The crucial role of complementarity, transparency and adaptability for designing energy policies for sustainable development

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Abstract

The UN Sustainable Development Goals (SDGs) and the Paris Agreement have ushered in a new era of policymaking to deliver on the formulated goals. Energy policies are key to ensuring universal access to affordable, reliable, sustainable, and modern energy (SDG7). Yet they can also have

considerable impact on other goals. To successfully achieve multiple goals concurrently, policies need to balance different objectives and manage their interactions. Refining previously contemplated design principles, we identify three key principles - *complementary*, *transparency* and *adaptability* - as highly pertinent for multiple-objective energy policies based on a synthesis of seventeen coordinated policy case studies. First, policies should entail complementary measures and design provisions that specifically target non-energy objectives (*complementarity*). Second, policy impacts should be tracked comprehensively in both energy and non-energy domains to uncover diminishing returns and facilitate policy learning (*transparency*). Third, policies should be capable of adapting to changing objectives over time (*adaptability*). These principles are rarely considered in current policies, implying the need to mainstream them into the next generation of policymaking by pointing to best practices and new tools.

Key Words

Energy Policies, Sustainable Development, Adaptability, Complementarity, Transparency

1. Introduction

The adoption of the Sustainable Development Goals - SDGs (United Nations, 2015) and the Paris Climate Agreement (UNFCCC, 2015) are fundamentally changing the course of energy policy making. These frameworks formulate long-term aspirational goals, each of which aim to increase human well-being. However, the different goals often compete with each other, implying that different dimensions of well-being must be balanced. In fast-growing, poorer Asian countries, for example, growth is driving a coal renaissance that may jeopardize subsequent greenhouse-gas (GHG) emission reduction efforts (Steckel et al., 2015). In industrialized countries such as Germany, renewable energy policy is implemented to protect the climate, but also needs to align with industry interests and create jobs (Joas et al., 2016). Consequently, stakeholders worldwide are now turning their

attention to how to design policies to balance multiple objectives and manage their interactions. This also resonates with a gap in evidence-based research in this field, as identified by the scientific community (Carraro et al., 2015; Kowarsch et al., 2017).

Turning to policy design for managing multiple objectives is, in fact, a logical next step to mapping interactions, which has been the focus of research so far. After the new global frameworks were adopted in 2015, a new line of research was initiated with the development of a general framework for assessing the interrelationships between different SDGs (Nilsson et al., 2016). Employing a similar approach, interactions have by now been analyzed using integrated assessment models - IAMs (von Stechow et al., 2016; Iyer et al., 2018; Roelfsema et al., 2020). More recently, the specific interlinkages between the SDG on energy (SDG7) and other SDGs have been mapped using expert elicitations (Fuso Nerini et al., 2018) and literature reviews (McCollum et al., 2018). However, while mapping interactions has received considerable attention, little is known about how to actually manage them through suitable policy design. Yet increasing evidence from multiple-objective energy policy experiments worldwide, e.g. on overlaying renewable energy polices with socioeconomic objectives (Pahle et al., 2016), provides considerable opportunity to identify important lessons for designing such policies. Here, we draw such lessons based on a comprehensive coordinated policy case study activity, substantiating high-level principles for policy design and management more broadly.

2. Background and Literature Review

Earlier work on the effectiveness of energy policies has contemplated or alluded to various policy design principles, with a focus primarily on single-objective policies. We identified three of them as having a high conceptual overlap with our findings.

A first one is *adaptability*, i.e. adjusting policies in the face of changing circumstances and high uncertainties in order to achieve their intended purpose (Gifford, 1994; Rathmann, Szklo and

Schaeffer, 2012; Bizikova et al., 2018). More specifically, empirical research has shown that achieving effectiveness requires adapting to changing interaction with other policies, new government priorities, evolving energy systems, and the evolution of energy technologies (Grubb et al., 1995; Glachant, 2001; Åhman, 2006; Dubois, 2009; Byrnes et al., 2013).

A second principle is *transparency*, i.e. the provision of comprehensive and reliable information about how policies perform and are governed (Dawes, 2010). Empirical research finds that transparency positively affects effectiveness by helping citizens to engage in policy making, avoiding common policy failures and thus enhancing the potential for success, enabling accountability and the scaling up of policy pilots (Haas et al., 2004; Howlett, 2009; Mendonça et al., 2009; Rodrik, 2014; Nair & Howlett, 2015; Yoon & Sim, 2015). Relatedly, recent research finds that long-term observations and monitoring play an important role if policy impacts only materialize after years or even decades (Sullivan et al., 2018).

A final more tacit principle is what we refer to as *complementarity*, which incorporates the theoretical premise that the success of one policy depends at least in part on other policies (Malagueta et al., 2013; Peters, 2018), and has some overlap with comprehensiveness as identified in policy mix research (Sovacool, 2009). This seems to be particularly relevant for managing interactions between different SDGs in order to achieve co-benefits and avoid tradeoffs. This is a design principle that has recently also been reflected in the UN Agenda 2030 as part of Goal 17 (means of implementation), included under Target 17.14, to: “enhance policy coherence for sustainable development”. However, there is no further elaboration of what this target should be or how it ought to be monitored. As such, it remains unclear and is largely ignored because of its lack of specificity, or is dropped as a target altogether, and referred to only as a vague commitment (McCollum et al.,2018; and see also Figure A and Table A in Supplementary Materials). Within multi-objective policy design, complementarity has not been proposed in the context of managing goal interactions. This is also because empirical studies that focus on multiple objectives, for example in

the context of renewable policies (Lipp, 2007), are rare. In this work we take these principles as a starting point and refine them in the light of a synthesis of coordinated case studies we conducted.

3. Methodology

3.1 Overview

This work derives three high-level design principles for multiple objective policies by charting the seventeen case studies of energy and energy-related policies conducted in the Horizon 2020 project CD-LINKS (https://www.cd-links.org/). Both activities were planned jointly in form of a two-stage research design, and the authors of this work are also the lead authors of the seventeen case studies. While the charting results (case study profiles) are published exclusively as an Appendix to this work (see the Appendix), these seventeen case studies have also been published alongside as a project report on the European Commission's CORDIS portal (Pahle et al., 2017).

The first stage (case study research) started in the Fall of 2015 and included more than 30 researchers from several developing and developed countries. To ensure common purposes and facilitate synthesis, the case studies were coordinated using common guidelines. To the best of our knowledge, this makes it the first activity of this kind conducted at such scale. The primary aim was to build evidence that specifically serves the needs of the new global frameworks. Research on international goal architectures (Aldy, 2014) suggests that (a) fostering lesson learning and (b) creating policy transparency are essential for goal achievement. Accordingly, the case studies aimed to infer lessons from experiences on which policy makers in various countries can draw for designing policies (Rose, 1991). Special emphasis was put on multiple objectives and their interactions. This is particularly relevant for policies that aim to achieve SDGs and studies with such focus (Lipp, 2007) are rare.

The second stage (charting to derive design principles) began in early 2017 after the case studies had been finalized, and comprised the development of the charting framework, the production of case

study profiles, and several iterations of synthesis and refinement. The second-stage research team included all case study lead authors.

3.2 Methods & Approaches

The used methods and approaches included creating a common set of guidelines for conducting and coordinating the case studies, defining a set of criteria to select cases, setting up a process for reviewing and revising cases, and finally synthesizing findings from across cases specifically for this paper (see Table 1 in the Results and Discussion section). The underlying methodology is grounded theory (Glaser & Strauss, 2009), which is typically used when no suitable theoretical framework exists. It is inductive in the sense that it focuses efforts on analyzing theoretically sampled cases chosen to fill theoretical categories (Eisenhardt, 1989). Qualitative and quantitative data are collected preferably by multiple research teams with each assigned to cover some cases but not others (Pettigrew, 1990). The within-case analysis involves detailed case write-ups to make researchers intimately familiar with each case, which facilitates perspective cross-case analysis, in which emergent ideas and concepts are identified, refined and structured into categories. In other words, the intention of the guidelines was to gather as much policy information and data as possible and thus to enhance the potential for discovery, without fully knowing in advance what particular observations, themes, and insights could emerge from it[1]. The only exception to the inductive approach in our case was *a priori* determination of policy effectiveness in the narrower sense of target attainment, for which a dedicated framework was provided (see below). In the following, we describe the process in further detail.

3.3 Developing Common Guidelines

[1] Such an exploratory approach had already been taken in an earlier related study conducted in the CD-LINKS project (Pahle et al., 2016). However, in this work no elaborated guidelines were used and the focus was specifically on socioeconomic objectives.

In a first step, common guidelines were developed for the seventeen case studies. These served three basic purposes. First, they provided a common terminology and understanding of core concepts to be studied, given the diverse disciplinary and cultural backgrounds of the researchers involved. Second, they provided a common structure to facilitate convergence in findings and generate insights that can inform the new global frameworks. Third, they provided some degree of flexibility by keeping questions open-ended so that all aspects deemed relevant by the authors could be included and covered extensively. This left room to inductively generating unique insights and theory from the case studies. Although early identification of possible themes might prove helpful, we also recognize that they are at most tentative in such inductive case study research.

The common guidelines contain two parts. The first part is descriptive and comprises a conceptual policy model and an extended policy fact sheet. The second part is evaluative and is based on relatively broad questions related to policy effectiveness and other aspects likely to be relevant for policies and policy making in the context of the SDGs and the Paris Agreement. To help assess policy effectiveness, several potentially important constructs were included in the guidelines. These took the form of a comprehensive list of potential barriers and enabling factors based on a review of the literature. The full set of guidelines, including a detailed explanation of how the two parts relate to the specific purposes of the case study activity, can also be found in the comprehensive CD-LINKS project report (Pahle et al., 2017).

3.4 Selecting Cases

In a second step, theoretical, not statistical, sampling of case studies was conducted according to the following criteria. First, cases were meant to cover policies that typically have multiple objectives like renewable energy deployment, energy access, and efficiency policies, which are likely to extend emergent theory on policy development in the new global framework. Second, cases were meant to cover policies that are (a) relevant at the national level, e.g. important pillars of national strategies, and (b) suitable for learning due to their scale and high degree of policy innovation, so that the process of interest can be relatively well observed. Third, to assure high quality, cases were meant to

cover policies that are well known by the respective teams of researchers conducting the studies, so that they can draw on already existing expertise and practical knowledge.

Nearly all seventeen studies cover a single policy in a single country and thus fall under the classical (N=1) single-unit research design (Gerring, 2004). Two studies cover the same type of policy in more than one country, and are therefore focus more on breadth than on depth. Regarding coverage, altogether six types of policies (electrification, energy efficiency, renewable deployment, biofuels, agriculture/bioenergy, emission-trading schemes) were investigated in ten of the G20 members including five emerging economies (Brazil, China, India, South Korea and Russia) and five developed economies (former EU-28 as a block, France, Germany, Italy, and the USA). To also include Africa, a Moroccan policy was chosen as a further case. The studies were conducted by ten research teams from nine different countries and, with few exceptions, teams studied policies in their home countries.

3.5 Reviewing and Revising Cases

In a third step, the studies were conducted based on a comprehensive review of policy documents and data sources, public databases, gray literature, scientific publications, and in some cases also interviews[2]. In a first round, drafts were compiled and reviewed by at least one researcher, also involved in the activity, but from a team other than the authors own. Drafts and reviews were discussed among all involved researchers during a project meeting with the intention of tentatively identifying aspects of overarching importance across cases, and more broadly to refine and sharpen ideas and concepts in line with the requirements of grounded theory. A main outcome of this process was that case study data and information collated went well beyond lessons related to policy effectiveness in terms of target attainment, and a number of previously unexpected additional findings emerged. In a second round, the drafts were revised in light of the more refined

[2] Altogether, there are six sources of evidence typically used in case studies with different strengths and weaknesses (Yin, 2014).

understanding of key insights gained during the group discussions. This process of iterating toward findings that closely fits the data is considered as an important step to be taken after undertaking within- and cross-case analysis (Eisenhardt, 1989). The final versions of all seventeen case studies can be found in the comprehensive CD-LINKS project report (Pahle et al., 2017).

3.6 Synthesis

Specifically for the purposes of the cross-case analysis conducted for this paper, a technique for synthesizing and interpreting qualitative data called "charting" was used (Arksey & O'Malley, 2005). The method was originally developed as part of a qualitative data analysis approach for applied policy research (Ritchie & Spencer, 1994). This particular charting approach included two steps. In the first step, overarching key categories (issues, concepts and themes) were identified, according to which the case studies were examined and referenced. By doing so, a thematic framework was set up within which the case study material could be sifted and sorted (Ritchie & Spencer, 1994). For this, the policy cycle model (Howlett et al., 2009) proved particularly useful. It describes the process of policy making in four successive stages: (1) problem definition including a prioritization of objectives, (2) formulating and selecting proposals to achieve objectives, (3) implementing policies based on these proposals, and (4) evaluating policy outcomes in light of the original problem, objectives and policy targets. Stage 4 links back to Stage 1 creating a cycle, and a new cycle starts with revisiting the original problem in light of policy outcomes and of interim external developments.

Using the policy model as a framework for charting, the case studies revealed that the findings are more diverse than originally anticipated and cover different aspects of transparency and lesson learning. Using the policy cycle the following four categories of findings were identified (see Figure). The first category ("policy effectiveness & multiple objectives") corresponds to Stage 4 and its interlinkage to Stage 1 within a specific cycle in the model. Findings in this category comprise those relating to (a) if policies had reached their targets or not also considering additional effects on

climate and development objectives in a broader sense, and (b) which barriers and enabling factors were important in this regard. The second category ("policy change") corresponds to the evolution of a policy over cycles in the model. Findings in this category comprise how policies have changed over time in light of e.g. (a) earlier success and failure, (b) changing objectives or (c) external factors. The third key issue ("policy transparency") corresponds to Stage 4 in the model. Here, the focus was on findings related to how monitoring & evaluation (M&E) is handled, and whether its process is transparent enough to be revealed through the availability and quality of data. The fourth key issue ("policy lessons") covers learning in the model more broadly and thus cross-cuts the previous three categories. This category of findings comprises those related to experiences with policy effects or changes which were initially not anticipated or uncertain, or effects and changes that were expected but did not materialize.

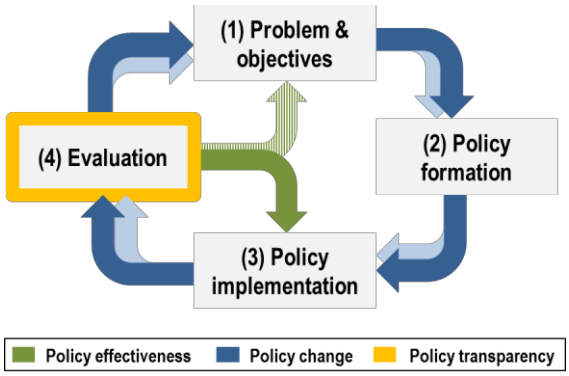

Figure 1: Categories of findings related to the policy cycle model; adapted from Howlett et al. (2009)

In the second step, the key categories of information identified in the first step were formulated as questions bundled in a questionnaire. The original case study authors were again asked to fill out these questionnaires to produce short targeted summaries (profiles) of each study. These profiles ("boxes") are included as an Appendix. These profiles serve as input for the category-wise cross-case synthesis conducted in this paper. This technique aggregates findings across a series of individual studies to identify common patterns through argumentative interpretation (Yin, 2014). In comparison to single case analysis, findings from such a synthesis are likely to be more robust. Importantly, because of the diversity of policies and contexts in this work, common

patterns typically only build on a subset of all studies, defining limits for generalizing lessons. Moreover, not all cases are equally rich in the novel insights they offer, among other reasons because data availability differed considerably across cases.

Importantly, what exactly can be learned from such a synthesis depends on the research strategy. As mentioned already, the strategy used in the CD-LINKS project was primarily exploratory and aimed at "detection" (Ritchie & Spencer, 1994), e.g. the identification of new policy approaches or specific policy experiences. The type of inference of such studies is descriptive, and the causal insights to be gained are about specific mechanisms, i.e. answering the question why a certain policy achieved an effect or not (Gerring, 2004).

4. Results and Discussion

In line with the needs of the new global frameworks, synthesizing lessons from our seventeen case studies (included in Supplementary Materials), we focused specifically on the design of multiple-objective policies – in contrast to most of the research reviewed here and other work on policy design that typically focuses on achieving single objectives (Aldy et al., 2010). Doing so, we also underline the important interlinkage between these principles, which has received relatively little attention yet in this context (Figure 2). The major contribution of our work is thus to deepen the understanding of how the principles are – or should be – reflected in current multiple-objective policy making, bringing them to policy makers' attention as evidence-based guidance for policy design (Howlett & Mukherjee, 2014). We elaborate on how these principles can be applied to reappraise the way current policies are designed and implemented, and thus to develop new solutions for transitioning to sustainable development in the energy domain and beyond.

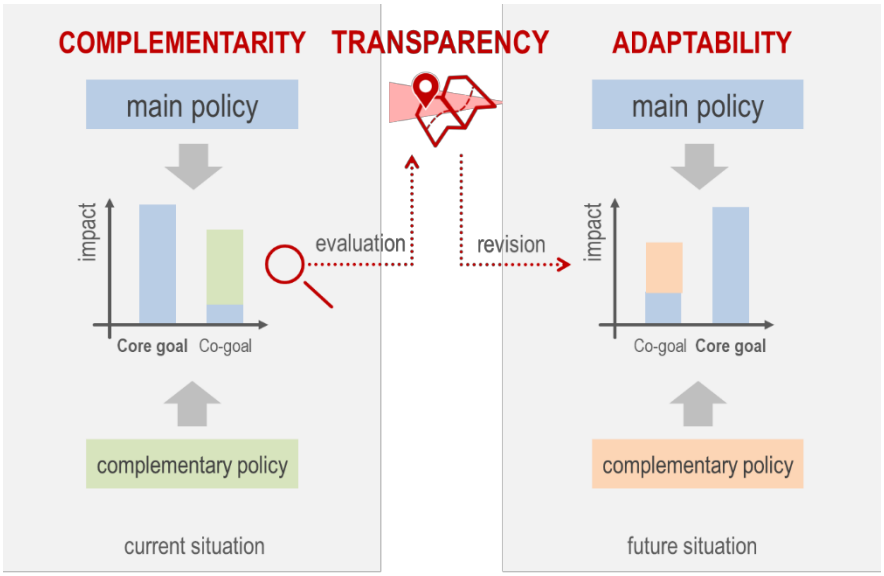

Figure 2: Three new design principles for multiple-objective energy policies. Case study findings (see Table 1) underpin the importance of three design principles to provide guidance for designing multiple-objective energy policies. *Complementarity* mandates consideration of measures and design provisions that specifically target non-energy objectives. *Transparency* mandates that policy impacts should be tracked comprehensively also in non-energy domains to uncover diminishing returns and facilitate policy learning. *Adaptability* mandates that policies should be capable of adapting to changing objectives and priorities over time.

Table 1 below shows how each one of our seventeen case studies performs in terms of Complementarity, Transparency and Adaptability, using a scale of "strong", "medium" and "weak".

Table 1. Representation and strength of the three new design principles for multiple-objective energy policies within the seventeen different case studies

	The three principles		
Case Studies	**Complementarity**	**Transparency**	**Adaptability**
1. Brazil's Low-carbon Agriculture Plan	Medium	Medium	Medium
2. Brazil's Biodiesel Program	Weak	Weak	Strong
3. Brazil's Rural Electrification Program	Strong	Strong	Medium
4. Brazil's Wind Energy Program	Strong	Strong	Strong
5. China's Biomass Power Policies	Medium	Medium	Medium
6. China's Green Lights Program	Strong	Strong	Strong
7. China's Wind Power Development Policy	Strong	Strong	Strong
8. France's Renewable Electricity Policy	Strong	Medium	Weak
9. Germany's Renewable Energy Act	Weak	Strong	Medium
10. India's National Solar Mission	Strong	Medium	Weak
11. India's Rural Electrification Program	Medium	Weak	Weak
12. Italy's Renewable Electricity Policy	Weak	Weak	Medium
13. Innovation in Agriculture – insights from the diffusion of hybrid corn in the USA and soybean in Brazil	Medium	Strong	Strong
14. Korea's New and Renewable Energy Policy	Weak	Medium	Weak

15. Morocco's National Rural Electrification Program	Weak	Weak	Strong
16. Russia's Energy Efficiency Policy	Strong	Strong	Weak
17. What can we learn from cap-and-trade? Empirical lessons for developing countries	Medium	Strong	Medium

A second major contribution of our work in comparison to the existing literature and related reviews (Karlsson et al., 2020) is methodological and relates to the coverage and selection of the case studies conducted and synthesized. As described in more detail in section 2, Methodology, in a first stage we conducted seventeen in-depth energy policy case studies – including some of the world's largest and long-lived policies and several national flagship measures – with a thematic focus on multiple objective policy design. Coherence between the studies was ensured through common guidelines we specifically developed for this activity. An overview of the selected cases and the research strategy is shown in Figure 3. In the second stage, we employed a "charting" approach to produce short structured summaries of the case studies (profiles), which are provided as an Appendix. Existing work on policy principles typically does not combine these two stages, and either focuses on (a) drawing lesson from one or a small number of policies or (b) reviewing such studies to synthesize overall findings. However, such syntheses are often fragmented because original case study designs were not coordinated and thematically streamlined as is in our case. So far only a few studies combine both stages with the aim of inferring policy lessons or principles, looking at e.g. EU emission standards (Glachant, 2001) or green industrial policies (Rodrik, 2014). These works, however, have put considerably less effort in conducting the case study in comparison to our work, both in terms of the depth of the investigation and the active involvement of national experts. Accordingly, our work is the first activity of this kind conduced at such a scale and comprehensiveness.

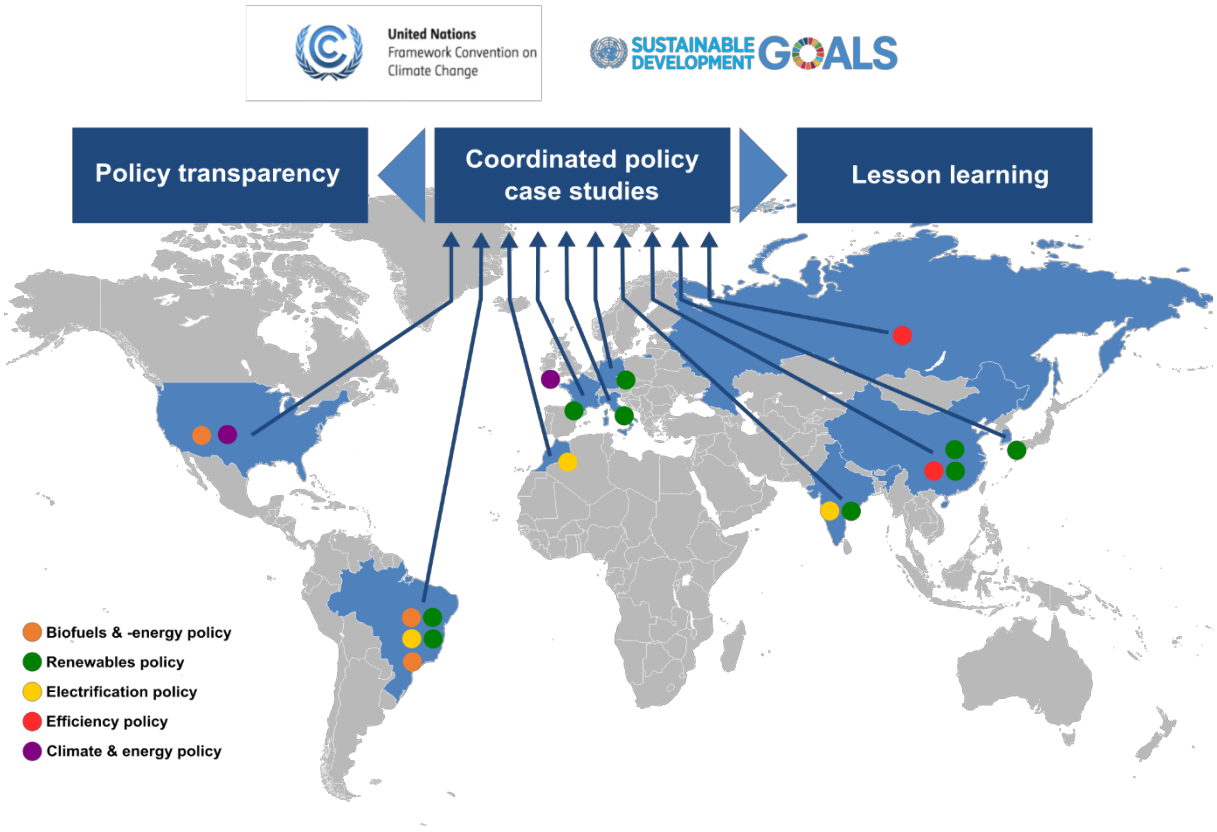

Figure 3: Selected cases and overall research strategy. Seventeen in-depth coordinated case studies of energy policies (many of them national flagship programs) were conducted to draw lessons and increase transparency (see Table 1 and Supplementary Materials). The aim was to build the evidence base to inform policymaking under the UNFCCC and the UN SDGs, with a specific focus on achieving multiple objectives. From the findings, three general high-level design principles for energy policies are synthesized.

4.1 Complementarity: Balancing impacts on multiple objectives

Perhaps the most pervasive design challenge is how to develop policies so that different objectives are achieved in accordance to their relative priority, while simultaneously accounting for the interactions between them (Keeney & Raiffa, 1993). The principle of complementarity resonates strongly with the integrated, equitable and inclusive spirit at the heart of the 2030 Agenda. It calls for designing policies to also ensure social protection of marginal groups that may be adversely impacted, and to facilitate social acceptance of reforms (Sterner, 2019). This requires understanding the distributional impacts of policies in addition to their potential interactions with other objectives. Conventional single-objective policy design primarily focuses on the choice of instruments, e.g. the use of prescriptive regulation vs. market-based instruments. However, this choice does little to

balance policy impacts across different objectives, begging the question how this can be accomplished and policies designed to achieve this.

Several of our case studies (see Table 1 and Supplementary Materials) suggest that companion policies and dedicated design features are essential to balance impacts and achieve additional objectives, especially in the socioeconomic domain. In fact, according to our assessment, 7 case studies present "strong" components of *complementarity*, 5 cases present "medium" components, and 5 cases present "weak" components.

For example, Brazil's biodiesel program aimed to achieve social inclusion by subsidizing small farmers to enable them to compete with large industrial suppliers (Rathmann, Szklo and Schaeffer, 2012). However, it had relatively little impact on social outcomes, as additional technical support, capacity building and infrastructure development programs in less-developed regions would have also been needed. In South Korea, the government implemented its renewable energy policy also with the aim of developing renewable technologies into competitive industries. But it focused relatively little on industrial policy elements, which eventually prevented the growth of a domestic industrial base and ensuing economic benefits. Likewise, the German renewable energy policy pursued job creation as a much-desired objective, but no specific provision was included to foster employment. Only fragmented and uncoordinated state policies subsidizing manufacturing capacity were implemented, which were insufficient in developing a competitive solar industry. In contrast, in the Indian National Solar Mission and the Brazilian Wind Energy Programs, job creation and domestic industry development were explicit policy objectives embedded in policy design. This was done through local content requirements, which mandate a certain share of used equipment to be sourced from domestic producers. While experiences with this feature in the two cases so far are mixed, they nevertheless directly tie job creation to energy policy making. The Chinese green lights case provides another such example, where a close symbiosis with industrial development policies resulted in building an essential technological foundation for the domestic efficient lighting industry. The fact

that such features and additional measures are rarely considered underlines the importance of "complementarity" as a first design principle.

4.2 Transparency: Thoroughly and persistently track impacts along all objectives

Pursuing multiple objectives makes evaluation, learning and responsive policy change (Hall, 1993) more complex. As effectiveness must be assessed along many dimensions, all policy choices need to be evaluated both individually and on their interactions to prevent lock-ins into inefficient policy pathways (Pierson, 2000). In addition, interactions may change over time, for example when market conditions change due to external factors (Pahle et al., 2016). This raises the question about suitable indicators and assessment approaches that are capable of comprehensively monitoring and tracking interactions.

A number of cases (see Table 1 and Supplementary Materials) suggest that, somewhat surprisingly, policy makers often put little attention into comprehensive monitoring and assessment. Even in the primary domain of energy-related objectives, the indicators employed are often one-dimensional, focus on short-term impacts, and data are of limited quality. According to our assessment, 8 case studies present "strong" components of *transparency*, 5 cases present "medium" components, and 4 cases present "weak" components.

For example, in both the Indian and Moroccan rural electrification programs, the measure of village or household electrification was a "one-time connection", considering neither potential subsequent disconnections nor the quality of electric supply. Consequently, while access in a technical sense was provided, the actual development benefits remained uncertain. Furthermore, in South Korea, the government was very active in monitoring the growth related indicators of its new and renewable energy policy, but virtually ignored assessing environmental and energy security impacts. In consequence, these dimensions received little attention in further policy development until recently. Likewise, in the Brazilian biodiesel program, both job and income creation were reported, but based

on unreliable data that basically left effect in these dimensions in the dark. For the sake of evading accountability for potential failures, the government sidelined thorough monitoring.

A subsequent in-depth review of the indicators used in the case studies also shows that types of impacts considered varied distinctly by type of policy. For e.g. energy access policies were more likely to consider impacts related to many of the social goals in the SDG set rather than those related to the economy or environment. On the other hand, renewable energy policies were more focused on assessing impacts related to economic and environmental goals within the SDG set. Overall though, tracking impacts along all objectives was found to be largely erratic and partial across most policies. Even in instances where certain impacts were identified in a policy, these were rarely evaluated and tracked. Indicators related to economic impacts of policies were more likely to be defined and assessed than those related to social or environmental impacts, in general.

These findings imply that unidimensional or unreliable monitoring hindered the opportunity to learn and harness complementary benefits. In contrast, in the case of Germany's energy transition, a process was institutionalized to track and evaluate impacts over time and along all policy objectives, including climate mitigation, job creation and energy security. A review of data related to these impacts published in the policy's annual reports has unveiled that climate and job creation impacts were strictly positive initially, but began diminishing and did not achieve set target levels more recently. These insights were instrumental in prompting policy reforms midcourse to rebalance objectives towards a higher priority on climate change. This example emphasizes the long-term benefit of thoroughly assessing policy impacts on all objectives, especially if the assessment reveals failures or diminishing outcomes along specific dimensions. The value of monitoring and evaluation as demonstrated by the German case emphasizes the need of *transparency* as a second design principle, and also points to the necessity to institutionalize a periodic and inclusive evaluation process that covers all relevant dimensions and not just energy alone.

4.3 Adaptability: Making policies capable of adapting to changing objectives

A final major challenge is how to design policies that are durable over long periods of time and robust across a range of different future developments (Patashnik, 2008; Carlson & Fri, 2013). This could be a particular concern for multiple objective policies, as policy makers may place emphasis on different objectives over the lifecycle of a policy, either because of shifting political regimes, changing constituent preferences, or new information that is made available over time. Intuitively, such changes may jeopardize the durability of a policy if it was originally designed to achieve different objectives.

Several cases (see Table 1 and Supplementary Materials) illustrate that objectives did indeed change over time, and adapting policies to the new socio-political environment is crucial to make them durable. According to our assessment, 6 case studies present "strong" components of *adaptability*, 6 cases present "medium" components, and 5 cases present "weak" components.

The Brazilian biodiesel program was originally conceived mainly as a social policy targeting small farmers, but their vegetable oil production proved insufficient to match demand, rendering the policy relatively ineffective (Rathmann, Szklo and Schaeffer, 2012). However, once the program was already in place, policy makers in Brazil became increasingly concerned about securing energy supply and addressing climate change. Seizing the opportunity, they changed the focus of the biodiesel program to these objectives by expanding to industrial farms, and the policy eventually became successful in these dimensions. Similarly, in Germany, renewable energy support was originally implemented primarily to develop clean technologies as an alternative to nuclear power. Yet by now basically all targeted technologies have become mature and the policy has thus achieved its original main objective. In response, the focus has increasingly turned to greenhouse-gas emissions reductions, which was only a secondary objective when the policy was originally implemented. The policy is now in the process of being re-shaped and its future will hinge on its ability to deliver mitigation in a more cost-effective manner. Likewise, in China, early stages of the wind policy were successful in deploying new capacity, but it put little emphasis on cost effectiveness. But persistent high costs have become a concern, and the introduction of market mechanisms is now considered

key to sustaining the promotion of wind power. This case illustrates the role of costs as an additional *de facto* objective to adapt to. Moreover, the Chinese biodiesel program was originally implemented as a climate policy and thus had a strong focus on sustainability. In recent years though, it has come under increasing pressure to reform due to unaccounted negative side-effects on air pollution. Chinese policy makers are now struggling with how to reconcile these objectives in order to sustain the market and industry development. Finally, the challenge of changing objectives is exacerbated when energy policies are governed by multiple agencies. Renewable policies in Italy and South Korea suggest that if coordination by government bodies with overlapping responsibilities is not accounted for in policy design, this can unbalance objectives over time especially if interests of the different bodies compete. Given the apparent need to attune multiple objective policies to changing goals, and a lack of explicit consideration of the need in policy designs thus far, "adaptability" stands out as a third important design principle.

5. Conclusions and Policy Implications

Our results point to the crucial role the three described principles play for designing energy policies that can also successfully achieve additional objectives from other policy domains. Given that they have rarely been put into action so far in the cases we looked at, we first of all intend our work to bring them to policy makers' attention as guidance for future multiple-objective energy policy design and experimentation. To that end, we outline starting points for putting these principles into action, elaborating further on some of the findings already discussed above and emerging related work in the scientific literature.

First, *complementarity* requires thinking of energy policies as an entire portfolio of interlinked measures rather than just a single instrument that may solve all problems at once. A key aspect of this is weaving complementary policies and dedicated policy features, which clearly link to other objectives, into conventional energy policy designs. An illustrative example is the use of local content requirements (LCR) in renewable energy policies as mentioned above. Notwithstanding that the track record of LCRs is still mixed, important insights have been gained about the preconditions under

which they can be successful, e.g. a stable and sizeable market and technologies with high learning potential (Kuntze & Moerenhout, 2013). In terms of management, *complementarity* requires a truly integrated design approach extending to all dimensions and objectives while also accounting for distributional impacts, for which novel multiple-criteria decision methodologies (Sreenivas et al., 2015) will be needed.

Second, *transparency* serves as a constant reminder that one can only manage what one measures, and in particular is crucial to uncover if synergies and tradeoffs change over time. The German case can potentially serve as a role model for policies elsewhere. Its main building block are annual monitoring reports (Federal Ministry for Economic Affairs and Energy, 2016) commissioned by an inter-departmental government agency, explicitly covering multiple objectives. While the report is based on official energy statistics, additional studies are also commissioned for assessing non-energy related indicators like jobs and GHG emissions reduction. These data are an important basis for further scientific analysis, for example on the success of energy transitions as a green industrial policy (Pegels & Lütkenhorst, 2014). In addition, a scientific expert commission provides critical comments that are published alongside the report (Expert Commission on the Energy of the Future Monitoring Process, 2016). Finally, an additional progress report (Federal German Government, 2014) is published every three years to discern trends and track whether goals and targets have been achieved. Institutionalizing *transparency* in such a way seems essential to ensure that monitoring and assessment becomes a persistent process capable of tracking policy impacts and interactions over the long term.

Third, *adaptability* requires thinking about policies as a sequence of measures and contingency plans that can be readily deployed or adjusted as objectives change (Pahle et al., 2017). At the instrument level, this for example comprises the subsequent introduction of market elements into regulation as is currently happening in Germany (Pahle & Schweizerhof, 2016) and needed in China, or foreseeing extensions to new sectors or actor groups as in the Brazilian biofuels case (Rathmann, Szklo and Schaeffer, 2012). At the governance level, *adaptability* requires effective coordination between

multiple government bodies to overcome policy "silos" and underlying conflicts from overlapping responsibilities and competing objectives (Peters, 2018; Giguère & Froy, 2010). Depending on the political system of a country, this can be accomplished through strong integration as aimed for in an approach laid out by the Colombian Government (Government of Columbia,2013), or through strong central agencies as is often done in China (Guo & Pachauri, 2017). For the latter, the Chinese green lights program is a case in point (Guo & Pachauri, 2017). On the level of tools, scientist have proposed several approaches policy makers might draw on for designing policies that are adaptive to the future (Walker et al., 2001; Swanson, 2010; Haasnoot et al., 2013).

Finally, these principles also describe important directions for future research. First of all, there is a need to develop new and innovative approaches that implement the three principles, which should include the apparent interlinkages between them. For instance, adaptive policy design necessitates the refining of a policy in light of new insights and shifting policy priorities, i.e. it heavily relies on *transparency*. Because new insights derive from putting such options into action, learning from policy experiments will become an increasingly relevant source of knowledge, especially for global assessment activities like the one performed by the Intergovernmental Panel on Climate Change – IPCC (Carraro et al., 2015). Accordingly, coordinated case-study activities as spearheaded in this work can become a critically important research strand driving progress towards the SDGs and Paris Agreement targets.

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