosure of information seems counter-productive in the government's fight against pollution. One of the suggestions a Chinese environmentalist made during an interview was that the government should disclose all the data it collects on pollution to raise people's awareness of pollution and its effects (Interview 26).

The survey data suggests that concern for environmental problems appears to be high in China. In discussions with the public it became apparent that the majority of people was aware of the high levels of environmental degradation in China. The rise of web based social-media platforms in China, especially micro-blogging sites, has provided a new kind of public forum to share information quickly and contributed to the high level of awareness regarding environmental matters. The censorship of these sites and suppression of important data could in the longer run lead to 'information gaps' regarding relevant issues and be counter-productive to encourage people to adopt pro-environmental behaviour.[67]

An open and transparent communication approach targeting all sources of pollution, the industrial sector and households alike, appears to be prerequisite for effective environmental policy. People need to be aware of the severity of the pollution they directly and indirectly cause. The analysis of the survey results discovered a 'missing link' between people's awareness of environmental pollution and their own actions. The majority of people sampled considered environmental pollution to be a major problem in China. However, people did not seem to make the connection between their own personal consumption habits and increasing pollution levels. Blame for environmental degradation is placed on heavy polluters such as the coal burning power stations and emission intensive steel and cement plants. People appear to rely on the State to resolve environmental issues. Pollution, like many other concerns, is perceived as the "government's problem".

In addition to making transparency a cornerstone of environmental policy campaigns, educational programmes could be instrumental in raising the awareness of the environmental impacts caused by people's consumption patterns. Without knowledge of the pollution embedded in the electricity people use, they find it difficult to understand their own relationship with the environment and to consciously make decisions that benefit the environment such as saving electricity. The government needs to replace quantity-oriented

[65] Air pollution targets were introduced for the first time as national policy goals in the current FYP.

[66] On 17 January 2017 China's Meteorological Administration issued a notice requiring all local weather bureaus to stop issuing smog warnings (Huang, 2017).

[67] A Chinese app called Air Matters, which collects air quality information, was told by the government to stop releasing data exceeding official records. A provincial environmental protection department ordered the app to cap its air quality index readings at 500, which is the current maximum reported by government channels (Huang, 2017).

environmental campaign targets with those highlighting the responsibility of individuals for a clean environment. Past educational initiatives emphasised scientific facts to convey the message. This meant that frequently the message of people's moral obligation to adopt environmentally friendly behaviour was lost. People thought that their actions would only have little or no impact.

Cultural values are often thought to be an indicator for environmental behaviour. Understanding the reasons for this relationship and its origin could be useful in giving meaning to the observations made in China. A 2013 study by economists Halkos and Tzeremes evaluates the relationship between major cultural dimensions and a society's effectiveness to achieve pollution reductions. They found that power distance and the degree of individualism prevalent in a society are the most influential cultural determinants of environmental action.[68] A model developed by Geert Hofstede (1980) provides a good overview of the drivers of Chinese culture. Hofstede finds that in China power distance is high and the degree of individualism is low. The high power distance is reflected in the polarisation of the subordinate-superior relationship. Individuals are highly influenced by formal authority and are in general positive about people's capacity for leadership and initiative. The effect of high power distance on an individual's motivation to act in an environmentally friendly way is highlighted in the study of Chen et al. (2011). They found that people in leadership positions appear to be more inclined to take responsibility for their actions than their counterparts in lower employment ranks. The interviews conducted as part of this study highlighted that people of lower social standing in terms of education and employment would generally look to community leaders or others in positions of influence for guidance before taking action themselves.

In individualist societies people are more inclined to look after themselves and their direct family whereas in collectivist societies people tend to belong to 'groups' that take care of them in exchange for loyalty. In collectivist societies the role of the state is dominant and the political power is typically exercised by the interest of groups. According to Asproudis (2011) the state of environmental quality is associated with people's altruistic behaviour. Altruistic behaviour being a central feature of a group's actions suggests that the 'group-think mentality' of collective countries would encourage pro-environmental behaviour. Another line of research (Eom et al., 2016; Smith et al., 2012; Rimal and Real, 2005; McCarty and Shrum, 2001) associates a high degree of collectivism with a high efficiency to achieve environmental targets. The idea is that an autocratic regime in a collective society can prescribe pro-environmental behaviour of its citizens, leaving them no choice but to act in accordance with the state's mandatory policies. Halkos and Tzereme (2013), however, found that none of the two hypotheses about a collectivist society holds true in the real world. In individualistic countries there is a greater tendency towards environmentally conscious behaviour. In most collectivist countries with a dominant government people appear to lack

[68] Power distance represents views on inequality in terms of the distribution of power. In societies with high power distance an elite has privileges and in low power distance societies power is distributed equally. Individualist societies place importance on self-sufficiency and expect their members to look after themselves. Collectivist societies value group interests over individual interests and allow for the state to play a large role in the economic system.

a greater sense of duty and self-empowerment which could explain the low level of engagement in pro-environmental activities observed in China. Even in states with strong government control, the state cannot impose rules on every aspect of people's life. Also, the enforcement of rules and the sanctioning of non-compliance prove difficult, if not impossible, in the context of regulating household behaviour (Etienne, 2010). Numerous studies have highlighted the value of a departure from command-and-control measures. Regulation often fails to overcome internal barriers to individual and household behavioural change (Dietz et al., 2009; van den Bergh, 2008). The Norm Activation Model (Schwartz, 1977) applied by de Groot and Steg (2010) to environmental problems suggests that it is individual determinants such as personal awareness of an issue, feelings of responsibility and the moral obligation to act rather than rules prescribing certain actions that motivate pro-environmental behaviour.

In the context of promoting proactive environmental behaviour and voluntary energy savings in the household sector several studies point towards the benefits of moving towards a greater engagement of civil society through forms of participatory government. Participation is considered to have a number of benefits to environmental policy (Beierle, 1999; MacKinnon, 2002; Beer et al., 2005). In addition to educating the public, a participatory approach shapes public values and incorporates preferences into decision making. By making their voices heard people feel empowered and are more likely to take responsibility for their own actions. The quality of decisions is improved and interventions are more likely to be effective in achieving their objective.

China still relies on top-down governance (Lo and Leung, 2000; Kostka, 2016). China's model of environmental policy formulation and implementation is predominantly driven and initiated by the state. Conventional state-led and hierarchical policy models appeared to have hampered the implementation of mainly target led interventions at local level in the past (Kostka and Mol, 2013). In recent years the central government has increasingly recognised the value of public support, particularly in environmental matters. Over the last decade the field of environmental politics has been the ground for a variety of experiments allowing for more public participation. One effect has been the emergence and the establishment of environmental NGOs, local, national and international alike. During interviews with environmental activists it became apparent that the Chinese government has acknowledged that it needs the help of civil society actors to overcome the country's environmental problems. However, the attitude of the State towards environmental NGOs appears ambiguous or even contradictory (Saich, 2000; Ho, 2001). Environmental NGOs have made important contributions in awareness raising and improving policy implementation on the ground. The World Wildlife Fund as well as Roots and Shoots, for example, have been instrumental in improving local environmental conditions in and around Shanghai through initiatives improving water quality and promoting re-forestation (Interviews 14 and 44). Despite their important role NGOs have limited clout in terms of influencing government policy (Turner, 2004; Shi and Zhang, 2006; Carter and Mol, 2006). Particularly at provincial and local level are their activities closely monitored by local officials sceptical about the organisations' intentions (Interviews 13, 50).

In 2004 the Constitution was amended to safeguard and uphold the value of open information and public participation (Cheng, 2012). Whilst a step towards the inclusion of civil society in China's environmental governance approach, the implementation of mechanisms such as public consultations to incorporate people's opinions into the environmental policy making process appears limited (Zhang et al., 2007; Mol and Carter, 2006; Martens, 2006). Interviews conducted with representatives from registered NGOs, community activists and members from civil society brought to light that the constitutional change appears to be just a formality, one which is rarely put into practice (Interviews 1, 2, 13, 21). An academic involved in the Environmental Impact Assessment (EIA) of several industrial estates in the coastal area expressed concerns regarding the efficacy of the participatory process. Opinions though noted do not seem to be factored into any decisions regarding the impact of a project (Interview 3). Two research projects investigating public opinion on air pollution from a waste incineration plant and water pollution from textile industry found that people's concerns about poor environmental quality were largely ignored even though local authorities provided systems for citizens to log observed pollution incidents (Interviews 11, 35). A media report even suggests that feedback forms handed to locals in a city in central China were forged by local officials to play down the extent of the pollution caused by chemical plants (China Daily, 2016). Forward looking urban centres with a well-educated and affluent population such as Shanghai appear to be more open to forms of public participation compared to less developed parts of the country (Interview 13). For example, the public was invited to submit views on the city's carbon market prior to its roll-out. According to an interview partner involved in the pilot market only few comments were submitted. No submissions to the online poll could be located (Interview 23).

Despite good intentions to involve the public in the reform of the residential electricity tariff structure in 2012, implementation on the ground appears to have been hampered by local officials undermining the process. According to Zhang and Qin (2015) complaints were raised regarding the transparency of the proposal setting. In some locations, for example, hearings were interpreted as notice meetings of price increases. Failing to sufficiently involve households in the planning and implementation of the IBT electricity price reform could be one reason for the limited success of the electricity reform to induce behavioural change. It appears that residential electricity users were viewed as passive targets during the planning and implementation of the reform.

The Chinese government has recognised that command-and-control is reaching its limits when it comes to regulating environmental behaviour. The introduction of market-based instruments were intended to overcome these obstacles. This study and other research have shown that individuals, unlike organisations, do not react rationally to an intervention such as a price change. The idea that people maximise utility by weighing the price for a good against affordability is far removed from everyday life. Behaviours are complex, non-linear and unpredictable by traditional economic theory. Seeing residential electricity users as actors at the centre of the change process appears a necessity as household consumption is gradually replacing the industrial sector as a source of environmental degradation. The dominance of the State coupled with the lack of individualistic elements in China's society poses a significant barrier to behavioural change.

To allow individualistic components to enter into the political process requires transformational change. Transformational change of the cultural and political foundations on which a country is built are difficult and take time. The adoption of technical innovation could be a first step in empowering the public to make informed decisions of their electricity usage. Smart meters put consumers in control of their power consumption. They provide real time information on household energy use. Experience in countries with a high adoption rate of smart meters provides evidence for their effectiveness to induce electricity saving measures. Real time information on expenditure encourages consumers to conserve energy. Monitoring energy usage can cut a household's outgoings for electricity and offset any price increases following the introduction of a carbon market (UK Government, 2017). Appliance meters monitor electricity usage of energy intensive devices such as air conditioning units. Connected to the internet they allow users to turn an appliance on and turn off remotely in addition to monitoring electricity consumption. Despite a growing number of smart meter developers and manufacturers in China, the adoption of smart meters is still in its infancy and their roll-out has been plagued by technical problems (Metering and Smart Energy International, 2017).

Mandatory energy efficiency labels for electricity consuming appliances have been introduced in China in 2005 (Zhou, 2008). Energy efficiency labels provide useful information on the energy efficiency of appliances such refrigerators, washing machines and air conditioners, which contribute most to a household's electricity usage. Like smart metres they empower people to make informed choices about the impact of their consumption. They convey the message that through deliberate consumption decisions individuals can make a difference to their electricity usage and its effect on the environment. A global study by the International Energy Agency (2015) found that energy efficiency labelling has led to better air-quality and subsequently to the reduction of public expenditure on health. It is estimated that by 2020 energy efficiency improvements are equivalent to 11% of residential electricity use in China. Reducing the need for 28 GW of generating capacity is expected to result in annually avoiding 6.8 million tonnes of SO_2 emissions, 4.8 million tonnes of NO_x and 29 million tonnes of particulate matter.

Interventions should combine multiple types of instrument in a 'package' of measures to support behavioural change. Given the heterogeneity of China's society different demographic groups behave differently and a tailored approach to intervention design is required. To be effective policy measures need to be context specific. Devolving responsibility for policy development and delivery to local authorities could increase their suitability and contribute to their legitimacy. Care needs to be taken to convey a consistent message. In China policy implementation at local level is often hampered by regional officials who flaunt directives from the central government. The active involvement and consultation of provincial and municipal authorities in policy design could help to close the so-called implementation gap between different levels of government (Kostka and Mol, 2013).

Participatory forms of governance appear to be prerequisite for an effective market-based reform of the electricity sector. To reach a common goal, the decarbonisation of the electricity sector, the state ultimately has to gradually transfer power to the people in order to align their behaviour with their values and concern for the environment. Policy makers should not rely on a price based approach alone but should combine multiple types of instruments in a 'package' of measures. Open and transparent communication on environmental matters needs to be a cornerstone of the reform effort. Technical innovations could also play an important role in increasing people's sense of environmental responsibility for the environment.

The review of survey data suggested a gap between people's concern for the environment and their willingness to adopt energy saving behaviour. The review of relevant studies found that barriers to the adoption of pro-environmental behaviour could be traced to China's unique cultural and political system. Years of the government controlling many aspects of people's lives have resulted in a society relying on the State to take action.

7.3 Concluding Remarks

The study of people's attitudes towards clean energy demonstrated the complex interplay of internal and external determinants of households' environmental behaviour in China.
In rich societies energy demand is fundamentally driven by people's behaviour and ultimately their sense of responsibility for the environment. In China the combination of rising incomes and a low responsiveness of households to electricity rate changes suggests that tariff based interventions by themselves are not able to contain future increases in residential electricity usage. In particular, top users, who predominantly live in the affluent Eastern region of the country, appear to be unresponsive to a moderate rise in electricity tariffs. Simulation of different pricing scenarios found that it would require a factor three increase of the average tariff currently paid by households in Shanghai to trigger energy savings significant enough not to exceed current Western European usage levels by 2035. Survey data assessing the willingness to pay for green low carbon energy indicated that a tariff increase of this magnitude would not be socially acceptable at this moment.

The limited efficacy of price based policies suggests that a carbon market is ineffective in stabilising residential electricity consumption. The discussion on the 'action-value-gap' highlighted that energy demand is fundamentally driven by people's behaviour and ultimately their felt moral obligation to care for the environment. Success of an electricity sector reform will ultimately hinge on the extent to which responsibility for a clean environment is transferred from the pollution intensive coal based generators to the individual consumer.

Writing off a market based solution to facilitate pro-environmental behaviour, however, could be a foregone solution. A carbon market is much more than an instrument that solely puts a price on environmental degradation caused by the combustion of fossil fuels. It assigns responsibility for the damage. The cost-pass-through rate indicates how much of the carbon cost is borne by households and how much of it is borne by generation plants. The cost-pass-through rate can be adjusted along continuous scale from zero to 1 dividing responsibility for electricity sector related pollution between producers and consumers.

Supported by an appropriate communication strategy even a low to moderate ‘token’ price increase, acceptable to the majority of households, could send a powerful signal and trigger behavioural change in those consumers accountable for the pollution caused by electricity consumption.

Despite the adoption of market-based instruments to accelerate the switch to a more resource-efficient and low carbon growth path, China's environmental governance system continues to rely primarily on top-down command-and-control. Chapter 6 found that the influential role of the state could prove instrumental in the design a carbon market which overcomes the current shortcomings of the EU ETS. The over-allocation of permits led to a weak carbon price signal, which rendered the scheme ineffective in incentivising polluters to adopt green technology. The lack of interventions further caused the pass through of ‘fictional costs’ (of free permits) to end consumers. In addition to poor environmental performance the European carbon market resulted in increasing levels of inequality as windfall profits for power companies soared and households were pushed into fuel poverty. A functioning carbon market requires continuous oversight and an authority prepared to intervene in market proceedings when environmental and economic goals are in jeopardy.

China exemplifies the double edged sword of state dominance in environmental policy making. On the one hand, continuous market oversight and appropriate interventions in market proceedings appear to be a pre-requisite for an effective price signal generated by a carbon market. On the other hand, state control renders the price signal ineffective in addressing the issue of increasing household electricity usage. The lack of participatory features in the Chinese environmental governance system appears to be the external factor that has contributed most to the so-called ‘action-value gap’. The dominant role of the government has led to the disenfranchisement of people who generally feel not empowered to take action themselves. By limiting civil society’s engagement in the political process the state has created a climate in which people tend to abdicate responsibility to solve problems to the government. China’s leadership is faced with a dilemma. It needs to remain a tight grip on reform efforts in order to ensure important pollution targets are met. At the same time, it needs to let lose its reins to allow civil society to play an active part in the reform.

Addressing the distributional effects arising from the implementation of market based policies aimed at reducing residential electricity demand is another challenging task for the government, given the complexity of the relationship between income, consumption levels, price level and price elasticity of demand, the latter varying with income. The simulation of market based intervention alternatives demonstrated that economic, environmental and social consequences vary greatly between intervention scenarios. Consequences also varied significantly between regions, in particular between the affluent East coast and the low income inner provinces. By making explicit the different intervention alternatives and their contribution to the different decision criteria explicit, Multi-Criteria Decision Analysis was able to distinguish acceptable from unacceptable options in light of stakeholder preferences. The analysis also highlighted that every option implies winners and losers. Identifying winners and losers amongst different groups and thinking of ways to compensate the losers with the winners' gains could further increase the acceptability of measures and subsequently promote energy saving behaviour.

Survey data and other research suggest that a positive relationship exists between income, personal experience of pollution and the willingness to conserve energy. Households appear to be more inclined to adopt environmentally friendly behaviour once they have reached a certain standard of living. The improvement of the general economic situation becomes a pre-requisite for better environmental conditions in the long term. Price based interventions targeting environmental pollution should therefore include an economic development element tackling unemployment and poverty. Scenario 5a highlighted the economic benefits of such policies for the population in less developed electricity exporting and highly polluted parts of China. Apparently insignificant individual acts of saving energy when multiplied by the population in these provinces, which exceeds 300 million people, could have significant positive impact on the environment in the long run. Rising incomes almost inevitably led to rising consumption and thus more pollution. But at the same time individuals with higher income are more likely to engage in pro-environmental activities. The survey suggests that residents of Beijing are more likely to accept a tariff reform and cut electricity consumption levels than any other part of the country.

Understanding the values, concerns and priorities of the general public whose views have been absent from the policy making process is more important than ever in a country as heterogeneous as China. Public participation in decision making is crucial to the planning and implementation of initiatives which aim to transform fundamental ways a society functions. Participatory methods contribute to effective policy development and thus need to be a cornerstone of the residential electricity market reform. Addressing the main external factor explaining the lack of pro-environmental action amongst households, the disengagement of the public from political decision making, requires long term transitional change of the social and political system. Transitional change is far deeper and considerably more intrusive than developmental change. It requires the substitution of existing structures processes with something that is completely new.

In the short run a myriad of interventions designed around a carbon market could facilitate proactive environmental behaviour. The limited evidence available to fully understand to what extent different measures lead to energy conservation opens promising avenues warranting further research within the unique setting of China.

8 Conclusion and Avenues for Future Studies

This research focussed on the application of a framework built on systems theory and multi-criteria decision analysis for the sustainability assessment of various market-based scenarios in the Chinese residential power sector. The framework has taken into account economic, social and environmental aspects of sustainability and stakeholder opinions on the priorities of these. Although the focus of this study has been on the power sector, the framework may be applied to decision making in other complex situations.

The overall objectives of this study were met in that firstly, a methodology for stakeholder engagement was developed and employed to elicit opinions on different electricity futures. Secondly, a systems based model for the sustainability assessment of various market-based future electricity scenarios was implemented for different geographic areas. Thirdly, a multi-criteria decision analysis of the sustainability assessments taking into account stakeholder preferences was undertaken to establish the most preferred solution of a carbon market. Fourthly, an investigation was carried out to identify contextual factors that could support and inhibit an equitable market-based solution within the specific setting of China.

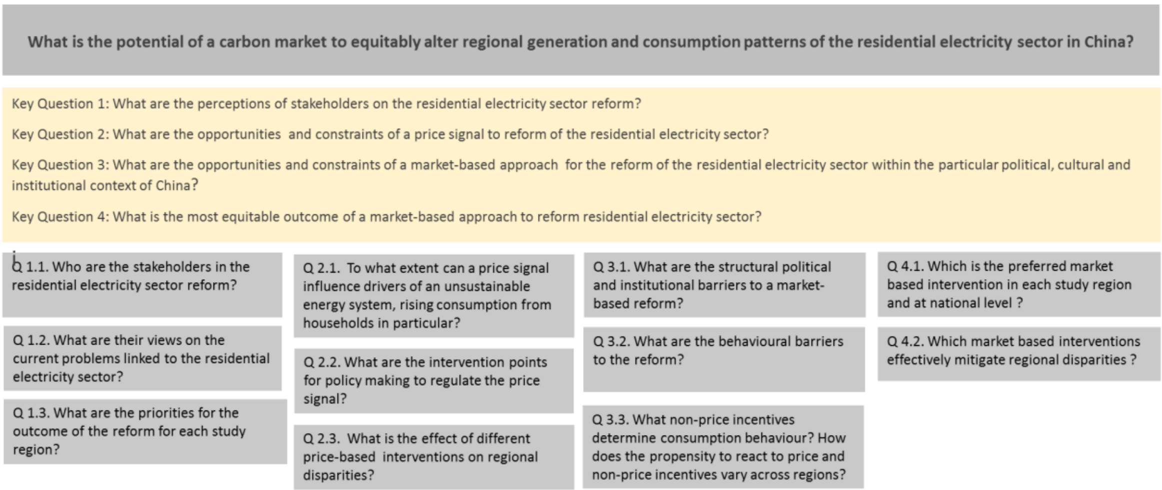
After presenting key answers for the research questions set out at the beginning of this study, the following section highlights some of the theoretical and methodological implications achieved in this research. It explains the limitations of the theories and the methods applied by this study. The discussion further provides suggestions as to how the conceptual and methodological framework could be enhanced to deliver additional insights into a market-based reform of the electricity sector and the wider economy. The chapter concludes with the presentation of ideas that could inform future research.

8.1 Summary of Research Findings

The study investigated the effect of a national carbon market on regional disparities that currently exist in terms of people's material standard of living and their exposure to environmental pollution. The examination of issues linked to China's economic reform highlighted that rising household affluence in the coastal region is emerging as a driver of unsustainability. While substantial environmental impacts still occur in industrial manufacturing and energy generation, households influence these impacts through their consumption choices and habits. Increasing residential electricity consumption was identified as a factor jeopardising the decarbonisation of the energy sector. The requirement to meet future demand from households could delay the retirement of pollution intensive coal plants.

Given that people are at the centre of China's sustainability transition*,* the analysis was carried out through the lens of residential electricity consumers. The adoption of a participatory approach provided the foundation to answer the research questions identified at the outset of the study. For the reader's convenience they are presented again in Diagram 8.1.

Diagram 8.1 Research Questions Posed by this Study



The first set of research questions was concerned with the perceptions of stakeholders on the residential electricity sector reform. Chapter 5 presented insights gained from Chinese and foreign experts with knowledge in diverse areas such as energy, pollution, carbon finance and socio-economic development. The chapter also investigated the views of residential electricity users on issues related to the electricity sector and its reform. The consultation of stakeholders proved helpful in better understanding the different facets of the problem. The identification of stakeholder areas of concern was useful in focussing the study. Stakeholder input made the research more relevant in terms of addressing real world problems. Concern about local pollution and associated health impacts, an issue often disregarded by studies investigating carbon markets, was identified as a reoccurring theme in interviews. Academic experts pointed out that air quality and climate policies can provide mutual benefits as climate change mitigation can help reduce air pollutants from the combustion of fossil fuels. The affordability of electricity along with the uncertain effects of the economy undergoing restructuring on people's material standard of living appeared to be another important issue. Stakeholder engagement also highlighted that different priorities exist regarding the outcome of the electricity sector reform. This inspired the further exploration of people's views through a questionnaire that formed the foundation of the analysis setting out to answer key research questions 3 and 4.

The second set of research questions dealt with the potential of a market generated price signal to change current patterns of unsustainabililty within the Chinese electricity sector. In Chapter 6 two key intervention points for policy making were identified, the carbon price level and the cost-pass-through rate (CPR). The carbon price determines the speed of the energy transition to a greener and more sustainable model. The analysis discovered that the CPR has important equity implications as it apportions responsibility for making emission reductions between consumers and generators. In light of China's distinct regional consumption and generation patterns the cost-pass through rate has implications for the current disparities that exist between the interior electricity exporting provinces with an emission intensive energy sector and the coastal regions with high residential consumption levels.

The simulation of different intervention scenarios in a system dynamic model quantified the effect of variations in the carbon price and the CPR on air pollution levels, residential electricity demand and household affluence in the three different regions of Shanghai, Beijing and Shanxi. On the supply side, generation became less pollution intensive through the application of low-emission technologies at price levels of 150RMB/t CO_2 and above. On the demand side, the market generated price signal was relatively ineffective in encouraging consumers in the affluent coastal region to adopt energy saving behaviour. Even in the face of a high tariff, a multiple of the current rate, the increase of residential electricity usage could not be contained. The most important feedback effect observed was the detrimental change in energy related pollution from households triggered unintentionally by the adoption of market facilitated technological innovation by the supply side. This was explained by the dynamics taking place between economic restructuring, employment opportunities, household affluence and residential electricity consumption. The exploration of the specific situation of the energy system in China found that these patterns play out differently across regions.

The third set of research questions set out to investigate the influence of China's particular political, cultural and institutional setting on the effectiveness of a market-based approach to reform the electricity sector. Chapter 6 identified a number of structural barriers currently inherent in the State controlled energy system that could render a market-based solution ineffective. Under the current arrangement a market generated price signal would neither reach the supply side nor the demand side of the electricity sector. Despite these drawbacks of State dominance for the market-based reform, the analysis recognised that the Chinese State's readiness to interfere in markets could turn out be an advantage for the functioning of an emissions trading scheme.

Residential electricity tariffs are highly political, particularly in China, as the discussion on the recent introduction of block tariffs has demonstrated. The review of policy documents led to the conclusion that the substantial rate increase required to effectively limit increases in residential usage is not likely in the near future. The de-facto limited effect of the national carbon market on consumers prompted the investigation into the environmental behaviour of Chinese electricity users. One key insight derived from the administration of a questionnaire to the general public confirmed the impression gained during the interviewing stage. People placed high importance on environmental issues, air pollution in particular. The analysis of responses to the survey brought to light a so-called action-value gap. On the one hand, most respondents were concerned about high pollution levels. On the other hand, they were hesitant to accept personal responsibility for deteriorating environmental quality. The majority of people questioned were reluctant to pay more for clean electricity despite their preference for renewables over coal-based form of generation. Study participants in the energy exporting and highly polluted province of Shanxi placed higher importance on economic growth than respondents from the affluent cities of Shanghai and Beijing. They were also less likely to accept a rate increase.

The exploration of cultural factors that could explain a society's propensity to adopt pro-environmental behaviour provided some explanation for the action-value gap observed in China. The majority of studies reviewed on the topic appeared to concur that in societies such as China with a low level of individualism and a high level of power distance between the leadership and people, individuals are less likely to adopt pro-environmental behaviour. The omnipresence of state authority is often attributed to an individual's lack of felt responsibility to act. In interviews with residential electricity users it become apparent that many look to the government to solve environmental issues. The study concluded that the dominant role of the State in China and its rules and target-based approach to governance could be counter-productive in promoting the adoption of energy saving behaviour. Rules prescribing certain action are somewhat effective in forcing compliance of industrial polluters, but they typically fail to overcome internal barriers to individual behavioural change.

The final set of research questions was concerned with the determination of the most equitable market-based solution. The analysis found that the solution preferred by most study participants was different from the scenario that emulated an equitable burden sharing arrangement. The theoretical and practical difficulty involved in objectively determining an equitable solution are explored in more detail below.

Based on these four strands of research a number of theoretical and methodological contributions were made by this study. Furthermore, implications can be drawn from the research relevant for the political process in China.

8.2 Theoretical and Methodological Contributions of the Study

This research both confirms and challenges the existing body of knowledge on market-based environmental instruments in China. The conceptual underpinning of this study sought to unify separate strands of research through the integration of both hard and soft systems theory. In academic literature the two theoretical approaches are often portrayed as polar opposites that pursue different objectives as explained in Chapter 3. The conceptual framework developed for the study demonstrated that that in combination hard and soft system approaches provide are a powerful toolset for creative problem solving. Only the amalgamation of different analysis tools and techniques was able to shed light on the various dimensions of complexity inherent in the research problem.

Market-led energy transitions are complex. A carbon market is positioned at the intersection of the environmental, social and economic system. Interventions within complex systems composed of many components, which may interact with each other, often trigger unexpected feedback leading to unintended and undesired results. Energy sector reforms are also complex because they involve humans, who often make decisions that do not conform with economic models, but are shaped by an individual's personal situation.

Hard systems thinking provided insights into the causal relationships and dynamics of a carbon market. The contribution of scenario modelling in a system dynamic model to this research has been explained in the preceding section. The benefits of testing the effects of a policy on selected parameters ex-ante in lab conditions are obvious. Often treated by researchers and policy makers alike as a crystal ball, this study demonstrated that the real strength of causal and dynamic modelling does not lie in the prediction of future developments but in its applications as tool of learning. Firstly, the causal model created awareness of a complex situation. It revealed systemic interdependencies hereto unknown-own to the observer. Secondly, the dynamic model offered a platform to apply the principles and concepts of emissions trading learnt from the review of literature. The use of the simulator provided an in-depth understanding of how these principles actually play out as different intervention scenarios in real-life situations. Thirdly, both the causal and the dynamic model increased the relevance of the research as their design was conceived with the involvement of stakeholders affected by the electricity sector reform.

Soft systems thinking was able to take into account the multiplicity of perspectives that exist among stakeholders in the Chinese electricity sector reform. Multi-criteria appraisal was able to handle the contradictory sustainability criteria, helping to reduce complexity further. The study highlighted the benefits of involving stakeholders in formulating and selecting an intervention. Participatory decision making appears particularly useful in situations where the outcome of an intervention is influenced by the behaviour of individuals. The relevance of a people-led intervention design is reflected upon in more detail as part of the discussion on this study's contribution to policy making.

In summary, the study demonstrated that Systems Thinking provides a suitable conceptual framework unifying a number of methodological approaches that are required to analyse situations that are characterised by different dimensions of complexity. The combination of causal and dynamic system instruments with scenario building and multi-criteria decision analysis involving stakeholders could offer a universal toolset to address the complexities and uncertainties inherent in energy transitions and to appraise future pathways of electricity sector reforms.

8.3 Contributions of the Study to Policy Making

A critical focus of this research was to interrogate the relationship between China's current political system based on a Party State and the adoption of a market-led approach to achieve the sustainability targets of the Five Year Plan.

A key implication drawn from the study is the ambiguous role of state authority in the implementation of market-based environmental instruments. One key lesson was that markets are political institutions that only deliver under very specific circumstances. Pollution allowance markets deal with a 'fictious commodity' and depend on good regulation in order to function properly. The carbon price level and the cost pass-through rate were identified as two key intervention points. Through their adjustment market regulators can influence the speed of achieving environmental targets, the size of the economic burden and the burden sharing arrangement.

The research highlighted that the role of the Chinese State in the market-based sustainability reform is pivotal for the achievement of the FYP's development objectives. The analysis of past and present emission allowance markets has demonstrated that a carbon market requires constant oversight and (appropriate) interventions in the market proceedings to maintain a strong price signal. Effective market oversight requires responsiveness to changes in the economy and technology. The experience of the EU ETS highlighted that the dominance of the power companies in the political process coupled with the market authority's laissez-faire attitude has been largely responsible for the sub-optimal environmental performance of the market and the increase in fuel poverty among vulnerable low income households.

In China decisions that influence the carbon price and cost-pass through are officially made by the NDRC, the country's central economic and social development agency. The concentration of authority within a key institution of China's Party State suggests that there is little or no inference from external interests in shaping the market design. Over the course of the study the review of press releases and policy papers covering the implementation of the national emissions trading scheme painted a different picture. The scarcity of official information on the implementation of a key policy instrument casts doubt on the notion that one single institution with shared political interests has been making all market design decisions with far reaching implications across economy and society. Most reports relied on unofficial sources and speculation rather than announcements from the authorities. The constant delay of the launch, in particular the failure of the State Council to approve the regulator's proposed scheme in time for the market opening to be announced during the Conference of Parties (COP 23) in November 2017, further illustrated the murkiness of policy making surrounding the ETS. In the absence of a firm institutional infrastructure and procedures, personal relationships play a significant role in political decision making and add complexity and unpredictability to an already opaque process (Dumbaugh and Martin, 2009).

'The Party' and its leadership are often treated as a homogeneous group by Western scholarship. Rather than being organised according to a rigid hierarchy, political power in China is increasingly becoming diffuse and competitive (Kirby et al., 2006; Lampton, 2014). As within China's population, many diverse and often contrasting interests exist amongst the CCP's members. Conflicting objectives between the central government and local officials, in particular regarding economic and environmental priorities, have been documented (Kostka, 2016; Kostka and Hobbs, 2012). This study found that the decision of provincial governments to construct new coal plants could undermine the central leadership's ambitions to de-carbonise the energy sector. Technocrats within the central leadership team see the socio-economic risk and opportunity associated with addressing environmental issues. They understand the urgency for China to make its economic model more sustainable (Kwan and Hanlon, 2016). Even though the Party elite has consolidated its power in recent years, an assessment of the current political situation by the Brookings Institute (Dollar et al. 2017) suggests that considerable entrenched interests resisting such reforms exist within lower cadres, which have yet to be overridden by the central leadership.

The plurality of private and public actors engaged in the set-up and implementation of the carbon market may impact the scheme's effectiveness in supporting China's sustainability transition. According to a report by ICIS (2017) companies across six business areas are expected to be involved in the national emissions trading scheme. These areas span compliance training and verification, CCER development and trading[69], proprietary trading as

[69] CCER development and trading includes CCER project registration and issuance of CCERs on an exchange traded platform as well as the facilitation of transactions on both the primary and secondary markets.

well as agency trading of allowances on the spot and forward markets[70], carbon finance[71] and other carbon related business such as energy management[72] and renewable energy certificates[73]. The experience of the EU ETS has demonstrated that business interests were more powerful than concerns for energy affordability, fair burden sharing and environmental pollution. Given the complex trade-offs that exist between China's development targets anchored in the 13th FYP, already disadvantaged societal groups or entire regions could be made worse off by the introduction of a national emissions trading scheme, unless these trade-offs are addressed by a leadership that is committed to delivering an equitable solution that might be contested from within their own Party. The increasing dilution of power opens up avenues for future research. This will be discussed in the following section.

All government policies affect citizen empowerment to some degree. The State can be a driver of empowerment, a facilitator or a blocker. As discussed at great length in the empirical part of this study, the success of China's consumer-based sustainability transition will at least partially depend on people adopting pro-environmental behaviour. Behavioural change can only be realised if people perceive that an intervention is explicitly recognising their needs. This requires that differences in the definition of the intervention targets and objectives between the so-called stakeholders are explored and addressed in the solution outcome. In China where the State currently appears to act as a blocker rather than a facilitator to empowering people, effective and equitable intervention design is unlikely. The State needs to involve civil society that is largely excluded from the political process in shaping interventions through an effective consultation process. Without the active support by the population at large China's sustainability targets might not be achievable within the period of the current FYP.

The central tenet of a participatory approach is built on the notion that only those affected by a decision know the value of a good and should therefore decide on a benefit-and-burden sharing arrangement. The decision analysis carried out by this study showed that in complex situations where individuals assign different values to a particular outcome, objective fairness is virtually impossible to achieve through a participatory approach alone. Treating every individual's views as equally valid promises the procedural value of equal power over the intervention outcome. In the context of inclusive policymaking, however, it needs to be

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[70] Seven Chinese government agencies published guidelines for a green finance system in 2016. The guidelines included a number of financial instruments or products to be developed for the national ETS, including futures, forwards, swaps, options, bonds and carbon asset securitisation. A liquid futures market is important to cover the compliance companies' needs for hedging (Carbon Pulse, 2016b).

[71] Carbon finance covers the trading of carbon underlying instruments such as repurchase agreements or bonds that can be used as a source of funding (ICIS, 2017).

[72] Energy management contracting (EMC) includes services ranging from energy audits and assessments, financing, equipment installation and maintenance to increase the energy efficiency of commercial and industrial users.

[73]A renewable energy certificate (REC) is a market-based instrument. RECs are issued when a specific amount of renewable electricity is generated and delivered to the electricity grid. RECs can be bought by electricity consumers that wish to prove the usage of renewable electricity (EPA, 2017b).

acknowledged that a democratically conceived intervention does not necessarily result in an equal outcome as the solution itself might not be equitable. In this study the multi-criteria appraisal process was led by the democratic ideal of 'one man – one vote', attaching the same weight to each study participant's preference for a particular outcome. The intervention scenario preferred by the majority of the population put individuals in the heavily polluted coal based provinces at a disadvantage.

Is equality in the outcome the overriding goal, an arbiter is to ensure equity in the process. The strong role of the Chinese State could prove to be an advantage in a situation where objective fairness appears impossible to achieve through a participatory approach alone. The study demonstrated that an equitable solution could be achieved through supplementary interventions such as transfer payments from the Eastern provinces to the inner regions. However, it needs be recognised that transferring decision making authority away from those affected by a situation to an arbiter albeit neutral contradicts the central notion of a participatory approach.

Above discussion highlighted that the State acts as a lynchpin between the people and the market. The dominance of the Party State in China is both a boon and a curse at the same time. The positive aspects associated with a strong leadership committed to steering China towards the 'New Normal' rest on two conditions. Firstly, the effectiveness of the State to act as facilitator of sustainability related changes is determined by the central leadership's ability to shield its ambitious targets from being diluted by vested interests that exist within the Party. Secondly, the opening up of the political decision making to civil society is inevitable. This process should be actively encouraged rather than blocked through measures such as the censorship of pollution data. Civic involvement should not be regarded by the Party as undermining its authority but rather as reinforcing the legitimacy of its authority.

8.4 Limitations of this Study

This study is not devoid of limitations. Firstly, the insights gained from causal and dynamic modelling were constrained by the assumptions that were made to contain complexity. Secondly, the participative element of the study was influenced by the researcher's own background and perspectives. Thirdly, due to the time constraint and difficulties with accessing certain experts in the empirical study this research bears further limitations that shall be clarified. The following also provides suggestions as to how this study could be enhanced to generate additional insights.

The limitations of the systems based model were explained in Chapter 6. Future enhancements to the model could encompass more interactions that take place between different spheres of the system. A detailed view of the links between demand and supply side could provide a more holistic picture of the transition and generate new insights as to how a price on carbon may influence the adoption of low pollution forms of generation. On the demand side, the inclusion of the manufacturing and service sectors could shed additional light on the linkages between economic development and the consumption of electricity by industrial, commercial and household activities.

The analysis in a systems dynamic model could further be enriched through the simulation of interventions that overlap with the policy objectives of a carbon market. As explained in Chapter 2, in case of the EU ETS supplementary policies supporting the renewables sector led to a drop in the carbon price following a significant reduction in the demand for allowances. The introduction of air pollution regulation at state level made the national U.S. sulphur market redundant and led to the decision to terminate it. Careful ex-ante impact evaluation in a systems model may be useful to assess the effect of supplementary intervention scenarios on the market effectiveness of China's national ETS. More specifically, the study of China's market-led energy transition could be enriched by creating awareness as to how such additional interventions, a tax on pollution for example, may conflict with the ETS to achieve specific environmental and social outcomes. An enhanced system dynamic model could also provide insights as to how supplementary interventions affect the cost efficiency of abatement.

In the participatory study the researcher was not independent from the participants as the researcher herself was part of the instrument for data collection and data analysis. She directly engaged with the study participant in constructing his point of view. The interview questions and the survey applied by this study were designed against the researcher's past experience, ethnicity and other factors that might have influenced what was observed and recorded (Ambert et al., 1995). For example, in the semi-structured interviews that formed the basis of the empirical study the researcher selected the questions and was involved in sense making of answers.

Neutrality was further compromised because of pragmatic reasons such as time and funding constraints. In general, research requiring stakeholder participation is typically very time and resource intensive. In case of this study, these constraints meant that only a limited number of paper questionnaires could be administered to the public in a relatively small study area. Conducting the survey online boosted the number of questionnaire submissions. The approach took advantage of the internet's ability to provide access to individuals, who could not have been included in the study otherwise (Wright, 2005). Despite reaching a relatively large sample within a short period of time, the selection bias of participants in the internet survey (Ahern, 2005; Khazaal et al., 2014) proved a major challenge for the study. The online questionnaire was dominated by responses from the young and well educated. Only a few questionnaires were completed by the elderly and individuals with a lower educational status. The experience demonstrates the practical issues involved in obtaining a random sample that is representative of the overall population. The relatively small sample turned out to be a constraint that made the interpretation of study results limited.

Due to access issues to certain experts some areas of study remained underexplored. One particular area that would have benefited from expert consultation was the supply side of electricity generation. The view of Chinese energy providers on the carbon market could have enhanced the understanding on the effects of a price on carbon on the different forms of electricity generation. In an attempt to fill this void, individuals with knowledge in the European energy sector were interviewed. In light of the regulatory differences between the Chinese and Western electricity sector the insights gained from the European interview partners were only partially transferable to the study of the Chinese energy sector.

Despite these limitations, the study demonstrated the benefits of involving stakeholders in research. The engagement of individuals provided insights that could not have been gained from desk research alone. Future research projects could improve the understanding of people's views on energy related issues through the inclusion of a wider demographic in more study locations across China. A large-scale population-based survey may provide evidence whether the reported differential preferences for competing development objectives in Shanghai, Beijing and Shanxi are applicable to other regions.

In addition to the suggestions made for further research in this section, three areas could be explored in future studies to enhance the general understanding on China's sustainability transformation. Firstly, the wider social and cultural aspects that could influence the outcome of the reform; secondly, the power networks that exist between business and politics and thirdly, the impact of future technological advancement, often referred to as the Fourth Industrial Revolution.

8.5 Outlook and Avenues for Future Research

The study of the electricity sector reform highlighted that an understanding of the context within which the transition takes place is required. The awareness of the social, cultural and political environment within which a change occurs is a pre-requisite for the meaningful interpretation of quantitative data, such as the output from system dynamic models.

The study provided a high level investigation of these factors. Through the perusal of previous research and interviews with the electricity users insights were gained regarding the influence of culture on environmental behaviour. Literature also provided awareness of the policymaking process and the involvement of civil society in shaping decisions. Greater academic attention attached to the complexity and the heterogeneity of China's real world context could deepen the understanding of the role of these factors in shaping individuals' consumption behaviours. In light of the growing influence of individuals in China's development, the social and cultural context increasingly matters for the formulation of effective policies. The following briefly discusses how new avenues for future research could enhance the understanding of the interplay between markets, civil society and the State.

The study highlighted that civil society in China should not be regarded as a monolithic block, but rather as a group of individuals with diverse views and interests, who share some basic values anchored in the same culture. Collectivistic values were identified as important building blocks of traditional Chinese culture as well as the Communist political regime. Society in China, however, has undergone rapid and radical change since the early 1980s. Given that economic reform and accompanying social transformations are moving at different rates, Chinese society and its value system are reflective of the different socio-economic conditions that exist across the country (Yan, 2009). A number of studies have discovered that urbanisation, increasing household affluence and access to modern technology have fostered the emergence of individualistic trades. Collectivist values, however, persist, in particular in the rural areas where a substantial part of China's population relies on traditional subsistence farming, with little personal wealth and limited access to technology (Zeng and Greenfield, 2015).

Other Asian countries that share cultural characteristics with China could provide further insights into the influence of culture on pro-environmental behaviour. China, South Korea and Japan have a similar Confucian background that embraces state or family-centred values (Kim and Kim, 2010; Ahn, 2011). Yet, each society has gone through different political reforms and social changes in the process of technological innovation and modernisation. The review of several cross-cultural studies (e.g. Hofstede, 1980; Schwartz 1992; Bond, 1996; Chen, 2004; Rozman, 2014; Inoguchi, 2017) suggests varying degrees of value endorsement within the three countries.

Unlike China that developed within a short order over the past thirty years, Japan entered the realm of global capitalism soon after the Second World War. Even though Japan and China are both considered anti-individualistic, the two countries appear to express the importance of collectivism in subtle but significantly different ways. The Chinese form of collectivism is ambitious, attaching a positive connotation to forward advancement within a regimented structure. Japan's interpretation is harmony-driven and reinforced by consensus and unanimity[74] (Doctoroff, 2017). Despite its exposure to Western culture the pace of change has remained slow and Japanese society has held on to a lot of its traditional values that conform with an environmental way of thinking (Sun et al., 2004; Kim and Kim, 2009). A study by Zhang et al. (2005) found that fundamental principles of traditional conservatism that are in contrast with modernity and consumerism (e.g. being content in one's life, thriftiness, non-competitiveness, having few material desires) are upheld in Japan. Conservatism was the least endorsed value in China. In China harmony is associated with 'order' and 'stability', not with 'peace' and 'tranquillity'. It is characterised by pragmatism. The sustainability objectives of the current Five Year Plan are a reflection of China's matter-of-fact approach to change. The drive for change appears to be triggered by the spectres of economic stagnation and environmental Armageddon, rather than concerns for human wellbeing and environmental quality. The question that remains to be answered is whether relentless pragmatism alone can propel China on a more sustainable growth path or whether motivation anchored in the moral obligation to reverse past patterns of human and environmental exploitation is required to reach the 'New Normal'.

Japan's interpretation of Confucianism as a system of knowledge differs from that of China and Korea, where Confucian thought became inextricably intertwined with everyday life (Wang, 2012). In addition to a common value system, South Korea's development path shows similarities with China's current trajectory as discovered in Chapter 1. South Korea transformed from an autocratic regime that drove the country's rapid industrialisation to a parliamentarian democracy with an economy based on technology and innovation within a short order of time. As the economy evolved and the standard of living improved, attitudes have gradually shifted away from collectivism towards more individualism (Kihl, 2015), another parallel to China's rapidly developing coastal region. The degree to which the

[74] The different notions attached to collectivism in China and Japan are illustrated by two proverbial sayings. The Chinese say "The leading goose gets shot down." The Japanese say "the nail that sticks up get hits down."

experience in Korea is transferable to China requires a systematic review of relevant studies as factors encouraging environmental actions differ by country and by type of actions. As more market data is released, the experience of the Korean carbon market, operational since 2015, could provide valuable lessons for the design and implementation of an emissions allowance market in an East Asian emerging economy setting.

The current central leadership has bolstered its position across all sectors during the 19th National Congress of the Communist Party of China (October 2017) (Phillips and Haas, 2017). However, as noted in the previous section, in reality present-day China's political process is permeated with a multitude of political actors that officially and unofficially influence and frequently determine policy. Other factors that add to the complex picture of Chinese policymaking is the inter-wovenness of state and non-state actors. Many business leaders in the non-state sector have emerged from the Party elite or are closely linked to the Party through personal connections (Dickson, 2003). While gaining membership was once considered a purely ideological act, a major motivation for many to join the Party now is to make personal connections crucial for career advancement (Dumbaugh and Martin, 2009). Private business leaders with the objective of gaining advantage over rival companies often seek proximity to the Party by securing membership (Chen, 2007).

The study of political and business power relations could contextualise the State's logic for decisions involving the trade-off between the environment and the economy. It is understood, however, that the investigation of the frequently invisible power networks ('guanxi') poses an empirical challenge, in particular for Western scholars.

Today economic development takes place at a time of technological progress that is often dubbed the 'Fourth Industrial Revolution' (Schwab, 2016)[75]. The Fourth Industrial Revolution comprises the development and deployment of a range of new technologies fusing the physical, digital and biological worlds with impacts across many disciplines, economies, and industries. It represents entirely new ways in which technology becomes embedded within societies (Schwab, 2016). Emerging technologies can contribute to achieving environmental goals, narrow or even leapfrog technology gaps with advanced economies and create new sources of growth (Davis, 2016). Grasping the potential of new technologies, innovative development was made a policy priority in the current Five Year Plan. Historical experience illustrates that a consumer society tends to gain from industrial revolutions. The Third Industrial Revolutions provided products and services that increased people's material standard of living. New products made possible through advancements in information and communication technology have contributed to the rapid rise in consumption expenditure for personal devices such as mobile phones (Davis, 2016). The Fourth Industrial Revolution is set to accelerate the shift from an investment driven to a consumption driven economy in China. New technology has the capability of providing goods and services that are tailored to

[75] The First Industrial Revolution is widely understood as the shift from the reliance on animals, human effort and biomass as primary sources of energy to the use of fossil fuels and the mechanical power. The Second Industrial Revolution occurred between the end of the 19th century and the first two decades of the 20th century. It brought major breakthroughs in the form of electricity generation and distribution, and both wireless and wired forms of communication. The Third Industrial Revolution started in the 1950s with the development of digital systems and advances in computing power, which have enabled new ways of generating, processing and distributing information (Schwab, 2016).

meet personal requirements. Increased consumption creates increased pollution. Technology, however, empowers individuals to adopt pro-environmental behaviour. It offers transparency about green claims in production, consumption and waste disposal processes providing consumers with information that allows them to re-evaluate their lifestyle and their environmental, social and economic impact (Nayyar, 2016).

To fully leverage the benefits of innovation, Chinese policymakers need to understand the positive potential applications of these new technologies as well as the potential risks leading to social and economic disruption (Nassiry, 2017). The discussion on the concept of 'creative destruction' explained how industrial revolutions create and destroy jobs. There is evidence that these effects have become more pronounced over time as new industries are creating relatively fewer positions than in the past. According to calculations by Frey and Osborne (2017) only 0.5% of the U.S. workforce is employed today in industries that did not exist at the turn of the 21st century. This is a considerably lower percentage than the 8.2% of new jobs created in emerging industries during the 1980s and the 4.4% of new employment opportunities that emerged during the 1990s. In the field of advanced technology China will have to directly compete against developed countries currently operating at the high end of the value chain. At the lower end of the value chain, industrial transformation will lead to the phase out of traditional industries. Supporters of rapid structural transformation openly advocate a 'burn one's boat' policy based on the proverbial power of self-destruction to motivate one's fight for survival. The high risk strategy of deliberately closing down outdated production facilities will inevitably lead to a vacuum in certain areas leaving China's economy as a whole exposed to the risk of being hollowed out should the experiment fail (Rui, 2016).

The systems based study (Chapter 6) elicited the dynamics of a carbon-market induced innovation process and how it could unfold across China. It highlighted the challenges inherent in technological change within the energy sector and its far-reaching impacts on socio-economic development. The embrace of technological advancement by the Chinese leadership as a key policy to reach the 'New Normal' warrants further study of how the Fourth Industrial Revolution could improve lives in the most equitable and meaningful way possible. While increases in computing power and expanding mobile networks have the potential to improve the lives of millions, they also threaten to leave those at the bottom even farther behind unless the benefits of innovation are not evenly distributed. The complexity of the technologies and the breadth of their impact on society suggest a stakeholder based study bringing together experts and those affected to collaborate on innovative ways to harness the benefits of innovation.

Another area that requires future academic attention is the effect of new communication technology on China's modernisation process that is characterised by contradictions as the Party State continues to rely on repressive measures when being confronted by challenges to its authority. As supported by a number of studies discussed earlier (Chapter 2), modern information technology can foster free speech and democracy through the exchange of information between state and non-state actors. As the recent experience in Western democracies has demonstrated access to online media does not necessarily result in more diverse worldviews. Paradoxically, controversial views can be undermined by states and other actors through the use of new technologies (World Economic Forum, 2016). Whether or not emerging communication technologies increase diversity and the potential for collaboration between State and civil society or restrict free speech and manipulate public opinion in China requires observation as the Fourth Industrial Revolution unfolds.

In summary, when studying China's energy transition, future oriented research needs to leave the narrow confines of technologies and regulations. Social positions shaping awareness, attitudes and behaviour of electricity consumers and other actors in society will have a strong impact on China reaching the 'New Normal'. By taking into account the complex meshing between cultural values, innovation, politics and markets future studies could so recognise that the human factor plays a central role in this shift.

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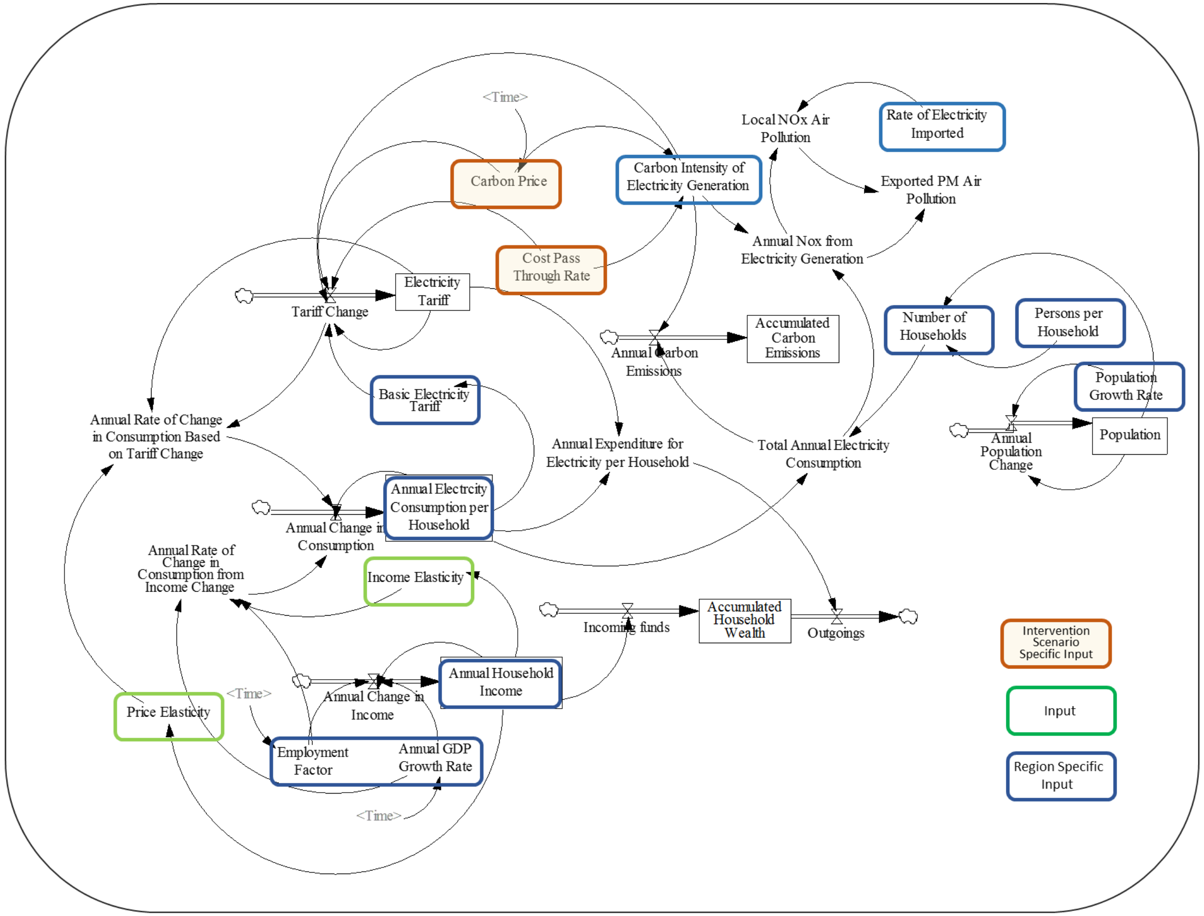
Appendix

Appendix Diagram 6.A Stock-and-Flow-Diagram – Input Variables



Appendix Table 6.A Description of System Variables

Name	**Unit**	**Description**	**Variable Type**
Population	Number of People	Population of study area	Stock
Persons per Household	Number of People	Average number of people per household in study area	Auxiliary
Number of Households	Number of Households	Number of households in study area.	Auxiliary
Population Growth Rate	Percentage	Annual growth rate of the population in study area. This can be negative or positive.	Auxiliary
Annual Population Change	Number of People/Year	Annual change in the population. This can be negative or positive.	Flow
Annual Household Income	RMB	Average Household Income in study area.	
Annual Income Change	RMB/Year	Annual Change in Income dependent on GDP and employment available in the study area. Determined by Employment Factor and GDP Growth Rate.This can be negative or positive.	Flow
GDP Growth Rate	Percentage	Annual rate of change of GDP in study area. Indicator of general economic development. Determinant of average income. This can be negative or positive.	Auxiliary
Employment Factor	/	Employment opportunities in electricity sector related sectors such as mining, renewables, innovation specific to study area. Determinant of average income.	Auxiliary
Accumulated Household Wealth	RMB	Annual household income adjusted by household expenditure on electricity accumulated over the entire study period. Indicator of material standard of living.	Stock
Incoming Funds	RMB	Average annual household income in study area.	Flow
Outgoings	RMB	Average annual household expenditure in study area.	Flow
Annual Electricity Consumption per Household	kWh	Average annual household electricity consumption in study area.	Stock
Total Household Annual Electricity Consumption	kWh	Annual electricity consumption of all households in study area.	Stock
Annual Change in Electricity Consumption per Household	kWh	Annual Change in Income dependent on GDP and employment available in the study area. Determined by Employment Factor and GDP Growth Rate. This can be negative or positive.	Flow
Income Elasticity Of Electricity Demand	/	Responsiveness of the demand for electricity demanded to a change in its price.	Auxiliary

Name	Unit	Description	Variable Type
Price Elasticity Of Electricity Demand	/	Responsiveness of the demand for electricity demanded to a change to average level of household incomes.	Auxiliary
Annual Electricity Price Adjustment	RMB/kWh	Annual change of electricity tariff. Considers merit order effect and other supply side policies as well as carbon price. This can be negative or positive.	Auxiliary
Basic Electricity Tariff	RMB/kWh	Residential electricity price per kWh. Tariff structure follows a flat rate approach or block tariffs increasing with consumption levels.	Auxiliary
Carbon Price	RMB/MtCO_2	Average annual price of a CO_2 emission permit. Emission permits are held by polluting power plants and traded in a national carbon market.	Auxiliary
Cost-Pass-Through-Rate	Percentage	Percentage of the carbon price covered by households. Indicator of burden sharing arrangement between generators and consumers.	Auxiliary
Annual Expenditure for Electricity per Household	RMB	Total annual expenditure of households for electricity.	Flow
Total Carbon Emissions	MtCO_2	The amount of carbon by weight from the generation of electricity for usage by households in the study area accumulated over the entire study period.	Stock
Annual Carbon Emissions	MtCO_2	The amount of carbon by weight from the generation of electricity for usage by households within the study area.	Flow
Carbon intensity of Electricity Generation	gCO_2 /kWh	The amount of carbon by weight emitted per unit of electricity generated for usage by households. Initial value dependent on the generation fuel mix and CO2 emission factors of coal plants (consumption emissions). Influenced over time by reduction burden placed on coal generators.	Auxiliary
Annual NOx from Electricity Generation	t	Total NOx emissions carbon by weight from the generation of electricity for usage by households within the study area (consumption emissions).Influenced over time by reduction burden placed on coal generators.	Stock
Exported NOx Air Pollution	t	NOx emissions carbon by weight from the generation of electricity for usage by households within the study area which is imported from provinces outside the study area.	Stock
Local NOx Air Pollution	t	NOx emissions carbon by weight from the generation of electricity for usage by	Stock

Name	Unit	Description	Variable Type
		households within the study area which is generated within the study area.	
Rate of Electricity imported	Percentage	Percentage of of electricity for usage by households within the study area is imported from provinces outside the study area.	Auxiliary
Rate of Imported Electricity	Percentage	Percentage rate of electricity consumed by households which was imported from other regions. Used to estimate the impact of electricity generation on local air quality.	Auxiliary

Appendix Table 6.B Vensim Simulation Equations

Variable	Simulation Equation
Population	INTEG (Annual Population Change, initial value) Annual Population Change =Population*Population Growth Rate
Number of Households	Population/average persons per household
Total Annual Electricity Consumption	Number of households * Annual Electricity Consumption per Household
Annual Electricity Consumption per Household	INTEG (Annual Change in Consumption, initial value) Annual Change in Consumption = ((Annual Rate of Change in Consumption Based on Tariff Change+Annual Rate of Change in Consumption from Income Change)*Annual Electricity Consumption per Household) Annual Rate of Change in Consumption Based on Tariff Change= ((Price Elasticity*((100/Electricity Tariff)*Tariff Change))/100) Price Elasticity is a function of household income defined via a table LOOK UP Annual Rate of Change in Consumption from Income Change= Annual GDP Growth Rate*Employment Factor*Income Elasticity Income Elasticity is a function of household income defined via a table LOOK UP
Accumulated Carbon Emissions	INTEG (Annual Carbon Emissions, initial value) Initial value = 0
Annual Carbon Emissions	(Total Annual Electricity Consumption*Carbon Intensity of Electricity Generation)
Electricity Tariff Carbon Price	INTEG (Tariff Change, initial value) Tariff Change = (Basic Electricity Tariff+(Carbon Price/1000*Cost Pass Through Rate*Carbon Intensity of Electricity Generation))-Electricity Tariff Carbon Price is a function of time defined via a table LOOK UP

Variable	Simulation Equation
Carbon Intensity of Electricity Generation	DELAY3((1-Cost Pass Through Rate)*Carbon Price, 3) Function of Carbon Price and Cost-Pass-Through Rate and defined via a table LOOK UP
Annual Nox from Electricity Generation	Carbon Intensity of Electricity Generation*Total Annual Electricity Consumption*4/1e+006
Local NOx Air Pollution	Annual Nox from Electricity Generation*(1-Rate of Electricity Imported)
Exported PM Air Pollution	Annual Nox from Electricity Generation-Local NOx Air Pollution
Accumulated Household Wealth	INTEG (Incoming funds-Outgoings, initial value =0) Incoming funds = Annual Household Income Outgoings = Annual Expenditure for Electricity per Household
Annual Household Expenditure for Electricity	Electricity Tariff*Annual Electricity Consumption per Household
Electricity Tariff	INTEG (Tariff Change, initial tariff) Tariff Change =(Basic Electricity Tariff+(Carbon Price/1000*Cost Pass Through Rate*Carbon Intensity of Electricity Generation))-Electricity Tariff
Carbon Price	CONST or Carbon Price is a function of time defined via a table LOOK UP
Cost Pass Through Rate	CONST
Annual Household Income	INTEG (annual income change, initial income)
	Annual Household Income*Annual GDP Growth Rate*Employment Factor Employment Factors is a function of time defined via a table LOOK UP

Appendix Table 6.C Input Variables for the Scenario Simulations

Variable Name	Unit		Shanghai	Beijing	Shanxi
Region Specific Input					
Initial Population	Number of People		24,256,800	21,520,000	36,480,000
Persons per Household	Number of People		2.7	2.4	3.2
Annual Population Growth Rate	Percentage		0.53	0.41	0.5
Annual GDP Growth Rate	Percentage		6.5->3.5	6.5->3.5	2.5->3.5
Annual Household Income	RMB		65,417	68,989	23,876
Employment Factor[76]	/		1.1-1.3	1.1-1.4	0.5-1.4
Initial Annual Electricity Consumption per Household	kWh		716.87 kWh per capita x 2.7 persons per household = 1935.55	729.72 kWh per capita x 2.4 persons per household = 1751.34	306.3596 kWh per capita x 3.2 persons per household =980.3509
Basic Electricity Tariff	RMB/kWh		Block1: 0-260 kWh/pcm: 0.617 Block2: 261-400 kWh/pcm:0.622 Block3: 401+ kWh/pcm 0.917	Block1: 0-240 kwh/pcm 0.488 Block2: 241-400 kWh/pcm 0.493 Block3: 401+ kWh/pcm 0.3+ 0.488	Block1: 0-260 kWh/pcm 0.462 Block2: 261-400 kWh/pcm 0.467 Block3: 401+ kWh/pcm 0.762
Rate of Imported Electricity	Percentage		35%	99%	0% (-33% net exporter)
Initial Carbon Intensity of Energy Generation	MtCO$_2$/kWh		0.8[77]	0.95 [77]	0.998[77]

[76] An Employment Factor of 1 indicates that a carbon market has no impact on employment in the study area. An Employment Factor > 1 indicates that a carbon market has a positive impact on employment in the study area in terms of salaries and the creation of jobs. An Employment Factor < 1 indicates that a carbon market has a negative impact on employment in the study area in terms of salaries and job losses.

[77] According to statistics of the IEA, the carbon intensity of the electric power industry in China was 867 g/kWh in 2005, and dropped by 109 g/kWh to 758 g/kWh in 2010. In comparison Germany: 0.672220452 kg/kWh, United Kingdom: 0.508501975k g/kWh and United States: 0.547096737 kg/kWh.
Based on CO2 emissions from the power sector by region in 2010 using the consumer responsibility method Local electricity generation in Shanghai mainly in super-critical or ultra-critical coal plants. Electricity imported by

Variable Name	**Unit**		**Shanghai**	**Beijing**	**Shanxi**
Intervention- Scenario Specific Input					
Carbon Price	RMB/tCO_2	0 RMB to 300 RMB[78]			
Cost-Pass-Through Rate	Percentage	0-100			
General Input					
Income Elasticity Of Electricity Demand	/	Annual Income <25,000 RMB: -0.5 25,000 RMB<Annual Income<50,000 RMB: -0.4 50,000 RMB < Annual Income <100,000 RMB: -0.3 Annual Income>100,0000: -0.25			
Price Elasticity Of Electricity Demand	/	Annual Income <25000 RMB: 1.1 25,000 RMB<Annual Income<50,000 RMB: 1.2 50,000 RMB < Annual Income <100,000 RMB: 1.25 Annual Income>100,0000: 1.3			

Shanghai mainly generated from hydropower plants of Hubei and Sichuan. Beijing imported power via the North China grid, which is dominated by thermal power generation. Therefore, electricity consumed in Beijing is emission intensive. Generation capacity in Shanxi mainly based on coal and obsolete technology.

[78] Estimates of 'optimal carbon price' ranging from \$32/t CO_2 to \$220/t CO_2 (220RMB/t CO_2 to 1515 RMB/Mt CO_2). China specific studies suggest an optimal carbon price between 150RMB/t CO2 and 300 RMB/t CO2.

Appendix Table 6.D Simulation Output

Appendix Table 6.D1 Intervention Simulation Output for Shanghai

Annual Electrcity Consumption per Household (in Kwh)						Annual Household Income (in RMB)					Annual Household Expendiure for Electricity (in RMB)					Electricity Tariff (in RMB/kWh)				
	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035
SHGSC8	1935.55	2480.56	3394.74	4575.19	5381.01	65417.00	89580.58	115861.96	145980.20	179148.55	1194.23	2125.84	3079.03	4149.69	6225.83	0.6170	0.8570	0.9070	0.9070	1.1570
SHGSC7	1935.55	2949.65	4265.69	5318.32	7261.28	65417.00	94653.29	128106.97	168144.78	213986.00	1194.23	2019.04	3133.15	5235.89	7148.73	0.6170	0.6845	0.7345	0.9845	0.9845
SHGSC6	1935.55	3126.53	4647.32	6099.72	8523.67	65417.00	97274.29	134655.30	180367.64	233727.09	1194.23	2005.81	3213.83	5743.16	8025.43	0.6170	0.6416	0.6916	0.9416	0.9416
SHGSC5	1935.55	3278.39	5014.58	6732.11	9627.27	65417.00	99952.96	141502.89	193414.66	255187.81	1194.23	2022.77	3344.73	6173.34	8828.21	0.6170	0.6170	0.6670	0.9170	0.9170
SHGSC4	1935.55	2669.15	3642.94	4909.69	5664.72	65417.00	89580.58	115861.96	145980.20	179148.55	1194.23	1967.16	2866.99	3863.93	5874.31	0.6170	0.7370	0.7870	0.7870	1.0370
SHGSC3	1935.55	2890.31	4054.72	5425.94	6524.50	65417.00	92089.02	121846.29	156697.61	195833.67	1194.23	1904.71	2874.80	3846.99	6257.00	0.6170	0.6590	0.7090	0.7090	0.9590
SHGSC2	1935.55	3030.39	4375.52	5586.03	7626.80	65417.00	94653.29	128106.97	168144.78	213986.00	1194.23	1926.85	3000.92	5227.65	7137.49	0.6170	0.6358	0.6858	0.9358	0.9358
SHGSC1	1935.55	3168.38	4705.34	6150.72	8594.95	65417.00	97274.29	134655.30	180367.64	233727.09	1194.23	1954.89	3138.46	5640.21	7881.57	0.6170	0.6170	0.6670	0.9170	0.9170
SHGBL2	1935.55	2857.73	3885.39	4684.34	5878.83	65417.00	89580.58	115861.96	145980.20	179148.55	1194.23	1763.22	2591.55	4295.54	5390.89	0.6170	0.6170	0.6670	0.9170	0.9170
SHGBL1	1935.55	2857.73	3885.39	4684.34	5878.83	65417.00	89580.58	115861.96	145980.20	179148.55	1194.23	1763.22	2591.55	4295.54	5390.89	0.6170	0.6170	0.6670	0.9170	0.9170
SHGBAU	1935.55	2857.73	3885.39	4684.34	5878.83	65417.00	89580.58	115861.96	145980.20	179148.55	1194.23	1763.22	2591.55	4295.54	5390.89	0.6170	0.6170	0.6670	0.9170	0.9170

Annual Carbon Emissions in Mt						Annual NO_x Emissions					Annual Exported NO_x Emissions				
	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035
SHGSC8	13.91	18.31	25.72	35.60	42.99	55644.75	73223.08	102892.31	142384.83	171947.94	25040.13	32950.38	46301.54	64073.17	77376.57
SHGSC7	7.83	12.24	18.18	23.28	32.63	31300.17	48976.90	72725.73	93100.48	130517.61	14085.08	22039.61	32726.58	41895.22	58732.92
SHGSC6	5.69	9.44	14.41	19.41	27.86	22763.76	37755.54	57623.44	77657.70	111424.32	10243.69	16989.99	25930.55	34945.96	50140.94
SHGSC5	4.52	7.86	12.35	17.02	25.00	18084.54	31451.58	49396.31	68090.94	99981.59	8138.04	14153.21	22228.34	30640.92	44991.71
SHGSC4	13.91	19.70	27.60	38.20	45.25	55644.75	78789.88	110415.05	152794.94	181013.88	25040.13	35455.45	49686.77	68757.72	81456.24
SHGSC3	9.74	14.93	21.51	29.55	36.49	38951.32	59722.87	86027.14	118202.97	145941.53	17528.09	26875.29	38712.21	53191.34	65673.69
SHGSC2	8.74	14.05	20.83	27.30	38.27	34951.86	56187.82	83301.35	109195.42	153081.11	15728.33	25284.52	37485.61	49137.94	68886.50
SHGSC1	7.83	13.15	20.06	26.92	38.62	31300.17	52608.66	80221.38	107672.24	154489.56	14085.08	23673.90	36099.62	48452.51	69520.30
SHGBL2	11.22	17.00	23.74	29.38	37.86	44863.58	68012.59	94946.83	117536.73	151458.69	20188.61	30605.66	42726.07	52891.53	68156.41
SHGBL1	13.30	20.17	28.15	34.85	44.91	53210.29	80666.09	112611.34	139404.02	179637.05	23944.63	36299.74	50675.10	62731.80	80836.67
SHGBAU	13.91	21.09	29.44	36.45	46.96	55644.75	84356.70	117763.50	145781.98	187855.73	25040.13	37960.51	52993.57	65601.89	84535.08

Appendix Table 6.D2: Intervention Simulation Output for Beijing

	Annual Electrcity Consumption per Household (in Kwh)					Annual Household Income (in RMB)					Annual Household Expendiure for Electricity (in RMB)					Electricity Tariff (in RMB/kWh)				
	2015	**2020**	**2025**	**2030**	**2035**	**2015**	**2020**	**2025**	**2030**	**2035**	**2015**	**2020**	**2025**	**2030**	**2035**	**2015**	**2020**	**2025**	**2030**	**2035**
BJGSC8	1751.34	2098.80	2934.22	3977.01	4616.14	68989.00	99821.69	135102.05	177326.06	225670.38	854.65	1597.18	2203.60	2927.08	4690.00	0.49	0.76	0.75	0.74	1.02
BJGSC7	1751.34	2513.95	3725.35	4605.17	5954.69	68989.00	94472.00	122188.44	153951.25	188930.73	854.65	1582.53	2317.17	4188.40	5371.13	0.49	0.63	0.62	0.91	0.90
BJGSC6	1751.34	2736.73	4167.88	4861.34	6801.63	68989.00	102585.80	142007.92	190216.33	246489.38	854.65	1535.99	2323.60	4126.06	5747.38	0.49	0.56	0.56	0.85	0.85
BJGSC5	1751.34	2967.66	4642.28	5356.91	7660.92	68989.00	105410.75	149229.47	203975.78	269122.00	854.65	1463.06	2288.64	4221.25	6036.80	0.49	0.49	0.49	0.79	0.79
BJGSC4	1751.34	2347.32	3272.89	4426.07	4716.90	68989.00	94472.00	122188.44	153951.25	188930.73	854.65	1465.90	2035.74	2719.82	4254.64	0.49	0.62	0.62	0.61	0.90
BJGSC3	1751.34	2551.90	3667.28	5083.78	5398.71	68989.00	97117.42	128499.54	165253.88	206526.92	854.65	1432.25	2044.51	2815.14	4561.91	0.49	0.56	0.56	0.55	0.85
BJGSC2	1751.34	2706.49	4001.35	5280.82	5651.15	68989.00	99821.69	135102.05	177326.06	225670.38	854.65	1426.66	2101.71	2763.85	4614.16	0.49	0.53	0.53	0.52	0.82
BJGSC1	1751.34	2867.24	4358.61	4890.96	6834.76	68989.00	102585.80	142007.92	190216.33	246489.38	854.65	1413.55	2148.79	3854.08	5385.79	0.49	0.49	0.49	0.79	0.79
BJGBL2	1751.34	2584.13	3599.26	4850.90	4444.58	68989.00	94472.00	122188.44	153951.25	188930.73	854.65	1273.98	1774.43	2391.49	3502.33	0.49	0.49	0.49	0.49	0.79
BJGBL1	1751.34	2584.13	3599.26	4850.90	4444.58	68989.00	94472.00	122188.44	153951.25	188930.73	854.65	1273.98	1774.43	2391.49	3502.33	0.49	0.49	0.49	0.49	0.79
BJGBAU	1751.34	2584.13	3599.26	4850.90	4444.58	68989.00	94472.00	122188.44	153951.25	188930.73	854.65	1273.98	1774.43	2391.49	3502.33	0.49	0.49	0.49	0.49	0.79

	Annual Carbon Emissions (in Mt)					Annual NO_x Emissions					Annual Exported NO_x Emissions				
	2015	**2020**	**2025**	**2030**	**2035**	**2015**	**2020**	**2025**	**2030**	**2035**	**2015**	**2020**	**2025**	**2030**	**2035**
BJGSC8	14.92	17.31	23.37	30.47	33.89	59673.99	69252.78	93469.59	121881.62	135570.67	59077.25	68560.26	92534.89	120662.80	134214.97
BJGSC7	14.92	20.74	29.67	35.28	43.72	59673.99	82951.45	118670.97	141132.53	174882.31	59077.25	82121.93	117484.26	139721.20	173133.48
BJGSC6	14.92	22.58	33.19	37.25	49.94	59673.99	90302.23	132767.75	148983.23	199755.75	59077.25	89399.21	131440.08	147493.41	197758.19
BJGSC5	14.92	24.48	36.97	41.04	56.25	59673.99	97922.22	147879.61	164170.89	224992.00	59077.25	96943.00	146400.81	162529.19	222742.08
BJGSC4	14.92	19.36	26.06	33.91	34.63	59673.99	77453.16	104257.89	135643.75	138529.72	59077.25	76678.63	103215.31	134287.31	137144.42
BJGSC3	14.92	21.05	29.21	38.95	39.64	59673.99	84203.59	116821.12	155800.22	158553.77	59077.25	83361.55	115652.91	154242.22	156968.23
BJGSC2	14.92	22.33	31.87	40.46	41.49	59673.99	89304.55	127462.78	161838.78	165967.59	59077.25	88411.51	126188.16	160220.39	164307.92
BJGSC1	14.92	23.65	34.71	37.47	50.18	59673.99	94608.63	138843.30	149891.11	200728.78	59077.25	93662.54	137454.86	148392.20	198721.50
BJGBL2	14.92	21.32	28.66	37.17	32.63	59673.99	85267.05	114654.25	148663.34	130532.18	59077.25	84414.38	113507.71	147176.72	129226.86
BJGBL1	14.92	21.32	28.66	37.17	32.63	59673.99	85267.05	114654.25	148663.34	130532.18	59077.25	84414.38	113507.71	147176.72	129226.86
BJGBAU	14.92	21.32	28.66	37.17	32.63	59673.99	85267.05	114654.25	148663.34	130532.18	59077.25	84414.38	113507.71	147176.72	129226.86

Appendix Table 6.D3 Intervention Simulation Output for Shanxi

	Annual Electrcity Consumption per Household (in Kwh)					Annual Household Income (in RMB)					Annual Household Expendiure for Electricity (in RMB)					Electricity Tariff (in RMB/kWh)				
	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035
SHXSC12	980.35	1071.46	1234.15	1493.69	1921.98	23876.00	25885.90	29410.19	34855.37	43409.99	452.92	495.01	570.18	690.08	887.95	0.4620	0.4620	0.4620	0.4620	0.4620
SHXSC11	980.35	728.99	839.68	1016.26	1307.66	23876.00	25885.90	29410.19	34855.37	43409.99	452.92	555.05	639.33	773.78	995.65	0.4620	0.7614	0.7614	0.7614	0.7614
SHXSC10	980.35	741.20	832.93	940.80	1071.73	23876.00	26219.13	29130.13	32475.39	36428.52	452.92	564.35	634.19	716.33	816.02	0.4620	0.7614	0.7614	0.7614	0.7614
SHXSC9	980.35	1000.12	1123.89	1269.44	1446.11	23876.00	26219.13	29130.13	32475.39	36428.52	452.92	537.07	603.53	681.69	776.56	0.4620	0.5370	0.5370	0.5370	0.5370
SHXSC8	980.35	1042.05	1151.62	1278.08	1428.47	23876.00	25873.60	28320.93	31091.20	34313.71	452.92	507.79	561.19	622.81	696.10	0.4620	0.4873	0.4873	0.4873	0.4873
SHXSC7	980.35	1055.34	1147.02	1250.87	1371.89	23876.00	25531.70	27532.00	29762.20	32315.84	452.92	487.57	529.93	577.90	633.81	0.4620	0.4620	0.4620	0.4620	0.4620
SHXSC6	980.35	1071.46	1234.15	1493.69	1921.98	23876.00	25885.90	29410.19	34855.37	43409.99	452.92	495.01	570.18	690.08	887.95	0.4620	0.4620	0.4620	0.4620	0.4620
SHXSC5	980.35	900.22	1036.91	1254.97	1614.82	23876.00	25885.90	29410.19	34855.37	43409.99	452.92	550.66	634.28	767.67	987.78	0.4620	0.6117	0.6117	0.6117	0.6117
SHXSC4	980.35	913.93	1027.03	1160.04	1321.48	23876.00	26219.13	29130.13	32475.39	36428.52	452.92	559.05	628.23	709.60	808.35	0.4620	0.6117	0.6117	0.6117	0.6117
SHXSC3	980.35	1028.25	1155.49	1305.14	1486.78	23876.00	26219.13	29130.13	32475.39	36428.52	452.92	527.10	592.33	669.05	762.16	0.4620	0.5126	0.5126	0.5126	0.5126
SHXSC2	980.35	1046.31	1156.34	1283.31	1434.31	23876.00	25873.60	28320.93	31091.20	34313.71	452.92	505.96	559.16	620.56	693.58	0.4620	0.4836	0.4836	0.4836	0.4836
SHXSC1	980.35	1055.34	1147.02	1250.87	1371.89	23876.00	25531.70	27532.00	29762.20	32315.84	452.92	487.57	529.93	577.90	633.81	0.4620	0.4620	0.4620	0.4620	0.4620
SHXBL2	980.35	1151.71	1383.76	1678.40	2067.55	23876.00	27638.38	32579.09	38607.82	46191.58	452.92	532.09	639.30	775.42	955.21	0.4620	0.4620	0.4620	0.4620	0.4620
SHXBL1	980.35	1151.71	1383.76	1678.40	2067.55	23876.00	27638.38	32579.09	38607.82	46191.58	452.92	532.09	639.30	775.42	955.21	0.4620	0.4620	0.4620	0.4620	0.4620
SHXBAU	452.92	532.09	639.30	775.42	955.21	23876.00	27638.38	32579.09	38607.82	46191.58	452.92	532.09	639.30	775.42	955.21	0.4620	0.4620	0.4620	0.4620	0.4620

	Annual Carbon Emissions (in Mt)					Annual NO_x Emissions					Annual Exported NO_x Emissions				
	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035
SHXSC12	1.98	2.21	2.59	3.20	4.20	7911.43	8820.97	10365.20	12797.91	16799.52	0.00	0.00	0.00	0.00	0.00
SHXSC11	6.58	4.99	5.87	7.24	9.51	26318.70	19965.04	23460.18	28966.30	38023.37	0.00	0.00	0.00	0.00	0.00
SHXSC10	6.58	5.07	5.82	6.70	7.79	26318.70	20299.66	23271.66	26815.55	31163.28	0.00	0.00	0.00	0.00	0.00
SHXSC9	3.30	3.43	3.93	4.53	5.27	13185.72	13722.83	15731.94	18127.66	21066.79	0.00	0.00	0.00	0.00	0.00
SHXSC8	2.22	2.41	2.72	3.08	3.51	8897.03	9647.63	10877.05	12314.82	14041.34	0.00	0.00	0.00	0.00	0.00
SHXSC7	1.98	2.17	2.41	2.68	3.00	7911.43	8688.33	9633.48	10717.42	11991.35	0.00	0.00	0.00	0.00	0.00
SHXSC6	3.30	3.68	4.32	5.33	7.00	13185.72	14701.62	17275.33	21329.86	27999.20	0.00	0.00	0.00	0.00	0.00
SHXSC5	6.58	6.16	7.24	8.94	11.74	26318.70	24654.74	28970.87	35770.34	46954.87	0.00	0.00	0.00	0.00	0.00
SHXSC4	6.58	6.26	7.17	8.27	9.61	26318.70	25030.23	28694.81	33064.55	38425.47	0.00	0.00	0.00	0.00	0.00
SHXSC3	4.45	4.76	5.46	6.29	7.31	17800.72	19046.79	21835.37	25160.53	29239.92	0.00	0.00	0.00	0.00	0.00
SHXSC2	3.79	4.13	4.65	5.27	6.01	15163.58	16510.15	18614.08	21074.55	24029.17	0.00	0.00	0.00	0.00	0.00
SHXSC1	3.30	3.62	4.01	4.47	5.00	13185.72	14480.55	16055.80	17862.36	19985.59	0.00	0.00	0.00	0.00	0.00
SHXBL2	5.19	6.22	7.63	9.44	11.86	20767.51	24889.49	30507.03	37748.91	47438.68	0.00	0.00	0.00	0.00	0.00
SHXBL1	6.20	7.43	9.10	11.26	14.16	24789.16	29709.36	36414.74	45059.01	56625.22	0.00	0.00	0.00	0.00	0.00
SHXBAU	6.58	7.89	9.67	11.96	15.03	26318.70	31542.49	38661.61	47839.25	60119.12	0.00	0.00	0.00	0.00	0.00

Appendix Table 6.E Validity Test of the System Dynamic Model Key Input and Output Variables

Appendix Table 6.E1 Input Variables for the Model Validity Test (2005-2015)

Variable Name	Unit	China
Initial Population	Number of People	1,376,048,940
Persons per Household	Number of People	2.97
Annual Population Growth Rate	Percentage	0.5
Annual GDP Growth Rate	Percentage	10%->6.5%
Annual Household Income	RMB	13,789
Employment Factor	/	1.5 → 1
Initial Annual Electricity Consumption per Household	kWh	331.5
Basic Electricity Tariff	RMB/kWh	National average flat rate: 0.5
Initial Carbon Intensity of Energy Generation	MtCO2/kWh	1 [79]

Appendix Table 6.E2 Validity Test Key Output (2005-2015)[79]

Time (Year)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Annual Carbon Emissions (Model Simulation)	145.94	167.65	190.44	213.99	237.95	262.53	286.19	311.49	338.65	367.80	399.04
Total Annual CO2 (Reference)	188.55	208.77	224.80	241.50	255.82	280.60	311.22	320.65	327.99	329.07	324.82
Difference in %	0.23	0.20	0.15	0.11	0.07	0.06	0.08	0.03	-0.03	-0.12	-0.23

Average discrepancy between simulation output and reference CO_2 data is 13%.

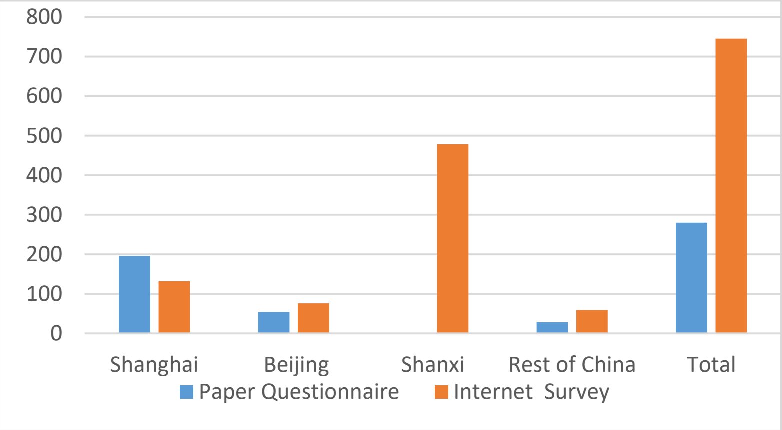
[79] Reference CO_2 data from The World Carbon Atlas (2017). Residential use of overall electricity generation 10% (see discussion in Chapter 1).

Appendix Table 7.A Demographic Profile of Survey Sample

Appendix Table 7.A1 Sample Size by Survey Method

	GROUP1: Shanghai	GROUP2: Beijing	GROUP3: Shanxi	GROUP4: Rest of China	Total	%
Paper Questionnaire	196	54	2	28	280	27.32%
Internet Survey	132	76	478	59	745	72.68%
Total	328	130	480	87	1025	100.00%

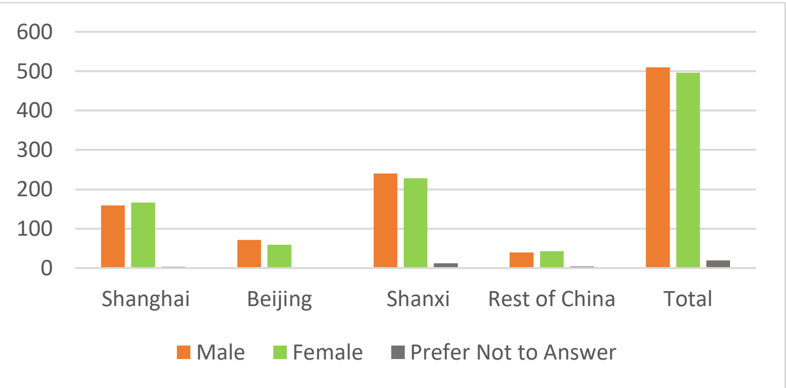
Diagram 7.A1 Sample Size by Survey Method (Number of Study Participants)



Appendix Table 7.A2 Sample Size by Gender (Number of Study Participants)

	GROUP1: Shanghai	GROUP2: Beijing	GROUP3: Shanxi	GROUP4: Rest of China	Total	%
Male	159	71	240	40	510	49.76%
Female	166	59	228	43	496	48.39%
Prefer Not to Answer	3	0	12	4	19	1.85%
Total	328	130	480	87	1025	100.00%

Diagram 7.A2 Sample Size by Gender (Number of Study Participants)



Appendix Table 7.A3 Sample Size by Age

	GROUP1: Shanghai	GROUP2: Beijing	GROUP3: Shanxi	GROUP4: Rest of China	Total	%
18-25 years	131	37	235	28	431	42.05%
26 -35 years	88	43	189	20	340	33.17%
36-50 years	62	23	30	23	138	13.46%
51-65 years	18	7	5	4	34	3.32%
66+ years	12	9	1	2	24	2.34%
Prefer Not to Answer	17	11	20	10	58	5.66%
Total	328	130	480	87	1025	100.00%

Diagram 7.A3 Sample Size by Age (Number of Study Participants)

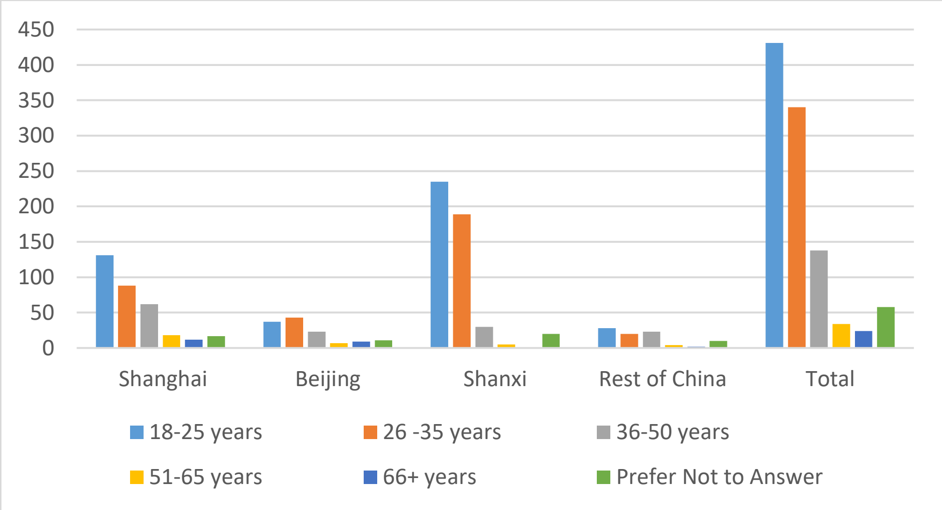


Table 7.A4 Sample Size by Educational Background

Junior High School and below	23	9	2	0	34	3.32%
Senior High School and Vocational College	65	12	40	5	122	11.90%
College	43	5	56	4	108	10.54%
Undergraduate Degree	96	67	235	50	448	43.71%
Post Graduate Degree	78	28	123	17	246	24.00%
Prefer Not to Answer	23	9	24	11	67	6.54%
Total	328	130	480	87	1025	100.00%

Diagram 7A.4 Sample Size by Educational Background (Number of Study Participants)

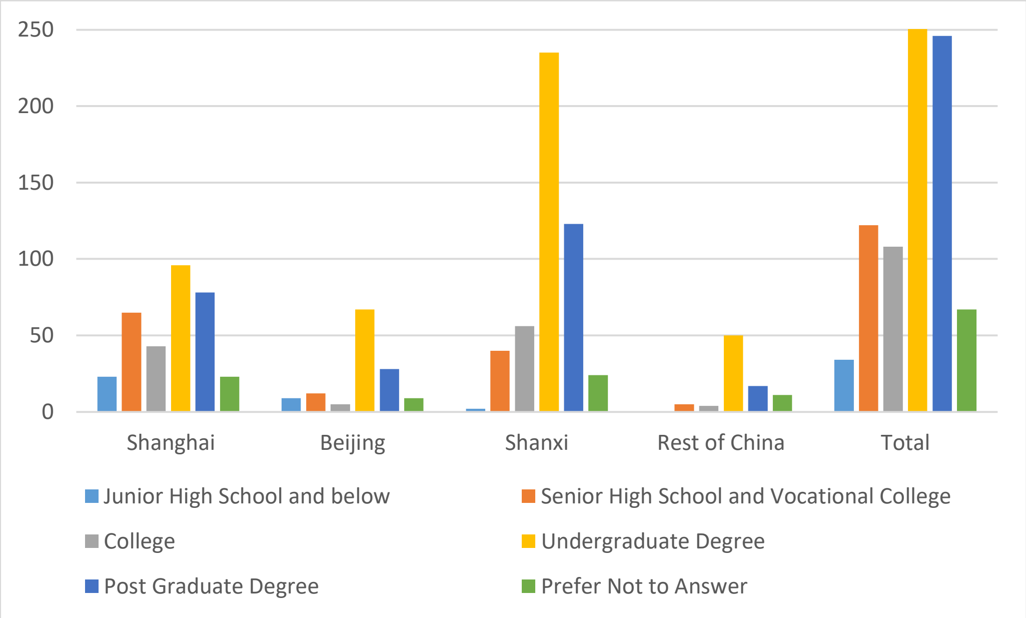
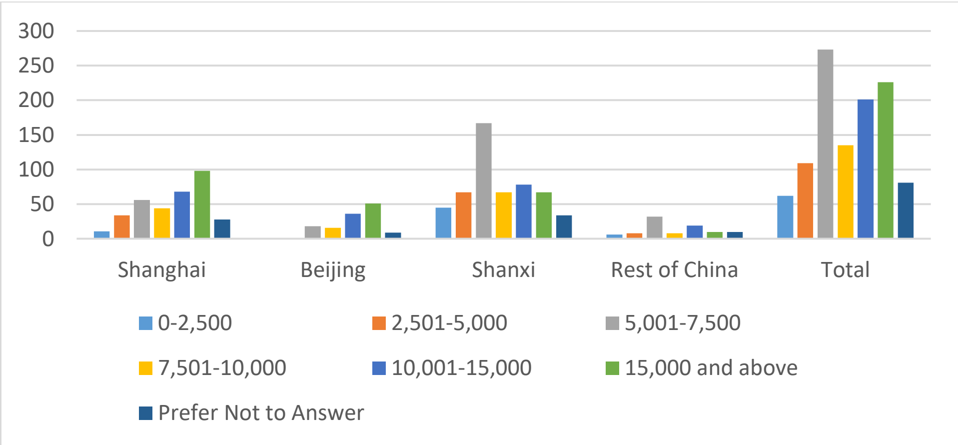


Table 7.A5 Sample Size by Monthly Household Income in RMB

	GROUP1: Shanghai	GROUP2: Beijing	GROUP3: Shanxi	GROUP4: Rest of China	Total	%
0-2,500 RMB	11	0	45	6	62	6.05%
2,501-5,000 RMB	34	0	67	8	109	10.63%
5,001-7,500 yuan	56	18	167	32	273	26.63%
7,501-10,000 yuan	44	16	67	8	135	13.17%
10,001-15,000	68	36	78	19	201	19.61%
15,000 and above	98	51	67	10	226	22.05%
Prefer Not to Answer	28	9	34	10	81	7.90%
Total	328	130	480	87	1025	100.00%

Diagram 7.A5 Sample Size by Monthly Household Income in RMB (Number of Study Participants)



Appendix Table 7.B Regional Performance Matrices for Intervention Scenarios

Appendix Table 7.B1 Performance Matrices for Intervention Scenarios - Shanghai

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Accumulated Household Wealth (RMB)																					
SHG SC7	0	64222.77	133758.3	208871	289714.7	376411	469045.2	567662.8	672398.8	783623.6	901594.9	1026569	1158799	1298534	1445189	1600791	1763700	1934998	2114896	2303592	2501273
SHG SC5	0	64222.77	134680.4	211660.3	295418.9	386175.6	484105.8	589208.5	701984.5	822824.8	952124.9	1090283	1236848	1392998	1559125	1735618	1922859	2121223	2331075	2552765	2786630
SHG SC4	0	64222.77	132867.5	206170	284204.3	367018.4	454631.8	547033.8	644383.4	746837.6	854429.3	967424.3	1085970	1210209	1340278	1476309	1618425	1765927	1920674	2080954	2247692
SHG BL2	0	64222.77	133017.8	206483.3	284693.8	367697.8	455515.2	548135.4	645718.5	748300.5	856150.6	969421	1088260	1212810	1343210	1479592	1621276	1770123	1924447	2085163	2252360
SHG BAU	0	64222.77	133017.8	206483.3	284693.8	367697.8	455515.2	548135.4	645718.5	748300.5	856150.6	969421	1088260	1212810	1343210	1479592	1621276	1770123	1924447	2085163	2252360
Exported PM Air Pollution (t NOx)																					
SHG SC7	14085.08	15060.55	16655.86	18353.75	20150.34	22039.61	24013.23	25610.66	27835.07	30205.48	32726.58	35402.62	38237.48	37340.9	43036.91	41895.22	44965.89	48185.41	51553.73	55070.09	58732.92
SHG SC5	8138.043	9162.968	10276.88	11480.6	12773.5	14153.21	15269.36	16817.1	18488.84	20290.62	22228.34	21814.28	23812.23	25946.63	28221.62	30640.92	33207.72	35924.63	38793.58	41815.8	44991.71
SHG SC4	25040.13	25580.79	27891.48	30313.54	32838.49	35455.45	38151.01	41017.91	44063.97	46374.08	49686.77	53164.8	56809.99	60623.59	64606.2	68757.72	66546.18	75422.79	72797.7	77057.63	81456.24
SHG BL2	20188.61	22081.71	24076.34	26167.09	28346.67	30605.66	32932.52	35407.26	37169.01	39877.46	42726.07	45716.86	48851.39	52130.74	55555.41	52891.53	60526.18	57466.33	60911.6	64476	68156.41
SHG BAU	25040.13	27388.17	29862.12	32455.31	35158.66	37960.51	40846.53	43915.98	46101.1	49460.42	52993.57	56703.07	60590.87	64658.28	68905.95	65601.89	75071.23	71276.06	75549.27	79970.22	84535.08
Local Air Pollution (t NOx)																					
SHG SC7	17215.09	18407.34	20357.17	22432.37	24628.19	26937.3	29349.51	31301.92	34020.64	36917.82	39999.16	43269.87	46734.7	45638.88	52600.67	51205.27	54958.32	58893.27	63010.12	67307.9	71784.69
SHG SC5	9946.498	11199.18	12560.63	14031.85	15612.06	17298.37	18662.55	20554.23	22597.47	24799.65	27167.97	26661.9	29103.84	31712.55	34493.09	37450.02	40587.21	43907.88	47414.38	51108.21	54989.88
SHG SC4	30604.61	31265.41	34089.59	37049.88	40135.94	43334.44	46629.02	50133	53855.96	56679.43	60728.28	64979.2	69434.43	74095.5	78963.13	84037.22	81334.23	92183.41	88974.97	94181.55	99557.63
SHG BL2	24674.97	26988.77	29426.63	31982	34645.93	37406.92	40250.86	43275.54	45428.79	48739.13	52220.76	55876.16	59707.26	63715.35	67901.07	64645.2	73976.45	70236.63	74447.52	78804	83302.28
SHG BAU	30604.61	33474.43	36498.15	39667.6	42971.7	46396.18	49923.54	53675.09	56345.79	60451.63	64769.93	69303.76	74055.51	79026.8	84218.38	80180.09	91753.73	87115.19	92338.01	97741.39	103320.7

Appendix Table 7.B2 Performance Matrices for Intervention Scenarios - Beijing

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Accumulated Household Wealth (RMB)																					
BJG SC7	0	68134.34	141918.6	221629.1	307430.5	399453.4	497780.3	602469.3	713796.1	832036.8	957467.1	1090361	1230991	1379624	1536523	1701062	1875449	2057915	2250785	2452133	2663103
BJG SC5	0	68134.34	142892	224579.6	313471.6	409792.8	513740.5	625451.4	745337.6	873817.5	1011315	1158255	1315068	1481270	1659338	1847588	2047342	2259006	2482972	2719619	2969313
BJG SC4	0	68134.34	140964.4	218743	301549.6	389436	482423.7	580493.3	683823	792581.5	906934.4	1027044	1153068	1285160	1423466	1568127	1719276	1877039	2041532	2211968	2390411
BJG BL2	0	68134.34	141125.8	219079.4	302075.4	390165.9	483364	581667.6	685247.9	794274	908912.6	1029327	1155675	1288111	1426782	1571831	1723391	1880754	2045920	2217106	2396335
BJG BAU	0	68134.34	141125.8	219079.4	302075.4	390165.9	483364	581667.6	685247.9	794274	908912.6	1029327	1155675	1288111	1426782	1571831	1723391	1880754	2045920	2217106	2396335
Exported Air Pollution (t NOx)																					
BJG SC7	28266.63	29781.32	32925.15	36270.29	39808.91	43417.78	47292.75	51434.58	55852.05	60554.34	65550	70846.8	76451.64	82370.42	75859.73	89190.44	81884.29	95967.91	87833.43	93740.83	99886.72
BJG SC5	16959.98	19090.73	21406.34	23908.54	26517.33	29376.67	32382.88	35633.48	39140.8	42916.91	46973.52	51321.85	46820.63	56185.22	51078.31	55407.68	59995.79	64846.67	69963.11	75346.59	80997.13
BJG SC4	56420.18	55391.17	60369.57	65585.42	71020.07	76649.58	82256.83	88404.91	94888.93	101712.5	108881	116398.6	124268.4	132492.1	141070.1	150001.2	159282.6	168910	155808.2	179344.4	164983.7
BJG BL2	44519.94	48673.87	53048.54	57631.86	62407.44	67147.81	72224.44	77622.66	83315.89	89307.23	95601.41	102202.1	109112.1	116332.8	123864.6	131706.4	116346	136354.9	120123.6	140402.6	123352.9
BJG BAU	56420.18	61684.46	67228.5	73036.95	79089.05	85096.52	91530.14	98371.34	105586.4	113179.2	121155.8	129520.9	138278	147428.8	156973.8	166911.8	147445.5	172802.8	152232.8	177932.5	156325.3
Local Air Pollution (t NOx)																					
BJG SC7	3140.737	3309.036	3658.351	4030.033	4423.213	4824.199	5254.751	5714.955	6205.785	6728.262	7283.335	7871.868	8494.629	9152.271	8428.86	9910.051	9098.257	10663.1	9759.272	10415.65	11098.53
BJG SC5	1884.442	2121.192	2378.482	2656.505	2946.371	3264.075	3598.098	3959.277	4348.979	4768.547	5219.282	5702.429	5202.294	6242.804	5675.37	6156.411	6666.201	7205.188	7773.681	8371.845	8999.683
BJG SC4	6268.911	6154.576	6707.732	7287.271	7891.121	8516.622	9139.649	9822.77	10543.22	11301.39	12097.89	12933.18	13807.6	14721.35	15674.46	16666.8	17698.07	18767.78	17312.03	19927.16	18331.53
BJG BL2	4946.661	5408.209	5894.284	6403.542	6934.162	7460.87	8024.939	8624.743	9257.323	9923.028	10622.38	11355.8	12123.57	12925.87	13762.74	14634.05	12927.34	15150.55	13347.07	15600.3	13705.88
BJG BAU	6268.911	6853.832	7469.835	8115.219	8787.675	9455.172	10170.02	10930.15	11731.82	12575.47	13461.76	14391.22	15364.22	16380.98	17441.54	18545.76	16382.84	19200.31	16914.76	19770.28	17369.49

Appendix Table 7.B3 Performance Matrices for Intervention Scenarios - Shanxi

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Accumulated Household Wealth (RMB)																					
SHX SC7	0	23423.08	47223.05	71455.3	96144.58	121316.8	146998.8	173219	199992.3	227334	255259.9	283786.5	312930.6	342709.6	373141.5	404244.7	436038.4	468542.3	501785.8	535799.6	570615.8
SHX SC5a	0	23423.08	47138.38	71192.15	95634.84	120521.5	145912.4	171873.4	198460.4	225732.9	253754.8	282594.8	312326.8	343030.5	374792	407704.7	441870	477398	514427.3	553111.1	593619.5
SHX SC5	0	23423.08	47138.38	71161.38	95508.06	120194.9	145239.1	170658.1	196460.2	222653.7	249247.1	276249.2	303668.9	331515.4	359798.1	388526.7	417711	447361.2	477493.4	508124.7	539272.3
SHX SC4	0	23423.08	47202.84	71414.46	96082.69	121233.4	146893.4	173091.2	199841.4	227159.5	255061.4	283563.3	312682.1	342435.2	372840.4	403916.4	435682.2	468157.5	501371.7	535355.4	570140.6
SHX BL2	0	23423.08	47489.05	72241.97	97728.61	123998.6	151104.9	179103.8	208030.7	237922.6	268818.3	300758.1	333784.2	367940.7	403273.6	439831.1	477663.5	516823.3	557382.9	599418.6	643011.6
SHX BAU	0	23423.08	47489.05	72241.97	97728.61	123998.6	151104.9	179103.8	208030.7	237922.6	268818.3	300758.1	333784.2	367940.7	403273.6	439831.1	477663.5	516823.3	557382.9	599418.6	643011.6
Exported Air Pollution (t NOx)																					
SHX SC7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHX SC5a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHX SC5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHX SC4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHX BL2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHX BAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local Air Pollution (t NOx)																					
SHX SC7	7911.433	8052.296	8211.674	8391.438	8593.673	8820.972	9076.153	9355.925	9662.392	9997.926	10365.2	10767.22	11207.38	11689.55	12218.07	12797.91	13434.73	14143	14932.18	15813.36	16799.52
SHX SC5a	13185.72	12418.75	12718.05	13034.38	13368.88	13722.83	14097.4	14485.04	14886.3	15301.73	15731.94	16177.56	16639.23	17117.65	17613.54	18127.66	18660.81	19219.78	19806.04	20421.14	21066.79
SHX SC5	7911.433	8052.296	8200.113	8355.172	8517.778	8688.334	8867.296	9051.132	9239.998	9434.059	9633.48	9838.44	10049.12	10265.71	10488.41	10717.42	10952.95	11197.68	11452.04	11716.45	11991.35
SHX SC4	26318.7	22651.61	23197.51	23774.51	24384.62	25030.23	25713.43	26420.48	27152.36	27910.11	28694.81	29507.6	30349.69	31222.31	32126.81	33064.55	34037.02	35056.57	36125.88	37247.83	38425.47
SHX BL2	20767.51	21481.31	22245.74	23065.02	23944.66	24889.49	25904.86	26971.14	28091.4	29268.87	30507.03	31809.62	33180.64	34624.39	36145.48	37748.91	39440	41244.75	43172.45	45233.33	47438.68
SHX BAU	26318.7	27223.3	28192.07	29230.34	30345.11	31542.49	32829.26	34180.57	35600.27	37092.48	38661.61	40312.38	42049.87	43879.54	45807.23	47839.25	49982.38	52269.53	54712.51	57324.27	60119.12

dAppendix Table 7.C Scenario Ratings and Scores by Region

SHANXI			Scenario Rating						Scenario Score					
Decision Criterion	Rank	Weight	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7
Environmental Quality	2	0.26	3	3	2	1	5	1	0.78	0.78	0.52	0.26	1.3	0.26
Household Wealth	1	0.37	1	2	2	5	4	3	0.37	0.74	0.74	1.85	1.48	1.11
Equity	1	0.37	2	3	2	3	5	3	0.74	1.11	0.74	1.11	1.85	1.11
								TOTAL SCORE	1.89	2.63	2	3.22	4.63	2.48

SHANGHAI			Scenario Rating						Scenario Score					
Decision Criterion	Rank	Weight	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7
Environmental Quality	2	0.34	2	3	2	5	5	3	0.68	1.02	0.68	1.7	1.7	1.02
Household Wealth	1	0.35	3	3	3	5	2	4	1.05	1.05	1.05	1.75	0.7	1.4
Equity	3	0.31	3	3	2	3	2	4	0.93	0.93	0.62	0.93	0.62	1.24
								TOTAL SCORE	2.66	3	2.35	4.38	3.02	3.66

BEIJING			Scenario Rating						Scenario Score					
Decision Criterion	Rank	Weight	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7
Environmental Quality	2	0.38	3	3	3	3	3	3	1.14	1.14	1.14	1.14	1.14	1.14
Household Wealth	1	0.27	3	3	3	5	2	4	0.81	0.81	0.81	1.35	0.54	1.08
Equity	3	0.35	3	3	2	3	2	4	1.05	1.05	0.7	1.05	0.7	1.4
								TOTAL SCORE	3	3	2.65	3.54	2.38	3.62

REST OF CHINA			Scenario Rating						Scenario Score					
Decision Criterion	Rank	Weight	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7	BAU	Scenario BL2	Scenario 4	Scenario 5	Scenario 5a	Scenario 7
Environmental Quality	2	0.32	2	3	2	5	5	3	0.64	0.96	0.64	1.6	1.6	0.96
Household Wealth	1	0.35	3	3	3	4	3	4	1.05	1.05	1.05	1.4	1.05	1.4
Equity	3	0.33	3	3	2	3	3	4	0.99	0.99	0.66	0.99	0.99	1.32
								TOTAL SCORE	2.68	3	2.35	3.99	3.64	3.68

Appendix Table 7.D Population Grouping by Pollution Levels and Energy Sector Profile (Population in 10,000)[80]

	Population Net-Electricity Importing Provinces			
	GROUP 1: Population Net-Electricity Importing Provinces Low to Medium Air Pollution PM 2.5 <=50 microgram/m^3	GROUP 2: Population Net-Electricity Importing Provinces High Air Pollution PM 2.5 >50 microgram/m^3	GROUP 3: Population Net-Electricity Exporting Provinces	GROUP 4: Population Remaining Provinces
Beijing		2171		
Tianjin	1547	1547		
Hebei	7425	7425		
Shanxi			3664	
Inner Mongolia			2511	
Liaoning	4382			
Jilin			2753	
Heilong			3312	
Shanghai	2415			
Jiangsu		7976		
Zheijiang	5539			
Anhui				6144
Fujian				3839
Jiangxi	4566			
Shangdong				9847
Henan		9480		
Hubei				5852
Hunan	6783			
Guangdong	10849			
Guangxi	4796			
Hainan				911
Chongqing		3017		
Sichuan			8204	
Giuizhou			3370	
Yunnan			4542	
Tibet				324
Shaanxi			3663	
Gansu				2600
Qinghai				588
Ningxia				668
Xinjiang				2360
TOTAL	48302	31616	32019	25151
%	0.35	0.23	0.23	0.18

[80] Population size (NSBC 2016); Provincial electricity import/export status (Mei and Sheng, 2014); Air pollution levels (Dong, 2016)

Survey - Attitudes towards Sustainable Energy Generation and Consumption

1. **Consider the following issues. What is the most import issue facing China today? Please select one option.**

- ☐ Consumption
- ☐ Environmental Pollution
- ☐ State of the Economy
- ☐ Food Safety
- ☐ Poverty
- ☐ Other

2. **How concerned are you about the economic future of China? Please select one option.**

- ☐ Very Concerned
- ☐ Concerned
- ☐ Mildly concerned
- ☐ Not concerned
- ☐ No opinion

3. **How concerned are you about environmental pollution in China? Please select one option.**

- ☐ Very Concerned
- ☐ Concerned
- ☐ Mildly concerned
- ☐ Not concerned
- ☐ No opinion

4. In general how serious do you think is the threat of environmental degradation relative to economic problems facing China? Please select one option.

- ☐ The current state of the economy is cause for great concern. In comparison pollution and environmental degradation only seem a small problem.
- ☐ Both are serious problems. However, environmental issues are considerably less serious than current economic problems.
- ☐ Environmental issues are as serious as current economic problems. Both are serious problems. However, environmental issues are much more serious than current economic problems.
- ☐ The current state of the environment is cause for great concern. In comparison the state of the economy seems are relatively small problem.
- ☐ No opinion

5. Consider the following issues. What is the most important environmental issue facing China today? Please select one.

- ☐ Water pollution
- ☐ Soil pollution
- ☐ Climate change
- ☐ Local air pollution
- ☐ No opinion

6. What activity do you think contributes most to environmental pollution? Please select one option.

- ☐ Commercial activity from industry and services
- ☐ Household consumption
- ☐ Electricity generation
- ☐ Transport
- ☐ No opinion

7. **How concerned are you about poverty and social exclusion? Please select one option.**

- ☐ Very Concerned
- ☐ Concerned
- ☐ Mildly concerned
- ☐ Not concerned
- ☐ No opinion

8. **Are you aware of social and economic inequality within your province? How serious of a problem do you believe social and economic inequality to be in your province? Please select one option concerned are you about poverty and social exclusion? Please select one option.**

- ☐ There is no inequality.
- ☐ There is some inequality, but I do not think there is a problem.
- ☐ There is moderate inequality. Some action might be desirable to address the problem in the future.
- ☐ There is severe inequality. Immediate action should be taken to resolve the issue.
- ☐ No opinion

9. **Are you aware of social and economic inequality between provinces? How serious of a problem do you believe social and economic inequality between eastern and central provinces? Please select one option.**

- ☐ There is no inequality.
- ☐ There is some inequality, but I do not think there is a problem.
- ☐ There is moderate inequality. Some action might be desirable to address the problem in the future.
- ☐ There is severe inequality. Immediate action should be taken to resolve the issue.
- ☐ No opinion

10. Should more affluent provinces help less well-off regions to develop and become better off? Please select one option.

- ☐ No. There is no difference in wealth between regions.
- ☐ No. Each province is responsible for itself.
- ☐ Yes. Rich provinces should provide some assistance as long as it does not impact their own development.
- ☐ Yes. The creation of an equitable society is the most important policy goal. Rich provinces have to provide assistance to poorer regions.
- ☐ No opinion.

11. What do you consider the most import aspect of electricity generation? Please select one option.

- ☐ Reliability of supply
- ☐ Affordability
- ☐ Low pollution
- ☐ No opinion

12. Electricity is vital for economic development. How strongly do you agree with the following statement: Cheap electricity for the commercial sector should be a priority even it means that the environment is polluted. Please select one option.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree
- ☐ No opinion

13. Electricity is vital for social development and wellbeing. How strongly do you agree with the following statement: Affordable electricity for households is a priority, even it means that the environment is polluted. Please select one option.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree
- ☐ No opinion

14. **Which is your preferred method of electricity generation. Please select one.**

- ☐ Coal – Cheap and reliable to meet demand but high emission responsible for air pollution and climate change.
- ☐ Gas – Moderate emissions, moderate cost and reliable.
- ☐ Nuclear – No emissions, reliable, medium cost but risk of radiation leaks with negative health impacts such as cancer and fatalities.
- ☐ Renewables – No emissions but more expensive than fossil fuel based electricity in the near future and potentially unreliable to meet demand
- ☐ No opinion.

15. Would you be prepared to pay more for clean energy? How much in % would be prepared to pay above your current electricity bill? Please select one option.

- ☐ Nothing extra.
- ☐ Increase of up to 10%
- ☐ Increase of up to 50%
- ☐ Increase of up to 100%
- ☐ Increase of above 100%
- ☐ No opinion

16. **Who should pay for environmental damage? Please rank in order of preference (1-3).**

__ Those who can afford it

__ The government

__ The generators of electricity and the manufacturing industry

__ The consumers of electricity and goods

☐ No opinion

17. **Please indicate your gender**

☐ Male

☐ Female

☐ Prefer not to say

18. **Please indicate your age**

☐ 18-25 years

☐ 26-35 years

☐ 36-50 years

☐ 51-65 Years

☐ 66 Years and above

☐ Prefer not to say

19. **Please indicate your educational status**

☐ Primary school degree

☐ Secondary school degree

☐ Vocational qualification

☐ Undergraduate university

☐ Postgraduate university

☐ Prefer not to say

20. What is the current monthly income of your household before taxes? Please select one of the options below.

- ☐ 0 RMB – 2,500 RMB
- ☐ 2,501 RMB -5,000 RMB
- ☐ 5,001 RMB – 7,500 RMB
- ☐ 7,501 RMB – 10,000 RMB
- ☐ 10,001 RMB – 15,000 RMB
- ☐ Above 15,000 RMB
- ☐ Prefer not to say

21. **Where are you originally from?** Please write city/district and province in the field below. If your place of origin is outside China, please also indicate the country.

____

22. Where do you currently live? If different from above, please write the city district as wells as province in the field below. If your current residence is outside China, please also indicate the country.

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List of Interviews

Expert Interviews in China				
ID	Date	Organisation Type	Area of Expertise	
1	May 2016	National NGO	Regional socio-economic disparities	In Person
2	May 2016	Social Enterprise	Community Development Poverty	In Person
3	June 2016	Academic Institution	Environmental Impact Assessment Sustainable cities	In Person
4	March 2015	Academic Institution	Economic development, Economic and environmental policy	In Person
5	June 2016	Academic Institution	Energy system China	In Person
6	May 2016	Municipal Governmental Organisation	Environmental regulation enforcement	In Person
7	June 2016	Academic Institution	Industry and energy generation	In Person
8	June 2016	Academic Institution U.S.	Sustainable production and consumption	In Person
9	July 2016	International NGO Private Company	Ecological innovation and start-ups in China	In Person
10a	August 2014	UK Governmental Organisation in China	Environmental Policy China	In Person
10b	March 2015			
11	June 2016	Academic Institution	Public opinion environmental issues (local water pollution)	In Person
12	June 2016	Not for Profit Business Agricultural Sector	Agriculture Urban migration	In Person
13	June 2016	Local NGO	Sustainable living Domestic reneweable energy policy (Home PV Plant)	In Person

Expert Interviews in China				
ID	Date	Organisation Type	Area of Expertise	
14	June 2016	International NGO	Regional Environmental Policy NGO-Government Collaboration	In Person
15	July 2016	Private Company Waste Water Treatment	Environmental stresses consumer society	In Person
16	July 2015	Academic Institution	Environmental governance China and international	In Person
17	June 2016	Research Institute	Governance system of China	In Person
18	June 2016	International NGO	Carbon Credits Sustainable development	Skype
19	June 2016	Energy Consultancy	Deployment of renewables	In Person
20	July 2016	National Governmental Organisation	Policymaking carbon control Carbon pricing	In Person
21	June 2016	International NGO	Inequality Poverty	In Person
22	June 2016	Academic Institution	Energy management Public Organisation	In Person
23a	March 2015	Carbon Market Pilot	Pilot market set up Carbon derivatives Training and cooperation with other pilot markets	In Person
23b	July 2015			
23c	June 2016			
23d	July 2016			
24	July 2016	NGO	Energy sector Social impacts of decarbonisation	In Person
25a	August 2014	Provincial Governmental Organisation	Policy making carbon control	In Person
25b	March 2015			
26a	June 2016	UK Governmental Organisation in China	Environmental policy China	In Person
26b	July 2016			
27	July 2016	Local NGO	Sustainable Living	In Person
28	July 2017	Academic Institution	China pollution and development Co-benefits approach	In Person

Expert Interviews in China

ID	Date	Organisation Type	Area of Expertise	
29	August 2014	Carbon Offset	Offset market	In Person
30	August 2014	Carbon Market Pilot	Pilot market set up MRV	Telephone
31a	August 2014	UK Governmental Organisation in China	Environmental Policy China	In Person
31b	March 2015			
31c	July 2015			
31d	June 2016			
32	June 2016	Municipal Government Affiliated Organisation	Provincial energy policy implementation	In Person
33	July 2016	Consultancy	Corporate Social Responsibility Consumer society	In Person
34	July 2016	National Non-Governmental Organisation	Urban Migration Inequality	In Person
35	June 2016	Academic Institution	Public opinion local environmental issues (waste incineration)	In Person
36	March 2015	Central Government	National carbon market design	In Person
37	May 2016	International NGO	Carbon Credits Sustainable development	Skype
38	May 2016	Academic Institution	Urban planning Water pollution	In Person
39	July 2016	International NGO	Energy sector and pollution	In Person
40	June 2016	Carbon Market Pilot	Carbon market design	In Person
41	March 2015	Air Pollutant Exchange Carbon Market Pilot	Market based solution air pollution and CO2 control	In Person

Expert Interviews in China				
ID	Date	Organisation Type	Area of Expertise	
42	June 2016	Start Up Company Air Pollution Consumer Product	Industrial policy	In Person
43	June 2016	Academic Institution	Sustainable Development	In Person
44	May 2016	National NGO	Environmental Education	In Person
45	June 2016	Carbon Market Pilot	Carbon market design	In Person
46	July 2016	PV Panel Manufacturer	Deployment of renewables	In Person
47	July 2015	International Stock Exchange	Corporate carbon disclosure	In Person

Expert Interviews outside of China				
ID	Date	Organisation Type	Area of Expertise	
48	July 2015	UK Government Department	UK energy and climate policy	In Person
49	December 2016	Academic Institution Belgium	China Carbon Market implementation	In Person
50	December 2016	U.S. Government Agency International Development	China environmental problems Citizen involvement	In Person
51	September 2016	UK Capital markets service provider	International carbon pilot analysis	In Person
52	October 2016	UK Power Company (Renewables)	Green energy Residential tariffs	Telephone
53	September 2016	European Power Company (Renewables and Fossil Fuel)	Power wholesale market	In Person
54	September 2016	UK Capital markets service provider	North American carbon market analysis	In Person

Expert Interviews outside of China				
ID	Date	Organisation Type	Area of Expertise	
55	December 2016	Academic Institution U.S.	International climate policy	In Person
56	September 2016	Capital markets service provider	China carbon pilot analysis	In Person

Residential Electricity Users Interviewed in China				
ID	Date	Location	Occupation	
57	July 2016	Shanghai Yangpu	Lecturer	In Person
58	July 2016	Shanghai Minghang	School Teacher	In Person
59	July 2016	Shanghai Xuhui	Professional International Company	In Person
60	July 2016	Shanghai Baoshan	Labourer	In Person
61	July 2016	Shanghai Minghang	Academic Researcher and Lecturer	In Person
62	July 2016	Beijing	Student	In Person
63	July 2016	Shanghai Yangpu	Retired	In Person
64	July 2016	Beijing	Professional International Hotel	In Person
65	July 2016	Shanghai Yangpu	Professional Finance	In Person
66	July 2016	Beijing	NGO Employee	In Person
67	July 2016	Nanjing (Jiangsu Province)	Government employee	In Person
68	July 2016	Baoding (Hebei Province)	Professional Governmental Organisation	In Person
69	July 2016	Shijiazhuang (Hebei Province)	Professional Retail Bank	In Person
70	July 2016	Shijiazhuang (Hebei Province)	Lecturer	In Person

Residential Electricity Users Interviewed in China				
ID	Date	Location	Occupation	
71	July 2016	Shanghai Zhabei District	Professional Horticulture	In Person
72	July 2016	Beijing	Student	In Person
73	July 2016	Souzhou (Jiangsu Provice)	Professional Financial Sector	In Person
74	July 2016	Shanghai Yangpu	Student	In Person
75	July 2016	Baoding (Hebei Province)	Labourer	In Person
76	July 2016	Baoding (Hebei Province)	Labourer	In Person
77	July 2016	Shanghai Pudong	Retired	In Person
78	July 2016	Shanghai Pudong	Professional Real Estate	In Person
79	July 2016	Shijiazhuang (Hebei Province)	Student	In Person