Improving climate resilience in the urban environment

Enhancing the uptake and use of building-scale to city-scale decision support models by policymakers and industry

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ARCC network

The Adaptation and Resilience in the Context of Change (ARCC) network is hosted by the UK Climate Impacts Programme (UKCIP) and funded by the Engineering and Physical Sciences Research Council (EPSRC).

UKCIP helps organisations, sectors and government adapt to the changing climate through practice-based research and by providing support and advice. The programme is based at the Environmental Change Institute, University of Oxford.

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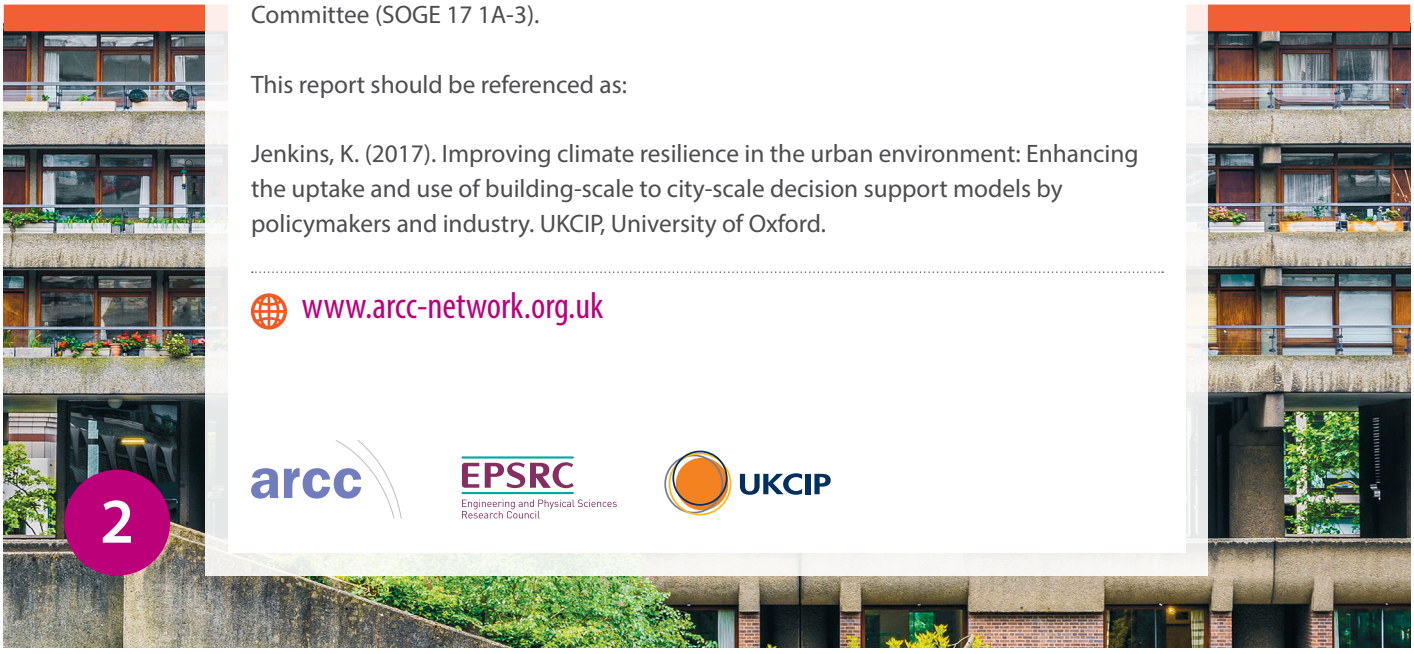

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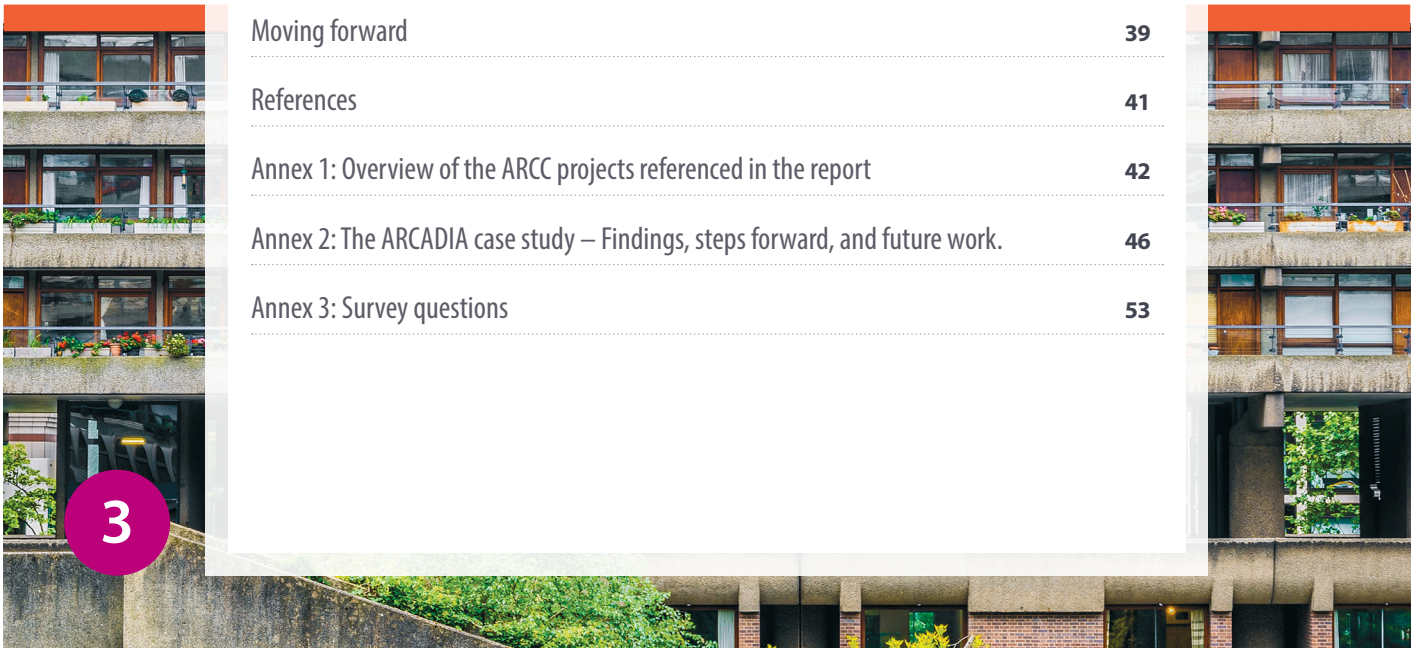


Overview

The ARCC network aims to develop and exchange knowledge and evidence to inform policy and practice. It covers a host of EPSRC-funded research projects focused on adaptation to changes in the built environment and infrastructure. There are currently 42 completed or ongoing projects listed on the ARCC website, which provides a focal point for knowledge exchange, information and engagement opportunities, and engages with a wide range of stakeholders.

The funded projects all include dissemination plans, including some which explicitly aim to provide models, visualisation tools, or data for stakeholder use. However, difficulties in the accessibility and readiness of outputs for industry integration or application by stakeholders means that many tools and research outputs do not transition from the academic sphere to potential end users. For example, researchers themselves have highlighted issues surrounding the usefulness of the data they provide, including whether decision makers can fully understand, interpret, and use data in the manner it is provided, and how outputs will fit to the specific needs of stakeholders involved in complex decision-making processes.

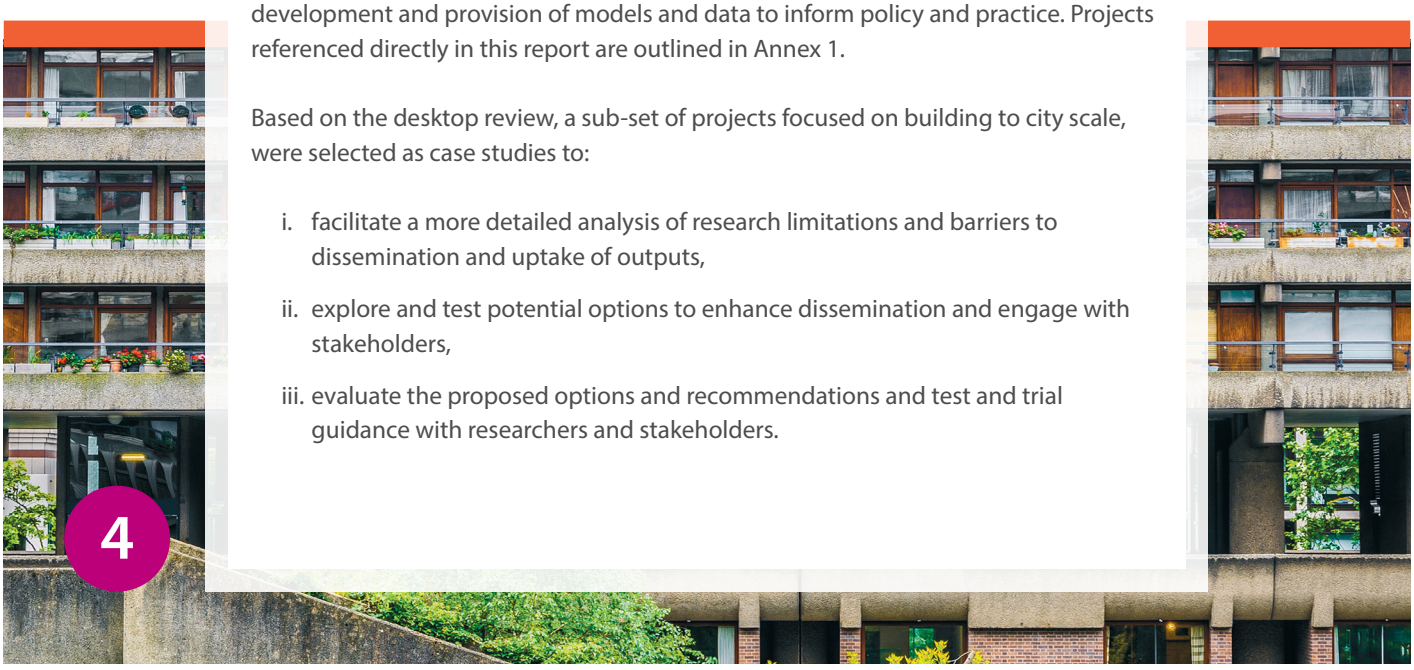
As such, it was felt that many of the ARCC projects have the potential for much greater policy and practice application beyond their past/current impact and stakeholder interest. A desktop review of the ARCC projects was undertaken with a key focus on projects aimed at the building to city-scale, and which explicitly highlight the development and provision of models and data to inform policy and practice. Projects referenced directly in this report are outlined in Annex 1.

Based on the desktop review, a sub-set of projects focused on building to city scale, were selected as case studies to:

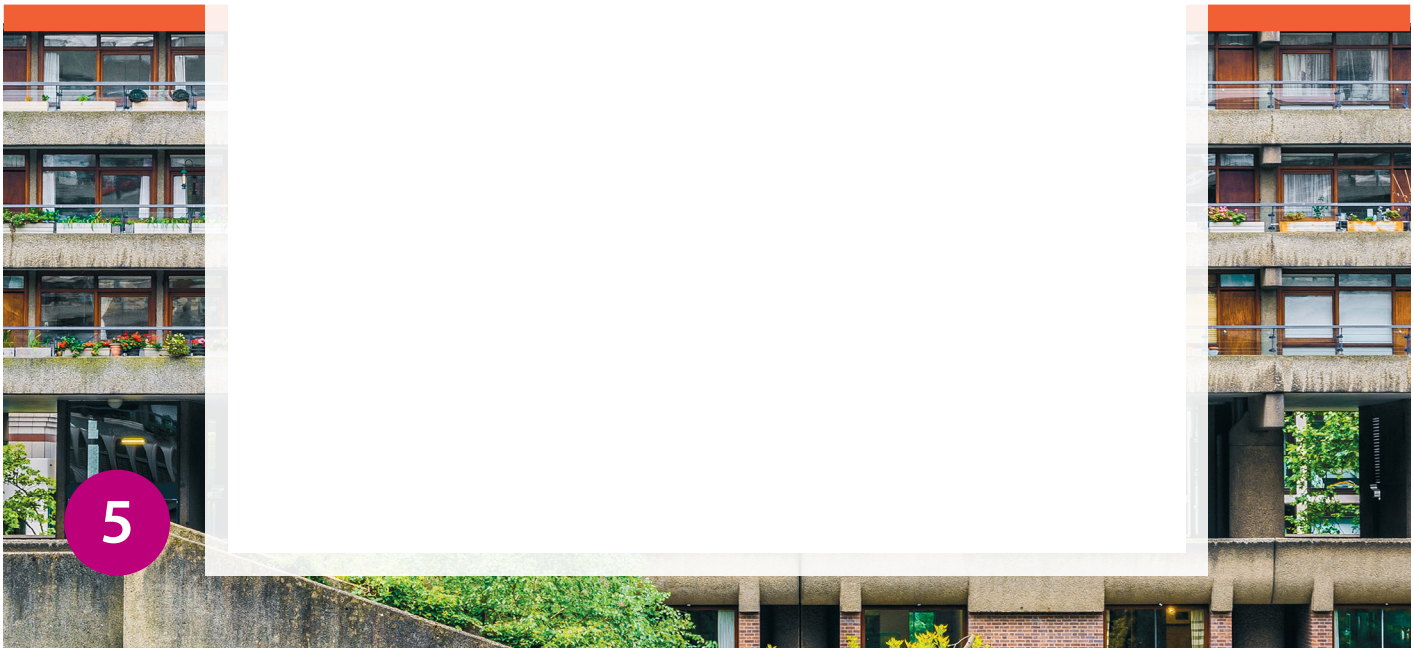
i. facilitate a more detailed analysis of research limitations and barriers to dissemination and uptake of outputs,

ii. explore and test potential options to enhance dissemination and engage with stakeholders,

iii. evaluate the proposed options and recommendations and test and trial guidance with researchers and stakeholders.



The report reflects upon information from the online review, the selected projects and case studies reviewed in more detail, and opinions gathered through researcher and stakeholder interviews. In addition, feedback and observations were collected from research and stakeholder based workshops, ARCC facilitated events engaging stakeholders, as well as through online surveys and one-to-one meetings with potential end-users. The information has been used to develop key recommendations to support clear and practical strategies to design, enhance, and manage the current and future uptake of research outputs.



Summary

The following section presents detailed findings of the project, key learning points and the subsequent recommendations developed based on researcher and stakeholder experiences and findings from the case studies.

In this report, the findings have been organised around 15 common themes. In many cases, there was overlap across the 15 themes in terms of the issues identified or the type of recommendation that could help address an issue, for example identifying where appropriate training could be used to support research staff.

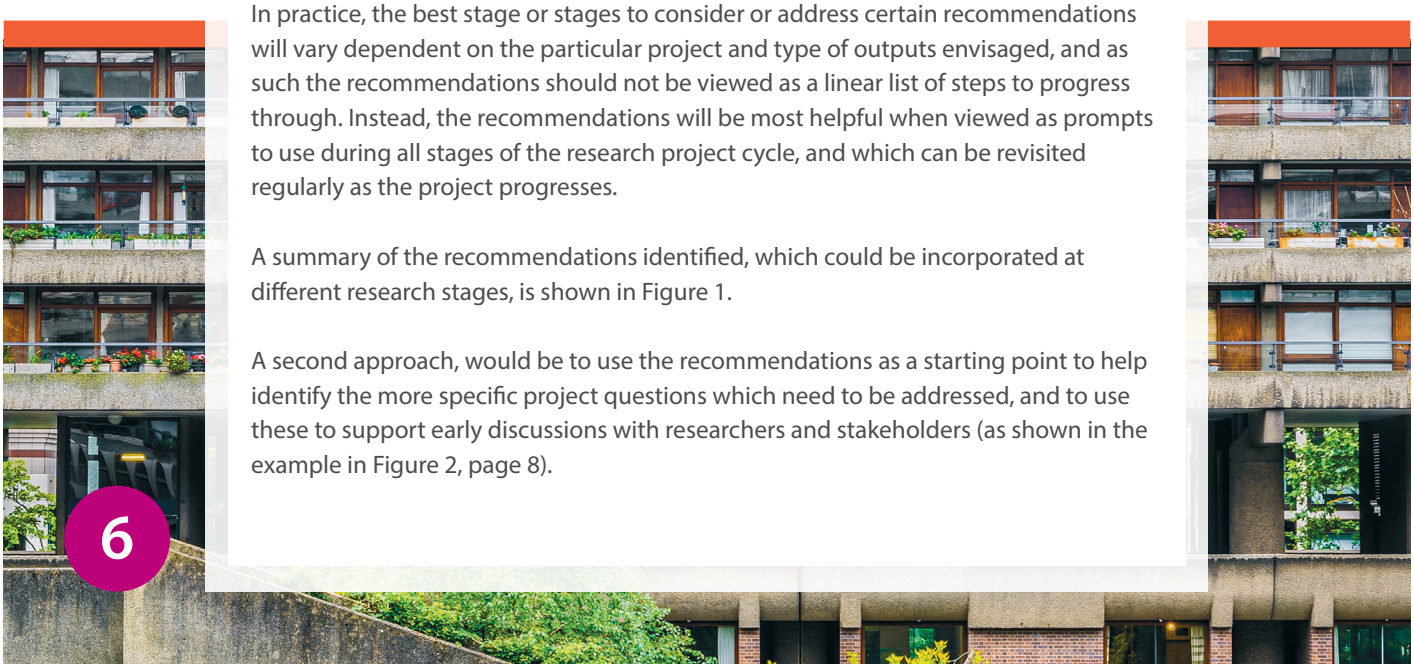
As an example, the recommendations have also been categorised based on the different components of the research cycle / process where they may be firstly considered or revisited. These are indicated in the following section by a bracketed number/s corresponding to the following list.

1. Project proposal stage
2. Project management
3. Research
4. Results / analysis
5. Implications of the results / what next?
6. Final stages and moving forward

In practice, the best stage or stages to consider or address certain recommendations will vary dependent on the particular project and type of outputs envisaged, and as such the recommendations should not be viewed as a linear list of steps to progress through. Instead, the recommendations will be most helpful when viewed as prompts to use during all stages of the research project cycle, and which can be revisited regularly as the project progresses.

A summary of the recommendations identified, which could be incorporated at different research stages, is shown in Figure 1.

A second approach, would be to use the recommendations as a starting point to help identify the more specific project questions which need to be addressed, and to use these to support early discussions with researchers and stakeholders (as shown in the example in Figure 2, page 8).



1 Project proposal

- Identify stakeholders who would use your data or model.
- Explore with these stakeholders what sort of data or models they currently use.
- Explore what data or models are currently in use and build on existing work, don't repeat it.
- Consider involving an industry champion to implement the model in their organisation.
- Work with stakeholders to develop strategies that are able to cope with a range of data requirements.
- Develop strategies for dealing with disparate or conflicting user needs.
- Establish agreements in principle for use of any private / public stakeholder data.
- Investigate resources needed for on-going data management and to ensure data remains accessible / usable after the project ends.
- Define what skills are required to transform research outputs into material suitable for users.
- Budget for phases of user-testing throughout the project.

2 Project management

- Will staff need additional training? e.g. data management, managing stakeholders.
- Assign tasks to specific people.
- Investigate details of stakeholder data requirements and working processes.
- Engage with specialist personnel from stakeholder organisations who work with data or models.
- Find out if the way stakeholders and researchers use data is compatible.
- Discuss preferred data formats with stakeholders and third party data suppliers before research begins.
- Explore output and dissemination channels, as well as potential constraints.
- Expectations and requests may change, so be prepared to be flexible.
- Help end-users communicate with researchers and vice versa.
- Manage stakeholder expectations and be aware of stakeholder fatigue.
- Store data in a standardised (open source) repository throughout the project.
- Design and implement a monitoring and evaluation programme to track data usage.
- Develop a data dissemination and legacy plan that is regularly updated.

3 Research

- Keep the needs of stakeholders in mind while research is underway.
- Re-evaluate stakeholder needs regularly.
- Allow stakeholders and practitioners access to provisional data so they can provide feedback.
- Use a range of engagement approaches, for example, participatory workshops.
- Provide progress reports to keep stakeholders informed.
- Look beyond your initial goals and stakeholders – could your data be useful for other users? Is it compatible with other systems?
- Keep evaluating your output plans to ensure there are no barriers to implementation.

4 Results & analysis

- Provide researchers with training on how to format outputs for different audiences.
- Continue discussions with users and personnel on findings, outputs, formats and uses.
- Continue evaluation and analysis of outputs and how they fit with stakeholder needs.
- Explore tools and mechanisms to support model and data management and sharing.
- Communicate the scale and limitations of the model to end-users.
- Researchers should make a note of any data format or model functionality they have proposed but could not use. This allows them to recommend improvements to stakeholders' systems, and also to revisit the output later should external systems be compatible in the future.

5 What next?

- Develop clear documentation on outputs, interpretation and limits.
- Take advantage of stakeholders' expertise to understand the practical uses of the data or model.
- Explore options for creating a less technical version of the model for a wider audience to use.
- Investigate other funding sources to develop the model further into a usable tool, for example, Impact Acceleration Account (IAA) or institutional grants.

6 Final stages

- Presentation and visualisation of data and tools should be clear, and geared to specific users and their needs.
- Focus on the usability of outputs as well as usefulness.
- Focus on how stakeholders could use the model, and what that means in their particular sector.
- Enable the industry champion to take ownership of the model & share widely, if appropriate.
- Tailor final engagement activities and locations to suit the stakeholders, for example, as part of industry events or where web-based activities are most effective.
- Explore collaborative grants to enhance the impact and usability of outputs, for example, working with web developers or other academics with different skill sets.
- Keep reviewing and monitoring after launch.
- Collect feedback on the usability of the data and model, for example, are the actual users those initially intended? Is the data discoverable and usable by new stakeholders?
- Consider how the data can be applied in future projects.

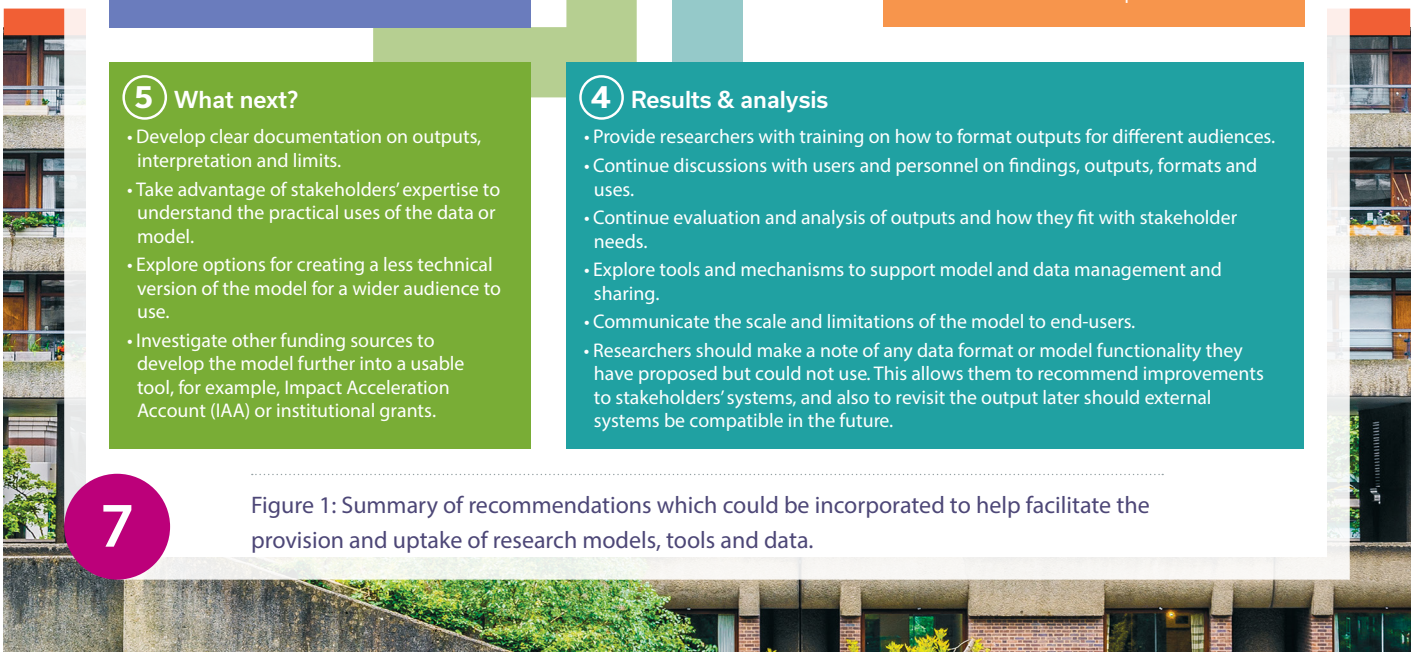


Figure 1: Summary of recommendations which could be incorporated to help facilitate the provision and uptake of research models, tools and data.

Figure 2: Example of how the recommendations could be used to help identify questions to be addressed and help inform early discussions with researchers and stakeholders.

The full report, a summary of the guide and recommendations, and interactive material has been placed online as a resource to help support researchers at all career stages, and during different stages of the project cycle. The information has been synthesised for quick reference to help ensure consideration of models and data is included throughout a research project.

Learning points and recommendations

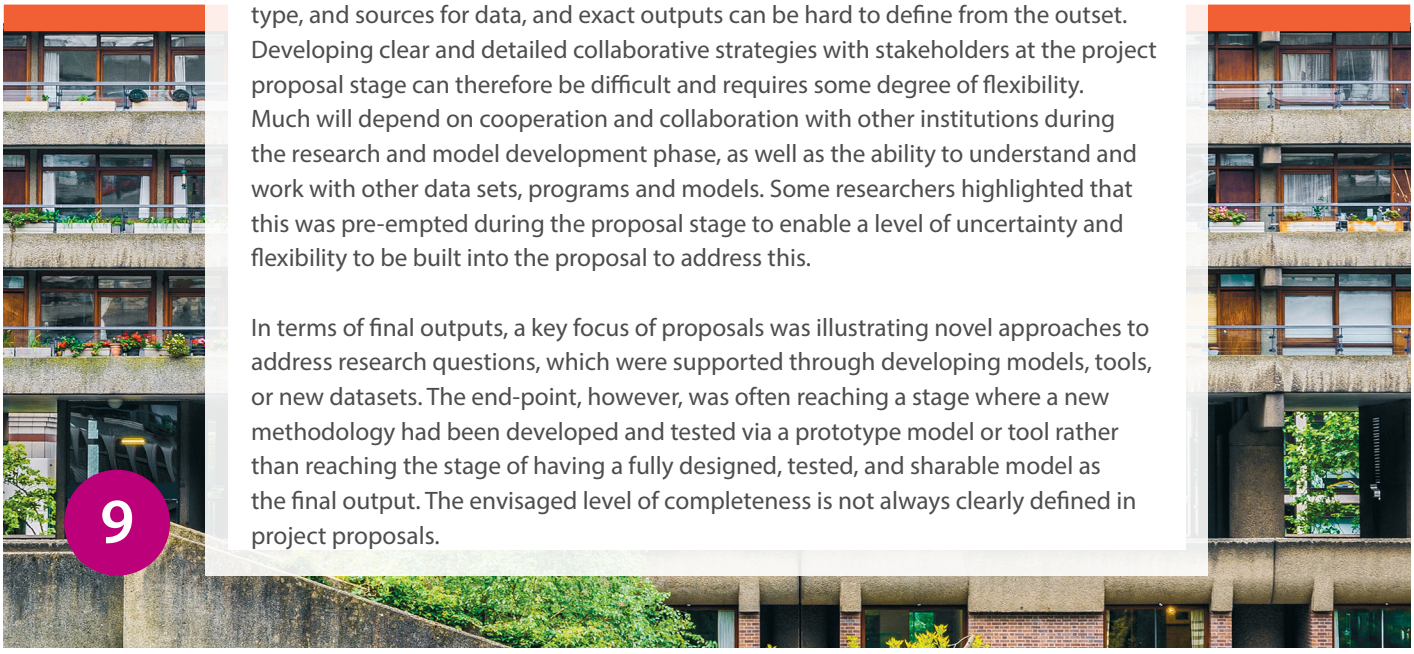
1. Developing research methodologies

In many cases the proposed research was developed based on experience and knowledge of available models and datasets that could be used to advance and take research forward. However, particularly for longer lifetime projects, there was evidence that the initial proposals used to frame the research outputs were harder to interpret as the projects progressed, particularly where researchers tasked with developing the methodologies were not involved at the project concept stage. The level of ambition required to attract funding, and the level of detail in explaining how the outputs would be achieved, did not always marry easily as the development of the methodology itself was often a key advancement of the project.

> “Basically, we knew what the output had to be but we didn’t know how we were going to get there.”

For larger projects that involve interdisciplinary and cross-institution collaboration, this can mean that the time-frames for research tasks, methodologies, the format, type, and sources for data, and exact outputs can be hard to define from the outset. Developing clear and detailed collaborative strategies with stakeholders at the project proposal stage can therefore be difficult and requires some degree of flexibility. Much will depend on cooperation and collaboration with other institutions during the research and model development phase, as well as the ability to understand and work with other data sets, programs and models. Some researchers highlighted that this was pre-empted during the proposal stage to enable a level of uncertainty and flexibility to be built into the proposal to address this.

In terms of final outputs, a key focus of proposals was illustrating novel approaches to address research questions, which were supported through developing models, tools, or new datasets. The end-point, however, was often reaching a stage where a new methodology had been developed and tested via a prototype model or tool rather than reaching the stage of having a fully designed, tested, and sharable model as the final output. The envisaged level of completeness is not always clearly defined in project proposals.



> “When you talk about a tool or a model in a proposal, you might give a lot of detail behind the kind of methodologies involved in creating that tool and the kind of data you’re going to use, but you’re often not particularly detailed in terms of what the tool will finally look like, because to actually get to a tool that can be commercialised or with genuine outreach, that’s kind of another step again.”

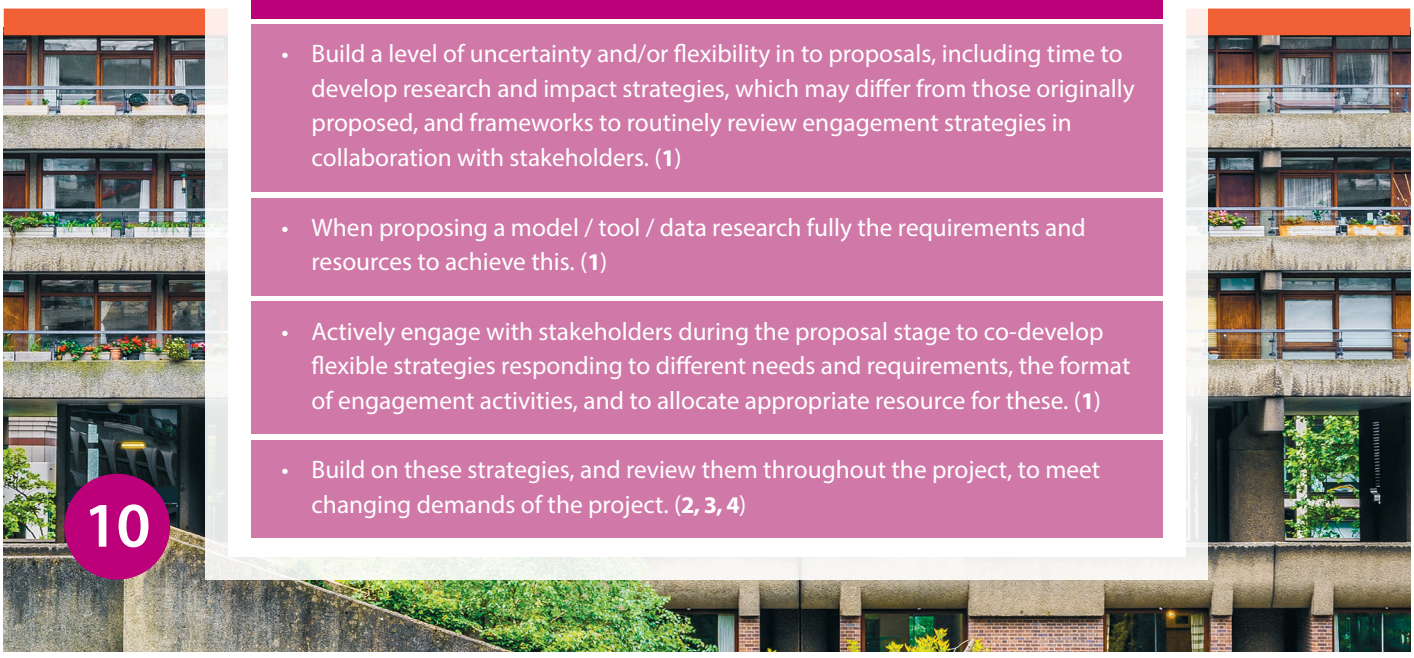
It was highlighted that to provide commercially viable or self-supporting models and tools would require different resources in terms of the level and length of funding and different expertise at the outset that can be hard to plan for, cost and justify given the early stage of model development. This discord between the ambition of the project proposal and realistic stage of development of the final model or tool meant that potential longer-term issues such as envisaging future impact, requirements for further development and additional resource requirements, and ongoing support required for models and tools, were less likely to be actively considered within the project proposal phase.

Learning points:

- Project proposals must address criteria as set out by funders. For example, through the case for support outlining the: research hypothesis; novel and timely aspects of the work; key aims and objectives; details of the methodology; the workplan and deliverables; academic impact; and national importance. However, the limited space to address such headings can mean the actual level of detail considered at this stage, alongside specific details for engagement and communication activities, can be restricted.
- There is often a discord between the ambition of proposed projects, clear vision of the type and state of final outputs and their level of development, and resources required to achieve outputs.

Recommendations:

- Build a level of uncertainty and/or flexibility in to proposals, including time to develop research and impact strategies, which may differ from those originally proposed, and frameworks to routinely review engagement strategies in collaboration with stakeholders. (**1**)
- When proposing a model / tool / data research fully the requirements and resources to achieve this. (**1**)
- Actively engage with stakeholders during the proposal stage to co-develop flexible strategies responding to different needs and requirements, the format of engagement activities, and to allocate appropriate resource for these. (**1**)
- Build on these strategies, and review them throughout the project, to meet changing demands of the project. (**2, 3, 4**)



2. Envisaging future impact

Pathways to Impact statements have been required since 2009 for most RCUK applications, with the aim to clearly show how public funding invested in research will bring about positive impact for society and the economy. Subsequent reviews led to a set of recommendations and the harmonisation of the approach across RCs. All RCs require a clear and acceptable Pathways to Impact statement as a condition of funding as of April 2015.

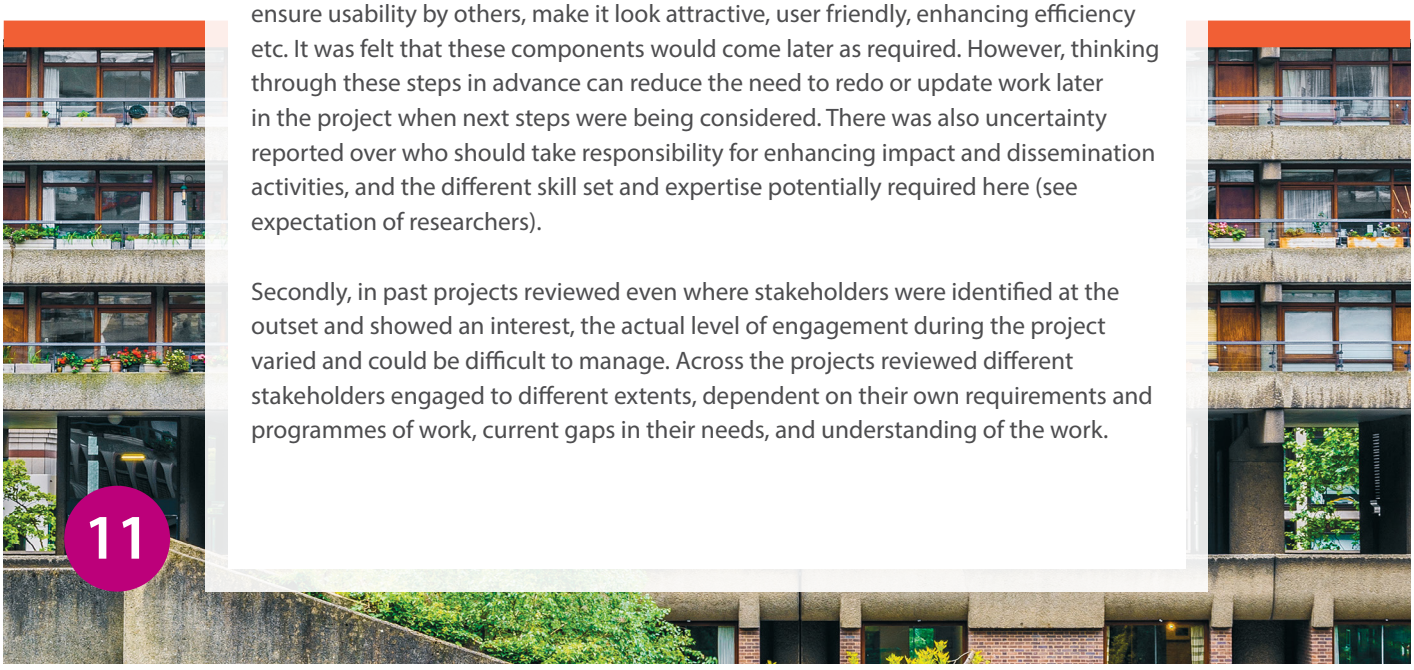
Benefits of this include the requirement for researchers to think through and explore how their research can make a difference right from conception of the project; identification of who could benefit; and how this could be facilitated, throughout the life of the project and beyond.

Impact was highly valued by interviewees as a key criterion of research undertaken. However, given that many of the ARCC projects reviewed for this document pre-dated the latest impact requirements of EPSRC it was noted that in the past delivering the research element was the primary goal, and concentrating on the dissemination at the end of the project could also be seen as beneficial in that it allowed a longer and more focused period of research. One project commented that if it was undertaken under the current structure it was less likely that they would have been able to devote as much time and resources directly to the research element.

The consideration and level of detail regarding planned engagement and pathways to impact could also be quite generic within project proposals, with the view to develop strategies further, alongside or following the research stage, as outputs became clearer. However, the ARCC network (ARCC, 2015) recommends early engagement with stakeholders, moving beyond just seeking letters of support, to co-develop flexible strategies responding to different needs and requirements. If carried out during the proposal stage this could help highlight any trade-offs required in terms of resources for research activities and engagement and impact related activities, but also make sure that such activities are embedded throughout the project cycle.

From a researcher perspective, it was often noted that the primary requirement of the job role was to get the model or tool working to meet the core research objectives, whilst less time was devoted to considering how the model could be developed to e.g. ensure usability by others, make it look attractive, user friendly, enhancing efficiency etc. It was felt that these components would come later as required. However, thinking through these steps in advance can reduce the need to redo or update work later in the project when next steps were being considered. There was also uncertainty reported over who should take responsibility for enhancing impact and dissemination activities, and the different skill set and expertise potentially required here (see expectation of researchers).

Secondly, in past projects reviewed even where stakeholders were identified at the outset and showed an interest, the actual level of engagement during the project varied and could be difficult to manage. Across the projects reviewed different stakeholders engaged to different extents, dependent on their own requirements and programmes of work, current gaps in their needs, and understanding of the work.



For example, in the SNACC project, led by the University of the West of England, it was highlighted that local authorities in Oxford and Bristol engaged with the project a lot, with Bristol asking for direct support in developing local guidance for tackling overheating in existing houses based on the DECORUM model findings. Identifying stakeholder 'champions' who have a vested interest to support, use, and promote outputs within their organisations can be highly beneficial.

Engagement was found to be most visible where the potential benefits, e.g. through provision of data or information to support reports and strategies, could be clearly defined. This would be supported through early and in-depth engagement with stakeholders as highlighted above, but also allows more emphasis to be placed on what stakeholders could contribute to the partnership such as providing feedback, expertise, and data inputs for use by projects. By utilising such resources, the stakeholders have a natural interest in how data is used and what is generated through its use. This is also beneficial in making sure that outputs are compatible with end-users as they are often familiar with the data formats. As an example, the DECORUM model used local authority data so that GIS based maps of energy and temperature data could be provided as additional layers that integrated easily with the maps local authorities already used.

Learning points:

- Given the change in funding proposal criteria there may be additional or competing demands for resources to undertake impact activities and dissemination, as well as research activities.

Recommendations:

- The time-frame and effort required to undertake impact activities, skill sets needed to actively drive the pathways to impact, and the responsibility for implementation and management need to be clearly accounted for, and outlined, at the project proposal stage. (**1**)
- Tasks and deliverables specific to impact pathways need to be defined so the time constraints and allocation of tasks is considered as a core component of the project proposal, and integrated throughout the project. (**1**)
- Early engagement and co-creation of flexible strategies with stakeholders, or the identification of stakeholder 'champions' is recommended. Research the drivers for stakeholders and their requirements to align research with their needs and incentivise the benefits of engagement. (**1**)

3. The purpose of the tool, model or data

Across the research projects investigated there were a range of reasons why certain tools, models or datasets were developed, and in the planned uses and dissemination of such outputs. However, at the researcher level in many cases the first criterion was to develop something useful to achieve the research objectives.

As models and tools are created and continue to be developed and updated this can lead to them being seen as useful tools for uptake into other projects, or applied for different purposes, enhancing their potential utility.

For example, two interviewees highlighted specific aspects of model development that came about as they could either not access more complex models already developed and used by industry, or that the industry tool used a simplified approach that researchers wished to improve upon. As such they were developed as research tools to overcome certain barriers, with the application focused primarily towards academic research. In another project, the tool and data outputs were designed from the outset to be used entirely by industry.

It may not be possible to identify all the possible applications and interested parties in terms of the proposed model / tool / dataset during the proposal and early research stages. Different directions and uses may arise organically as the project progresses and as researchers undertake different tasks. This is where embedding stakeholder engagement activities and flexible development of impact strategies throughout the project, alongside resources to facilitate this ongoing process, will be beneficial.

Examples were also highlighted of existing models that had been developed under other projects and provided as external software freely available to use by others, but developed with a broader, more generic, audience in mind. This approach, and the utility of such models, raised questions from researchers and stakeholders alike e.g. on their usability; why outputs had been provided in certain formats rather than others; limitations in terms of the options or function of user interfaces; and requirements for users to then understand the outputs and post-process data to make it compatible with their software.

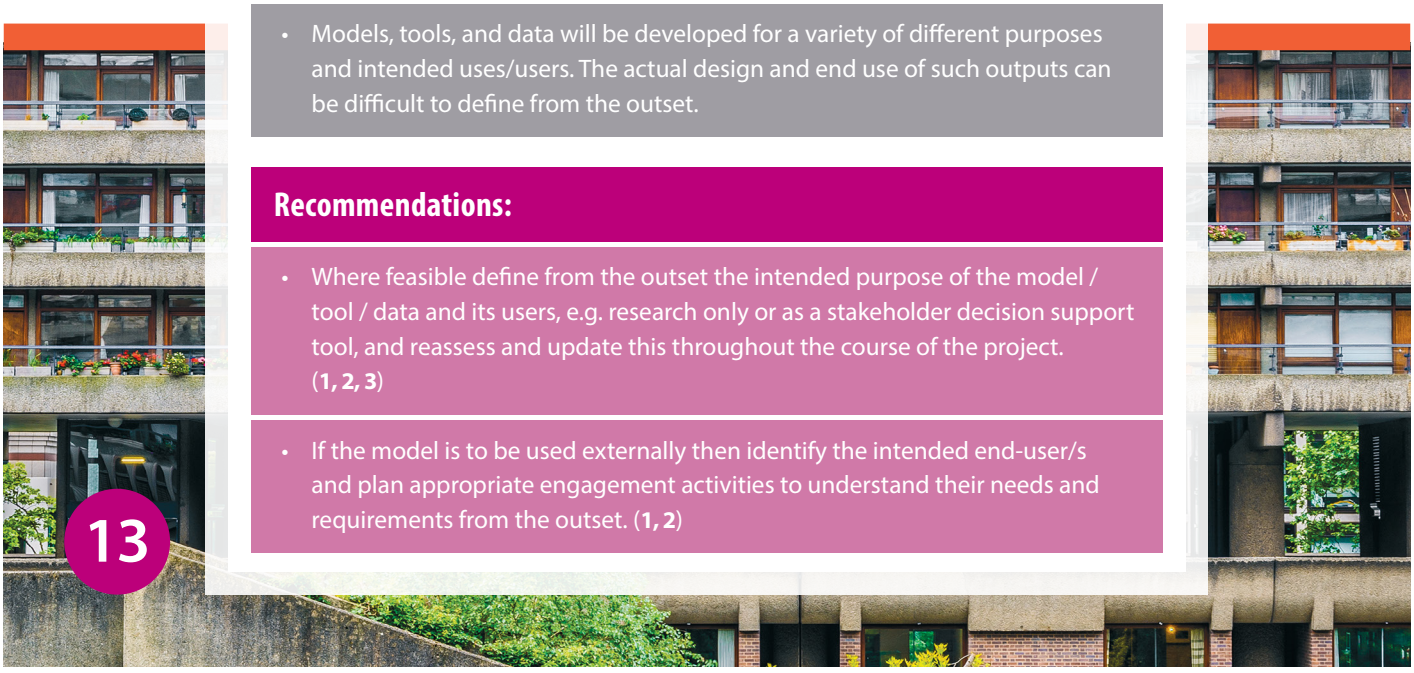
Understanding from the outset what already exists and what the limitations of such models are can help guide future strategies to avoid replicating these issues in new projects. It was highlighted that at the completion of projects such issues were very difficult to address due to resource limitations, but could be avoided or adjusted if developed during the project and in collaboration with end-users.

Learning points:

- Models, tools, and data will be developed for a variety of different purposes and intended uses/users. The actual design and end use of such outputs can be difficult to define from the outset.

Recommendations:

- Where feasible define from the outset the intended purpose of the model / tool / data and its users, e.g. research only or as a stakeholder decision support tool, and reassess and update this throughout the course of the project. (**1, 2, 3**)
- If the model is to be used externally then identify the intended end-user/s and plan appropriate engagement activities to understand their needs and requirements from the outset. (**1, 2**)



4. Expectation on researchers

There were several examples where researchers found themselves working on interdisciplinary projects where they often applied their experience to new topics or took on tasks outside their core discipline. A key example was in terms of software and model development where researchers often used programming languages and tools familiar to them to develop models to support their own research objectives, but did not have the expertise to professionally package these for external use. A related issue was the concern of researchers in sharing models they had developed given their limited experience in software and model development. For example, if issues arise when others try to run the models on different operating systems and researchers find themselves placed in the role of software support.

> "…that's often overlooked in projects being written or in just the way universities work, that kind of assumes researchers can just do this stuff when actually sometimes they struggle with it and we're not trained in it and we don't have the background in it."

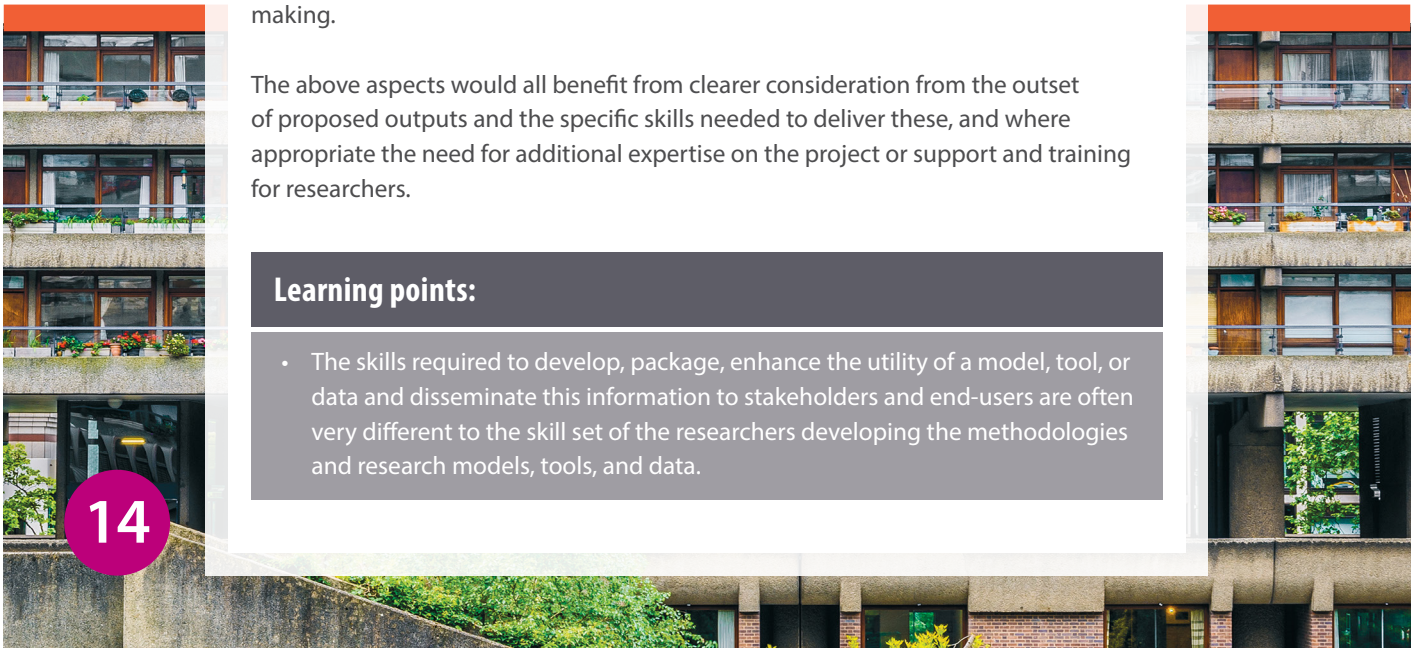
The role of departmental support was highlighted, for example, in reviewed projects that were hosted at Oxford and Newcastle University, where specific posts existed for Impact Officers and Programmers with the expertise to take researchers models and tools and develop or package them for external users. There are benefits of identifying institutional IT support from the outset, and engaging with such support staff early on to ensure that the planned approach is the most effective in terms of outputs and resources and to avoid any limitations later in terms of usability and sharing.

Similar issues were also raised in relation to the provision of data, whereby the data is there but there is a discord with the expertise to make this accessible, or more easily usable when accessed, particularly where researchers may have had little or no formal training with regards to data management. Likewise, whilst many potential benefits and uses of the research models and data generated by the projects reviewed were highlighted, visualising this in the most appropriate manner for stakeholders can also require different skill sets. For example, moving from static maps often displayed in reports and journal articles to interactive maps where the user could examine quickly the potential implications of different model outputs to support their decision-making.

The above aspects would all benefit from clearer consideration from the outset of proposed outputs and the specific skills needed to deliver these, and where appropriate the need for additional expertise on the project or support and training for researchers.

Learning points:

- The skills required to develop, package, enhance the utility of a model, tool, or data and disseminate this information to stakeholders and end-users are often very different to the skill set of the researchers developing the methodologies and research models, tools, and data.



Recommendations:

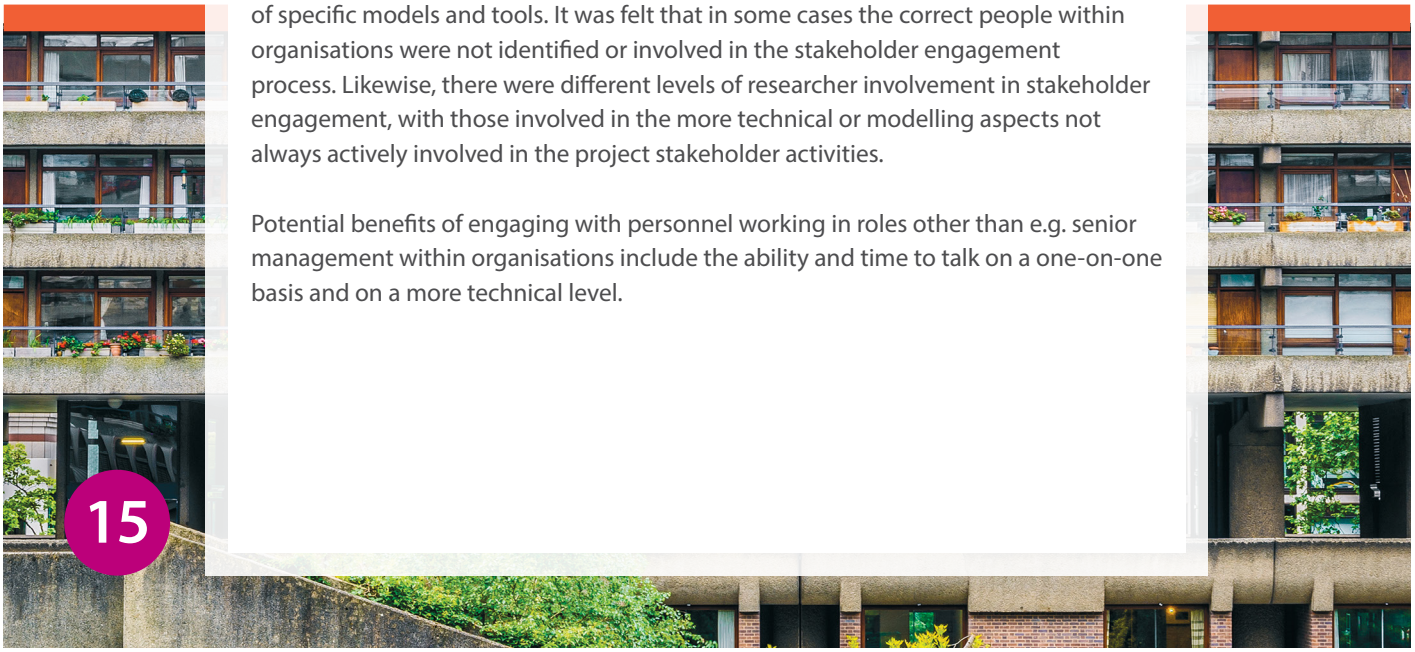
- In developing proposals where the provision of a model/tools is a key objective investigate the need for and costs for support from e.g. professional software developers or interface designers, either externally or from existing support staff. (**1**)
- Identify the strengths of researchers and where additional training will be required e.g. in data management, engagement, relationship management, communications skills. (**1, 2**)
- Clearly define these tasks as part of job descriptions and within researcher work plans from the outset, or identify where distinct roles are required to facilitate such activities. (**1, 2**)

5. Identifying appropriate stakeholders and individual contacts

As highlighted above, one recommendation for enhancing usability and usefulness of outputs is early engagement with stakeholders to co-develop flexible strategies responding to their different needs and requirements. Stakeholders can provide guidance on the most relevant areas of research in terms of their areas of focus, and can help to define the boundaries of research to make it as useful as possible to them in the longer-term. As well as providing expertise and feedback during meetings, other benefits of stakeholder engagement highlighted through the projects reviewed included facilitating specific tasks such as providing information and data, leading workshop sessions or utilising mailing lists for supporting qualitative studies.

The extent of engagement, and form this took, differed across the projects, but tended to centre around a core stakeholder advisory group who met regularly for meetings and were involved in the final dissemination workshop/s and events. A limitation of this approach was that the stakeholders who were principally identified and participated in the stakeholder advisory groups were not always the most relevant people to understand and provide feedback in terms of the use and technicalities of specific models and tools. It was felt that in some cases the correct people within organisations were not identified or involved in the stakeholder engagement process. Likewise, there were different levels of researcher involvement in stakeholder engagement, with those involved in the more technical or modelling aspects not always actively involved in the project stakeholder activities.

Potential benefits of engaging with personnel working in roles other than e.g. senior management within organisations include the ability and time to talk on a one-on-one basis and on a more technical level.



> “…what we’re trying to model and what’s useful to them and what they’re writing in terms of reports at the minute. And that is more useful from a researcher’s perspective, a more useful stakeholder engagement, because it’s on a similar level in the hierarchy than a workshop once every six months of people who are more interested in the bigger picture perspective.”

Other benefits highlighted of engaging with personnel working in other roles included that they are more likely to have time to sit for e.g. half a day and work through models and technical issues in person. It was highlighted that this can be a very valuable way of learning, understanding how stakeholders and different organisations work, understanding technical issues and requirements from their perspective, as well as providing information on research-based models, tools and data.

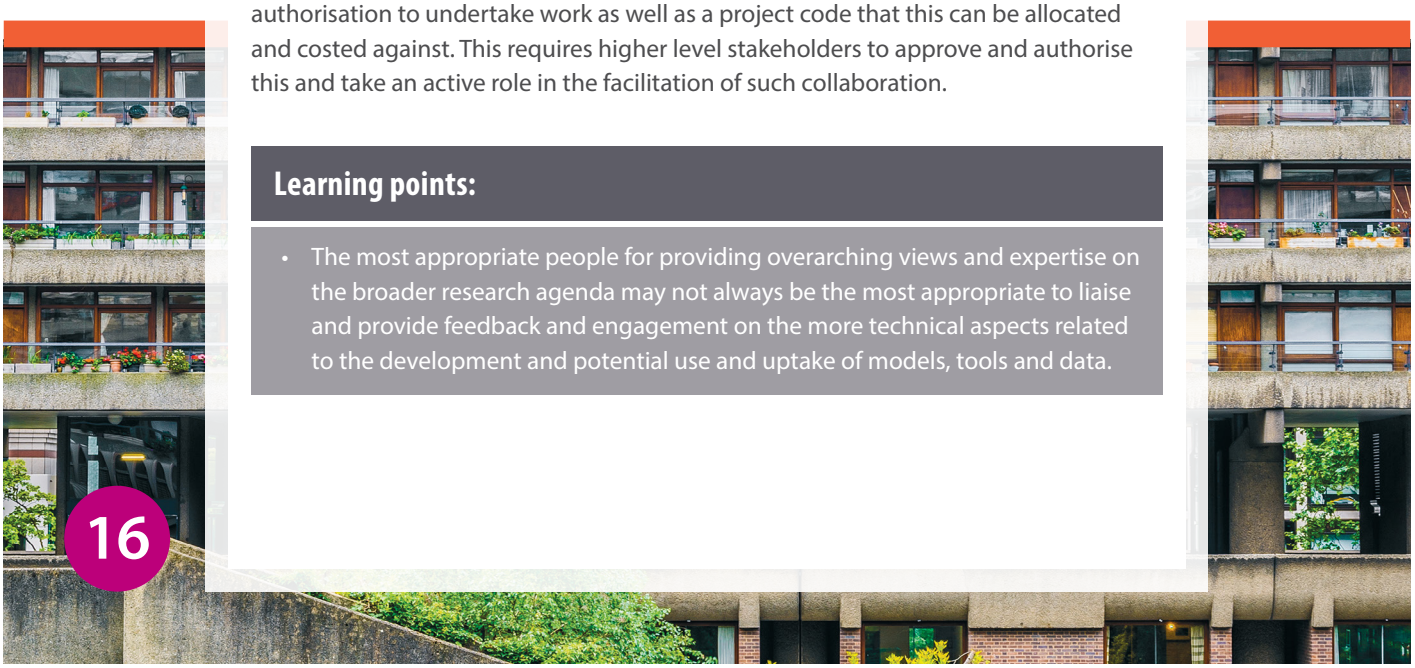
> “As a researcher, it makes you more aware of the landscape that you’re trying to fit into and the decisions that you’re trying to assist with and help them answer.”

In the SNACC project it was reported that it took some time to identify the appropriate contact within local authorities who could help provide data and input for the DECORUM model, as housing, energy and GIS were three different departments and often the initial contact was from the GIS team. Yet, once the correct contacts were made it facilitated the exchange of data, discussions and feedback. Similar issues were found with follow on work related to ARCADIA, led by the University of Oxford, where updates to a previously provided GIS dataset, highlighted by a stakeholder, were eagerly awaited only to find such updates were not being undertaken. This represented misunderstanding and miscommunication of work internally, and highlights how even within organisations the specific details of projects and what they are producing may not be immediately clear or documented across departments or teams.

In developing a working relationship, it was also highlighted that it is important to understand the stakeholders process for working. In many companies, an employee’s time must be accounted for and costed. As such, an employee may require authorisation to undertake work as well as a project code that this can be allocated and costed against. This requires higher level stakeholders to approve and authorise this and take an active role in the facilitation of such collaboration.

Learning points:

- The most appropriate people for providing overarching views and expertise on the broader research agenda may not always be the most appropriate to liaise and provide feedback and engagement on the more technical aspects related to the development and potential use and uptake of models, tools and data.



Recommendations:

- Stakeholder advisory groups will bring together appropriate people to support project proposals, research and dissemination, and can provide expertise at the broader level. Equally important is identifying through them individuals or certain teams within their organisations who can act as direct contacts to liaise, collaborate, and provide technical advice and feedback. Where introductions are made make sure that logistical information such as the cost or project code and amount of time allocated is provided to facilitate this, and understand any limitations or additional resources that could be required early in the project stage. (**1, 2**)

- Clearly define in workplans who will be responsible for facilitating and managing engagement processes, as well as resources required to support this. (**1, 2**)

6. Stakeholder engagement activities

As highlighted above stakeholder engagement is a key part of the project proposal and research process. Across the projects the extent of engagement with core stakeholders and wider audiences, and form this took, differed largely. Activities included:

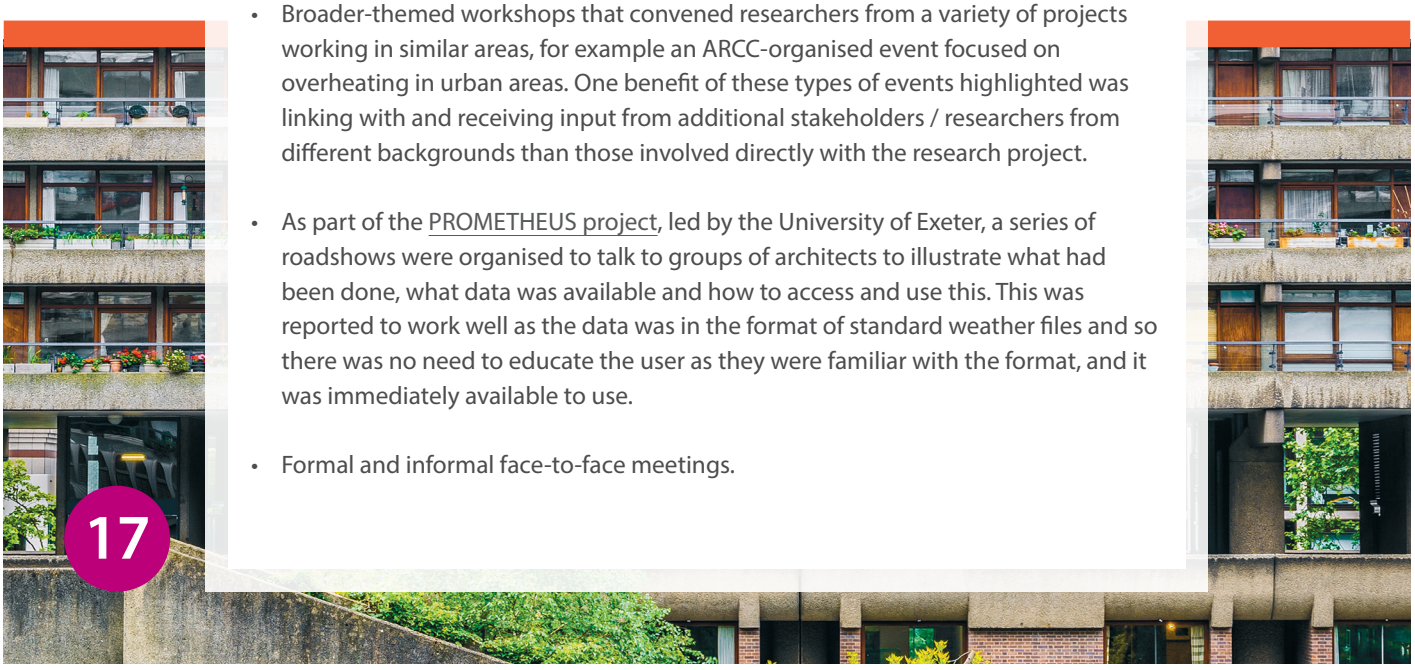
- The establishment at the project outset of stakeholder advisory groups who met annually/biannually for meetings to provide input and feedback, and were involved in final dissemination events. These were often structured around a series of presentations on the more technical aspects of the research and outputs, followed by a discussion session.

- Participatory project workshops, geared around break-out sessions and discussions that could lead to further engagement, new research directions, and potentially further funded work, as well as allowing hands-on interaction with tools and models.

- Broader-themed workshops that convened researchers from a variety of projects working in similar areas, for example an ARCC-organised event focused on overheating in urban areas. One benefit of these types of events highlighted was linking with and receiving input from additional stakeholders / researchers from different backgrounds than those involved directly with the research project.

- As part of the PROMETHEUS project, led by the University of Exeter, a series of roadshows were organised to talk to groups of architects to illustrate what had been done, what data was available and how to access and use this. This was reported to work well as the data was in the format of standard weather files and so there was no need to educate the user as they were familiar with the format, and it was immediately available to use.

- Formal and informal face-to-face meetings.



- As part of the Blue-Green Cities project, led by the University of Nottingham they used a Learning and Action Alliance (LAA) approach. The aim of creating the LAA was to allow stakeholders in Newcastle involved in flood and water management, as well as other stakeholders who aren't typically involved in these discussions, to come together and talk informally about how they would like Newcastle to progress. This allowed local authorities, businesses and communities to be at the centre of the research by establishing feedback practices between them and the project team. The process was highlighted as a very successful way to communicate the research being undertaken, but also to ensure the outputs were relevant and suitable for those practitioners that would eventually use them. This was found to be a stimulating approach as it facilitates engagement between researchers and stakeholders but also between groups of different stakeholders that may not have engaged otherwise. Moving forwards, it provided a positive example of the benefits of engagement to stakeholders, as they could learn and broaden their networks also.

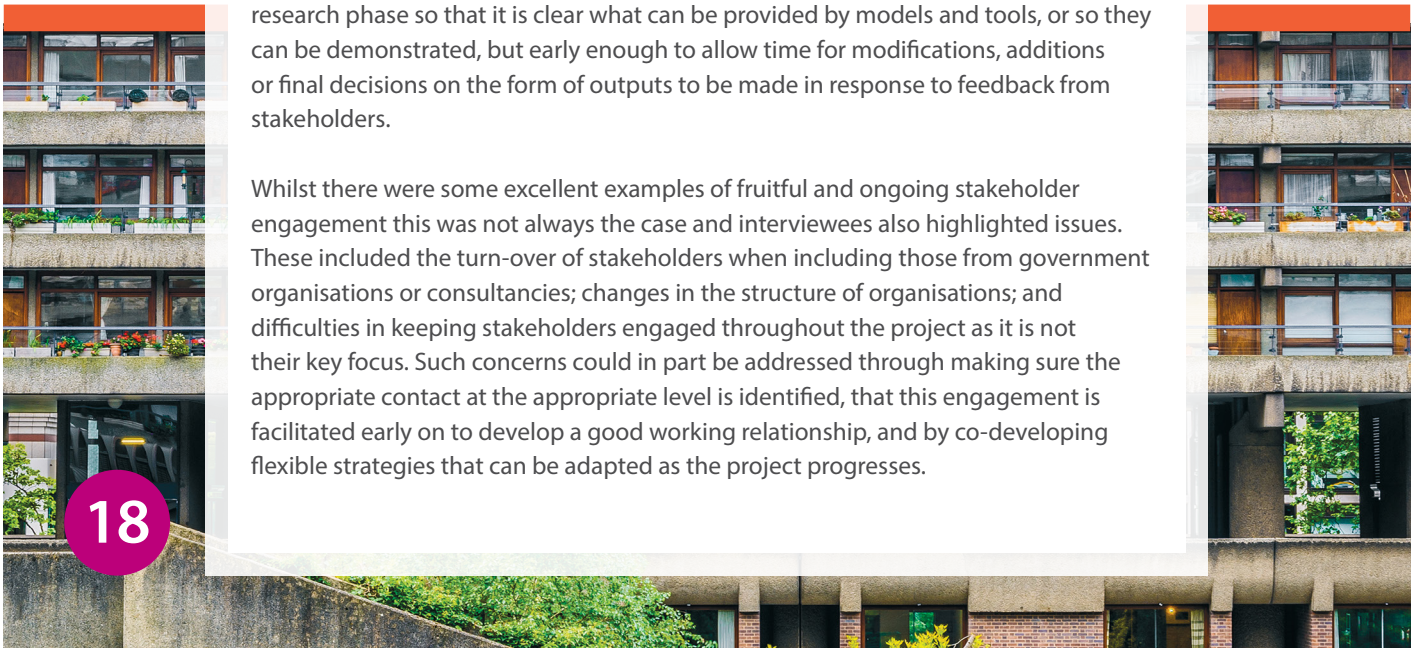
- Focus groups were used by projects, including the LCF project who geared them towards the social science practitioner engagement side, to see if the kind of models the project was producing had value or interest for building practitioners that they had identified as end-users. Similar focus groups were run by SNACC at a neighbourhood level to present findings of the DECORUM model to allow stakeholders to more actively participate in what was being modelled and how it could be used.

- Linking with industry workshops or events to reach out to potential end-users and understand from their perspective what tools need to do and use feedback to inform the development process.

The timing of activities also differed across the projects reviewed. Some projects, such as ARCADIA, engaged with stakeholders early on in terms of developing the project proposal and kick-off meetings to get input to drive the research direction, whereas other projects, where it was reported they had a very clear idea of the objectives and methods from the outset, engaged more towards the latter stages of the project when they had demonstrable outputs.

Dependent on the purpose of the engagement the timing of specific activities will be crucial, for example making sure activities are scheduled far enough into the research phase so that it is clear what can be provided by models and tools, or so they can be demonstrated, but early enough to allow time for modifications, additions or final decisions on the form of outputs to be made in response to feedback from stakeholders.

Whilst there were some excellent examples of fruitful and ongoing stakeholder engagement this was not always the case and interviewees also highlighted issues. These included the turn-over of stakeholders when including those from government organisations or consultancies; changes in the structure of organisations; and difficulties in keeping stakeholders engaged throughout the project as it is not their key focus. Such concerns could in part be addressed through making sure the appropriate contact at the appropriate level is identified, that this engagement is facilitated early on to develop a good working relationship, and by co-developing flexible strategies that can be adapted as the project progresses.



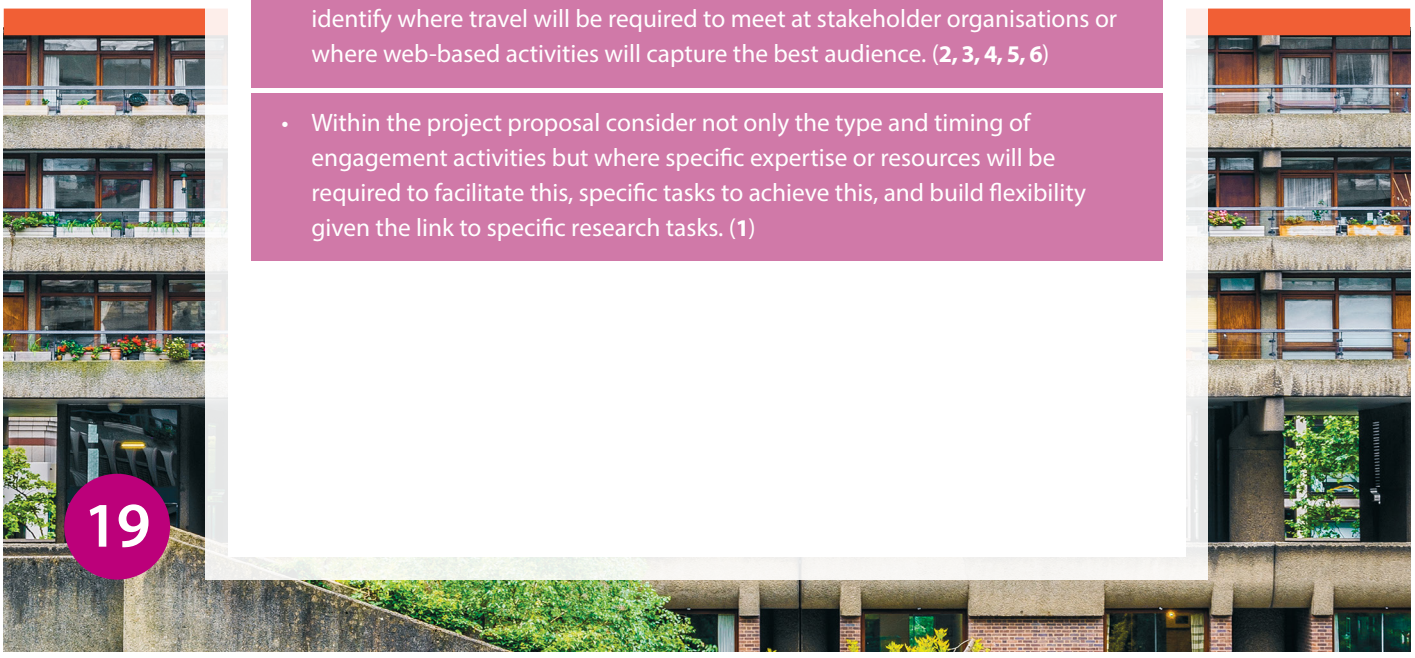
There were also locational constraints in terms of stakeholder's readiness to travel for meetings, and issues of availability to attend meetings. It is important to consider the constraints of stakeholders e.g. number of training days per year they may have to attend external events and reasonable travel times, and try to accommodate such issues. For example, consider where web-based dissemination could be more appropriate; linking with larger industry events they may already attend; and making sure the benefits of them attending which can be used to justify their time commitments to the engagement process are clear and tangible.

Learning points:

- Whilst stakeholder engagement was clear in all the projects reviewed, many opted for stakeholder based dissemination events structured around a series of presentations on the more technical aspects of the research and outputs, followed by a discussion session. The participants are then left to decide how this may be useful to them, and how it could be used or add value.
- Traditional approaches such as presentations and technical workshops may not be the most appropriate in terms of structure, content, and supporting attendance.

Recommendations:

- Through early engagement with stakeholders consider different approaches to support engagement and dissemination of information, for example through participatory workshops where stakeholders can actively explore outputs and visuals and discuss them with researchers. (**1, 2, 3**)
- Do not only focus on information provision but knowledge co-creation. Take advantage of expertise and skill sets of stakeholders to understand and emphasise how the outputs can be used in practice, the benefits to stakeholders of integrating them in current working processes, and the added value. (**3, 4, 5**)
- Tailor engagement activities and locations to stakeholder needs, for example identify where travel will be required to meet at stakeholder organisations or where web-based activities will capture the best audience. (**2, 3, 4, 5, 6**)
- Within the project proposal consider not only the type and timing of engagement activities but where specific expertise or resources will be required to facilitate this, specific tasks to achieve this, and build flexibility given the link to specific research tasks. (**1**)



7. Expectations of project stakeholders and potential end-users

From a stakeholder perspective, it was highlighted that there could be issues in terms of what they had expected from the project and what the project could/would ultimately deliver. What a stakeholder may want, and what the project aims to achieve and can realistically deliver, can be different. Whilst their requirements may not be possible/available, this could be communicated early on.

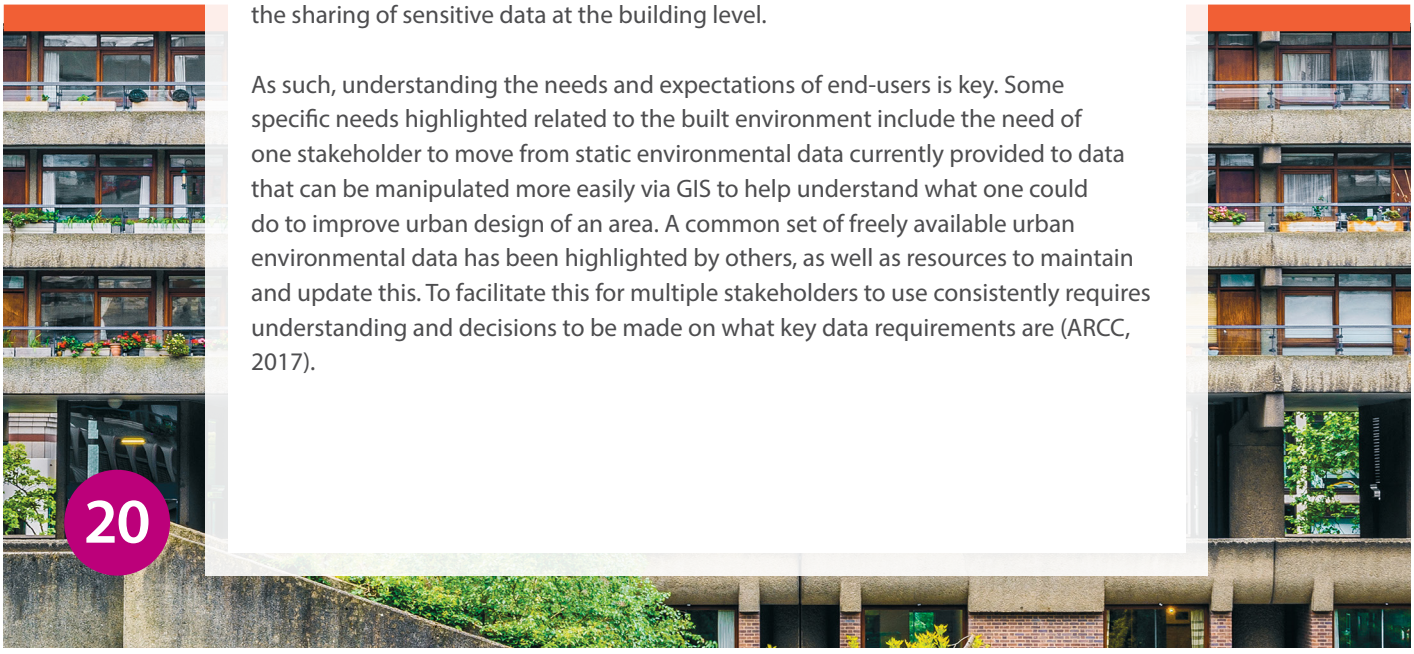
As highlighted by one stakeholder, colleagues, particularly people making decisions, often felt that research was more advanced than it was and they assumed research models and data existed but were just too difficult and time consuming to use and so left to specialist researchers, whereas in reality there were still research gaps in these areas. As such, as well as new advances, current gaps or limitations need to be clearly identified and understood, academically and professionally.

> “…what we think we can do and what we can actually do. Should know what we can do, and we don’t.”

The ARCC network (ARCC, 2015) has highlighted how through early engagement issues such as this can be clarified from the outset, and by building flexibility into proposals can be regularly re-assessed to avoid confusion and disappointment later in the project. This also requires the ability of researchers to clearly communicate the project aims and objectives in a manner that is readily accessible to different stakeholders.

This is crucial as the needs and requirements of different end users can vary widely, ranging from the provision of summary information and reports; provision of data that doesn’t exist/or that can’t easily be accessed (highlighted for local authorities); analysis of sophisticated data that stakeholders already have but wish to use to address specific questions (highlighted by consultancies); static or dynamic maps and datasets; or access to properly packaged tools and models that they could run independently to test different scenarios. The scale of outputs was also highlighted as an area where stakeholders may have very different requirements. Particularly at the finer scale projects may not be able to meet expectations due to licence restrictions on the sharing of sensitive data at the building level.

As such, understanding the needs and expectations of end-users is key. Some specific needs highlighted related to the built environment include the need of one stakeholder to move from static environmental data currently provided to data that can be manipulated more easily via GIS to help understand what one could do to improve urban design of an area. A common set of freely available urban environmental data has been highlighted by others, as well as resources to maintain and update this. To facilitate this for multiple stakeholders to use consistently requires understanding and decisions to be made on what key data requirements are (ARCC, 2017).



In terms of expectations there was also a clear and somewhat unmet desire, highlighted through stakeholder feedback at workshops, for outputs from research projects to be presented to policymakers and the public in simpler and clearer ways, as well as focusing more on the importance and use of outputs in the real world. Similarly, there was a call to disseminate research findings quickly to industry. For example, it was highlighted that those who work on building design or planning do not have the luxury of time.

> “...it’s not that we don’t want to innovate and it’s not that we don’t want to do these things, it’s just that we have so little time to do it and we need something else given to us that we can perhaps use as it comes.”

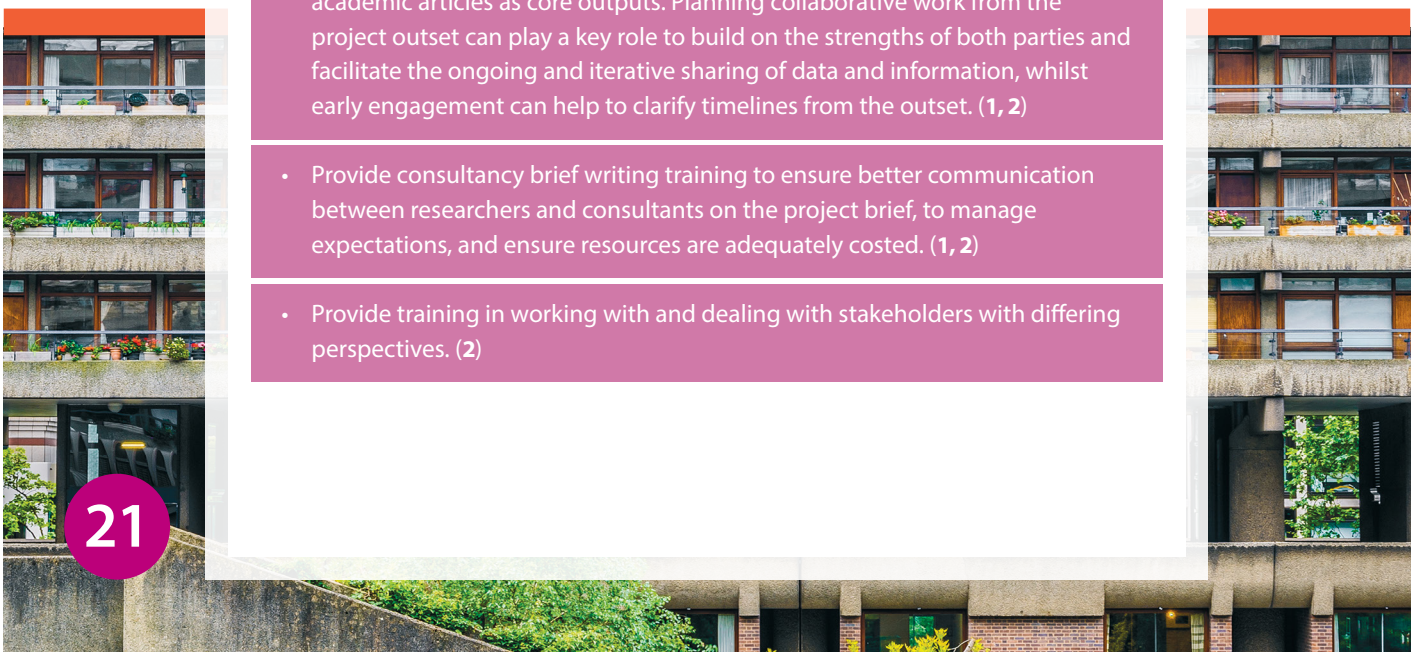
This can often be at odds with project timeframes where final outputs may take years to develop, and the onus is often on publishing academic articles as core outputs. Planning collaborative work from the project outset can play a key role in building on the strengths of both parties and facilitating the ongoing and iterative sharing of data and information, whilst early engagement can help to clarify timelines from the outset.

Learning points:

- A lack of clarity and engagement in the project and its intended deliverables can cause discord between what the stakeholder had expected from the project and what the project could/would ultimately deliver.

Recommendations:

- Build early engagement into the project from the outset to ensure any conflicting expectations are identified and resolved, as well as incorporating flexibility into impact strategies to account for changing stakeholder needs or expectations which can be re-assessed to avoid confusion and disappointment later in the project. This can often be at odds with project timeframes where final outputs may take years to develop, and the onus is often on publishing academic articles as core outputs. Planning collaborative work from the project outset can play a key role to build on the strengths of both parties and facilitate the ongoing and iterative sharing of data and information, whilst early engagement can help to clarify timelines from the outset. (**1, 2**)
- Provide consultancy brief writing training to ensure better communication between researchers and consultants on the project brief, to manage expectations, and ensure resources are adequately costed. (**1, 2**)
- Provide training in working with and dealing with stakeholders with differing perspectives. (**2**)



8. Enhancing the usability of outputs

Just as essential as understanding what stakeholder or end user expectations are, will be understanding how to best present the required outputs to enhance their uptake and usability in practice. It was felt that there was a real barrier in terms of the difficulty in accessing, understanding and using models and data, even by those who had committed time and effort to using them. It can also be difficult to justify time and money to use these tools, which could be better supported if the benefits of using such tools were made clearer and could be quantified in relevant terms.

Investigating such questions early on will help researchers and stakeholders to understand academic and practitioner methodologies, the amount of time and effort required to integrate outputs, and inconsistencies which could mean data could/ couldn't be used (Gething and Puckett, 2013). This can mean taking a step back from developing the model or tools as planned and finding out what works best for stakeholders as well as researchers. For example, the amount of time and resources that industry would be willing to invest in a model or tool. If it takes weeks to run a complicated model and then analyse outputs is this something they would find useful in practice? What software and systems do they use and will it need to be compatible with these?

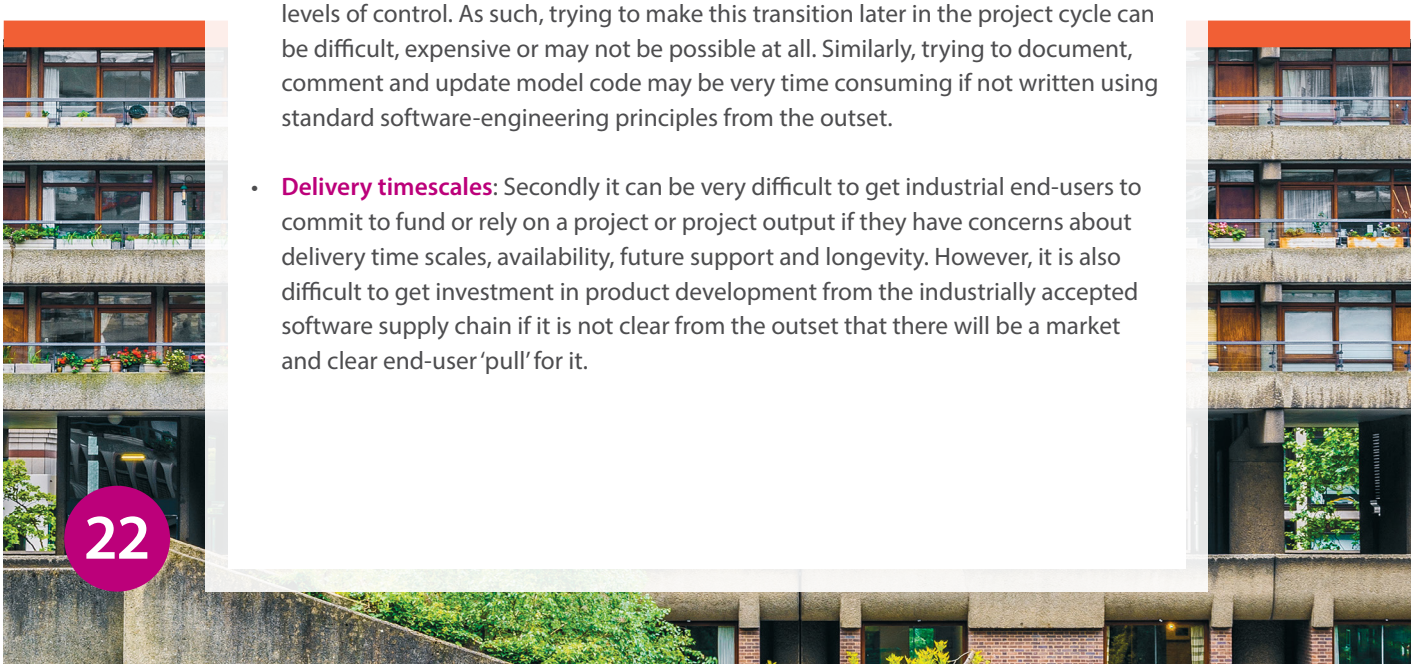
As part of this project, short, online researcher and stakeholder surveys were developed to test these types of questions. The surveys were publicised widely for example by distributing cards at the Ecobuild conference (geared towards forward thinkers in the built environment), as well as at other ARCC events engaging stakeholders. The types of questions, which could provide a useful starting point for discussions between researchers and end users are included in Annex 3.

Issues and barriers

The particular issues and barriers that may arise when transitioning from research tools and models to industry-ready tools are likely to vary across different industries. However, some common themes have been highlighted:

- **Software**: Academic software is very rarely written to industry standards using software-engineering protocols or may not be written using industrially accepted levels of control. As such, trying to make this transition later in the project cycle can be difficult, expensive or may not be possible at all. Similarly, trying to document, comment and update model code may be very time consuming if not written using standard software-engineering principles from the outset.

- **Delivery timescales**: Secondly it can be very difficult to get industrial end-users to commit to fund or rely on a project or project output if they have concerns about delivery time scales, availability, future support and longevity. However, it is also difficult to get investment in product development from the industrially accepted software supply chain if it is not clear from the outset that there will be a market and clear end-user 'pull' for it.



- **Transition costs of industry mainstreaming**: It was also highlighted that to transition and produce industry-standard programs or models can have large production costs that need considerable investment above what may be realistic or reasonable from a research grant. Costs of many times the original research project budget are often cited for putting research outputs into production, including software. Industry-led funding may be one solution to this, but may be difficult to support within an academic research group alongside other research goals and ambitions, which may take priority over the further development of any models, tools, or data.

Benefits of outputs compatible with business as usual

Benefits of making outputs compatible with end-users have been highlighted, for example in the PROMETHEUS project which achieved a high level of economic impact, developing data using an industry standard format. Data was compatible and familiar so there was no need to educate the users in how to use the data; it was in a format their software could read; and was easily recognisable to users.

The Low Carbon Futures project, led by Heriot-Watt University, provided input to CIBSE Guide A on use of climate data. This link meant that project outputs, and outputs of a subsequent project, ARIES (lead by the University of Edinburgh), were tailored towards the practitioner because it was clear to the project who the end user would be and what they would need.

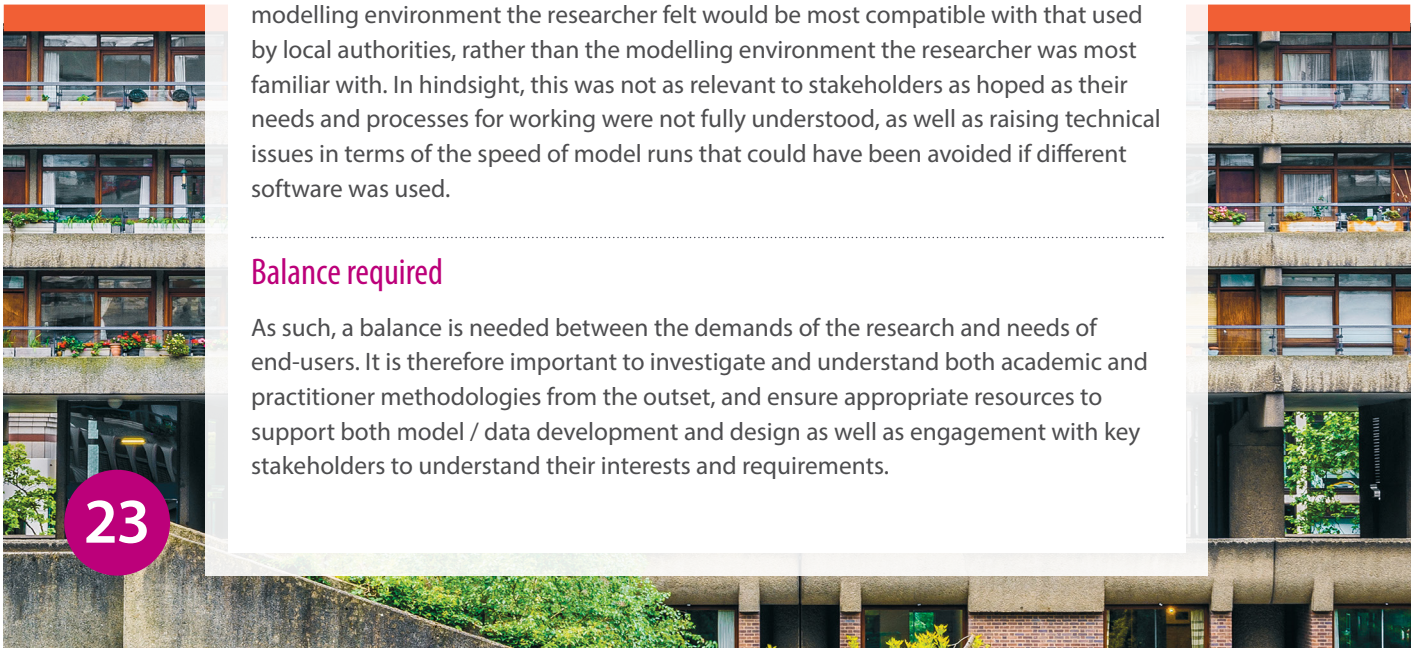
Likewise, the DECORUM model used data procured from local authorities. By utilising these resources, the stakeholder had a natural interest in how data was used and what was generated through its use. This is also beneficial in making sure that outputs are compatible with end-users as they are often familiar with the data formats and e.g. in the case of DECORUM that used local authority data GIS based maps of energy and temperature data could be provided as additional layers on maps that were already used.

> “If you could link it to publicly available data and show the results quickly, it helps them in making decisions.”

Another example given by a researcher was developing a methodology based on the modelling environment the researcher felt would be most compatible with that used by local authorities, rather than the modelling environment the researcher was most familiar with. In hindsight, this was not as relevant to stakeholders as hoped as their needs and processes for working were not fully understood, as well as raising technical issues in terms of the speed of model runs that could have been avoided if different software was used.

Balance required

As such, a balance is needed between the demands of the research and needs of end-users. It is therefore important to investigate and understand both academic and practitioner methodologies from the outset, and ensure appropriate resources to support both model / data development and design as well as engagement with key stakeholders to understand their interests and requirements.



Through the interviews it was highlighted that such activities are often considered a secondary component to the researchers key responsibilities, and so it is important to clearly define and resource for such tasks if to be carried out by researchers, or identify where additional expertise, skills, support or facilitation is needed. For example, specific interdisciplinary or integrative roles could be defined to help manage links from researchers to industry. This intermediary role could facilitate the joining-up process, whilst recognising that all three parts are essential.

Learning points:

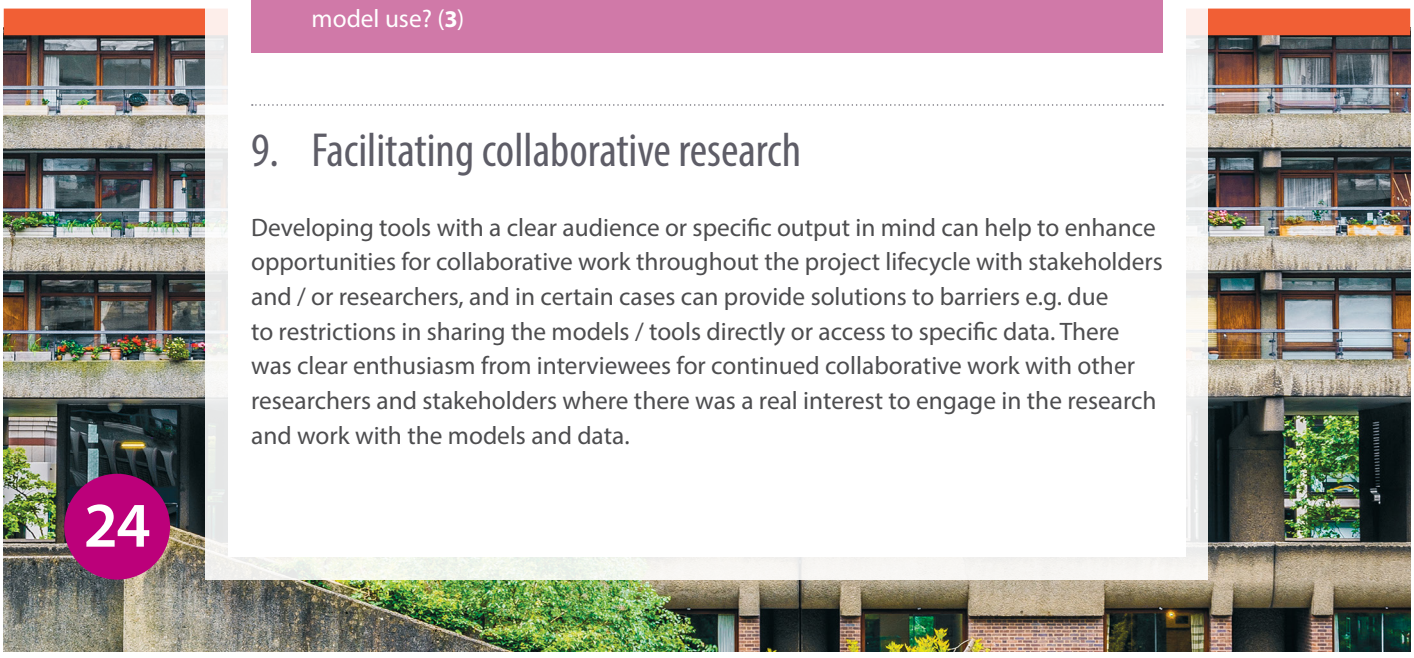
- Understanding the needs of researchers and stakeholders, and engaging to enhance the compatibility of project outputs is often considered a secondary component of the research and model design and development which can often fall to individual researchers to implement at later stages.
- From the project outset, it is important to identify what the potential applications could be, with whom, and requirements to facilitate this.

Recommendations:

- Conduct market research during the project proposal and commencement stages to identify potential users, needs and requirements. This will also help to identify relevant people within the organisation, who may be different to the key project stakeholders, who have the expertise to provide information required e.g. GIS or data specialists. (**1, 2**)
- Research practitioner methodologies e.g. what operating systems they use, what software, what data formats they need, how long would they expect to run models, do they just want outputs or require more support to understand the methodologies underlying the data? This would help to improve user interface and data set compatibility and integration with existing tools. (**1, 2**)
- Consider the use beyond the internal research application e.g. is it compatible with requirements of other users; has an acceptable run time; can run on different operating systems; is there a contingency for any future support of model use? (**3**)

9. Facilitating collaborative research

Developing tools with a clear audience or specific output in mind can help to enhance opportunities for collaborative work throughout the project lifecycle with stakeholders and / or researchers, and in certain cases can provide solutions to barriers e.g. due to restrictions in sharing the models / tools directly or access to specific data. There was clear enthusiasm from interviewees for continued collaborative work with other researchers and stakeholders where there was a real interest to engage in the research and work with the models and data.



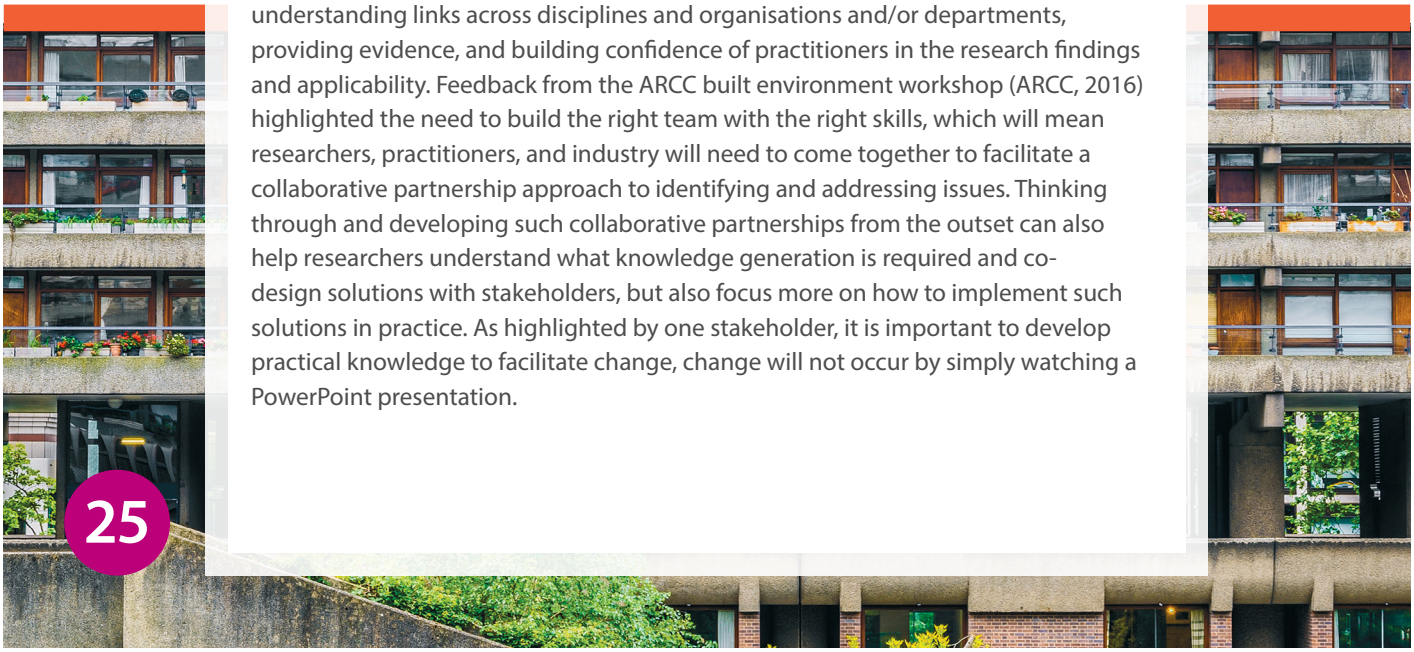
This will also be dependent on the intended use of the models. Across projects the models were developed with different end-goal purposes. For example, to be run 'with stakeholders' rather than 'by stakeholders'. The role of the models in this case could be to help drive a conversation; present evidence to talk though; to drive future collaboration; or understand stakeholder needs and interests.

An example of collaborative work from the ARCADIA project, that developed from stakeholder engagement and networking activities, was an extension to the model to investigate the implications of high temperatures and air conditioning on the London Underground. This was undertaken in collaboration with an employee from the Transport for London Cooling the Tube programme. Through discussions of different models, it was possible to share derived data outputs, rather than the models themselves, and integrate these.

In addition to collaboration with stakeholders, cross project collaboration was highlighted by some interviewees as particularly beneficial to understand how work could fit into the broader research theme; understanding different approaches to similar problems; to avoid duplication of research; and identify new research areas and uses for models, tools or data.

For example, collaboration with researchers involved with LUCID, led by the University College London, and follow on projects was valuable to enhancing and updating specific aspects of the ARCADIA impact model in terms of modelling residential discomfort and adaptation pathways in Greater London. To facilitate this, it required data outputs to be formatted differently by the collaborating model owner and revised data to be provided. Work was needed to make sure the appropriate data and format were provided for the specific needs of the model and the methodology revised to allow work-arounds where appropriate. This research was undertaken when models and data were readily available and research had neared or was nearing completion. However, this also meant that without flexibility, continued determination, and the goodwill of those collaborating on the work, the research would not have reached fruition.

Stakeholders also highlighted an increased need for, and desire to, collaborate with researchers and other stakeholders. This allows perspectives from different research disciplines and practitioners to be combined. For example, practitioners in health working with researchers on air pollution and energy use. Benefits of this can include understanding links across disciplines and organisations and/or departments, providing evidence, and building confidence of practitioners in the research findings and applicability. Feedback from the ARCC built environment workshop (ARCC, 2016) highlighted the need to build the right team with the right skills, which will mean researchers, practitioners, and industry will need to come together to facilitate a collaborative partnership approach to identifying and addressing issues. Thinking through and developing such collaborative partnerships from the outset can also help researchers understand what knowledge generation is required and co-design solutions with stakeholders, but also focus more on how to implement such solutions in practice. As highlighted by one stakeholder, it is important to develop practical knowledge to facilitate change, change will not occur by simply watching a PowerPoint presentation.



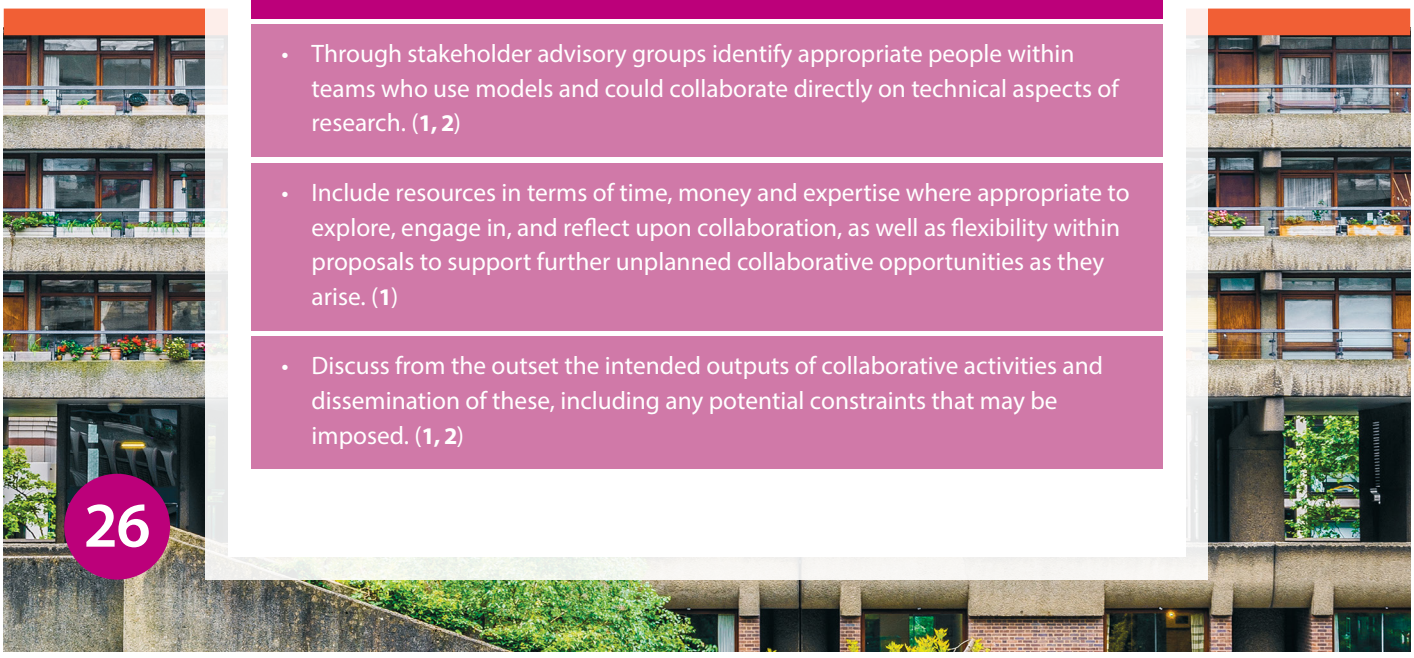
Close collaboration can also help overcome another obstacle in that stakeholders who may be enthusiastic and wish to use the data are often also working under their own internal pressures and may not have the time, budget or other resources to spend understanding the data and integrating it into their system. By addressing such issues during the development of models, tools, or datasets technical issues can be understood and planned for in advance. While it may not be feasible to tailor outputs for a wide range of stakeholders the benefits of having an active case-study can still be highly beneficial. For example, this type of buy-in to actively engage, use products, and provide feedback was highlighted as an essential step within the PROMETHEUS project, which was extremely successful in its aim to develop a new set of probabilistic reference years that could be understood and used by building designers. This provided the project with some case studies on which to promote the work in a way that was relevant and understandable to those working in a similar field. A second benefit of facilitating uptake by a stakeholder 'champion' is that they can then promote this through their own industry channels and networks publicising the research's existence and availability.

Learning points:

- Collaborative research can provide a mechanism for enhanced impact, demonstrating research outputs, support ongoing stakeholder engagement and communication, and provide a platform to disseminate and publicise the potential use and uptake of research.
- Collaboration during the research phase means stakeholders can help researchers to understand what information would be most valuable, and the depth of detail they require in terms of developing methodologies and outputs.
- Planned and unplanned collaborative activities may occur throughout the project or upon completion. Beyond the timeframe of the project collaboration often falls to the goodwill of researchers to undertake work in their own time.

Recommendations:

- Through stakeholder advisory groups identify appropriate people within teams who use models and could collaborate directly on technical aspects of research. (**1, 2**)
- Include resources in terms of time, money and expertise where appropriate to explore, engage in, and reflect upon collaboration, as well as flexibility within proposals to support further unplanned collaborative opportunities as they arise. (**1**)
- Discuss from the outset the intended outputs of collaborative activities and dissemination of these, including any potential constraints that may be imposed. (**1, 2**)



10. Dissemination of final project outputs

The ability to share and disseminate final project information to wider external audiences will depend on the ultimate purpose of the model / tool / data being developed. In the projects reviewed by this study, although many outputs were geared towards use by stakeholders, issues already highlighted (e.g. due to expectation of researchers) meant that mechanisms to deliver final products were often lacking.

Given the level of completion of models and tools, and competition for follow on funding, the further development of models beyond the lifetime of projects was a key barrier. For example, the development of more user-friendly interfaces or support for the commercialisation of tools and models. The resources in terms of time and cost to tidy up tools, make tools more accessible to those not directly involved in the work, and e.g. develop user interfaces, were estimated to be small in comparison to the funding of the project overall. Yet, without these additional resources in many cases the research simply 'ground to a stop' on project completion.

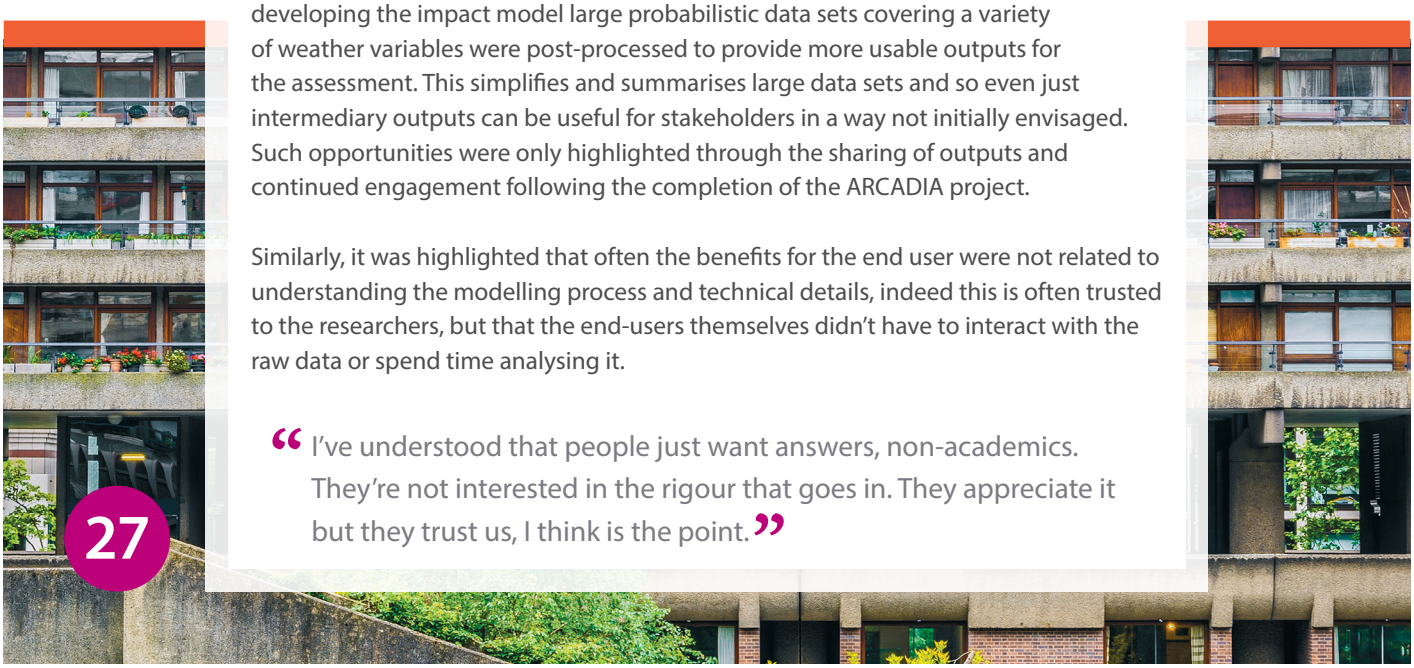
This was frustrating as interviewees could clearly highlight, and in many cases, had engaged with, specific stakeholders and private and public bodies who had an interest in using the tools, and could identify the potential impact they could have. However, stepping from the initial research or prototype models and tools was often seen as being a successive activity to the projects themselves. Issues that compound the sharing of prototype models and tools included the need to be able to tidy up models and code, quality control their use, provide resources to support further software development to professionally package them, and provide resources for ongoing software support.

Benefits of sharing models and data were highlighted by the Low Carbon Futures project which could present in a clear and usable format the risk of building overheating in future climates. An insight from this was that available models or datasets can output / contain a vast amount of data that can be difficult to use, yet models developed can, sometimes indirectly, provide a platform to simplify what is available and provide this in a framework that is more easily usable.

A second example is the Climate Impact Model developed as part of the ARCADIA project. While initially developed as an aid to the research undertaken, when developing the impact model large probabilistic data sets covering a variety of weather variables were post-processed to provide more usable outputs for the assessment. This simplifies and summarises large data sets and so even just intermediary outputs can be useful for stakeholders in a way not initially envisaged. Such opportunities were only highlighted through the sharing of outputs and continued engagement following the completion of the ARCADIA project.

Similarly, it was highlighted that often the benefits for the end user were not related to understanding the modelling process and technical details, indeed this is often trusted to the researchers, but that the end-users themselves didn't have to interact with the raw data or spend time analysing it.

> "I've understood that people just want answers, non-academics. They're not interested in the rigour that goes in. They appreciate it but they trust us, I think is the point."



In terms of the level of detail the above point also applies to the more general presentation of results at dissemination events, with it felt that sometimes too much attention was paid to scientific and technical advances rather than presenting key findings in a manner which highlighted their potential application to stakeholders. This again comes back to the specific expertise and background from which researchers usually present. The focus on research methods and results, through a series of PowerPoint presentations, can prove a barrier to the actual understanding and uptake of research as often this can be very technical and cover lots of information that isn't directly usable.

In some projects, it was more difficult to simply provide data or tools to potential users as in many cases these required a certain level of experience or expertise to use, particularly given developments and novel advances made through the research itself. To facilitate this could also require some level of training and/or short and longer-term support which is hard to facilitate once projects end, and given other commitments and experience of researchers.

As such, in some projects it was purposefully decided not to give out the tool as it required some expertise to use and fully understand (e.g. the DECORUM model), but dissemination instead focused around other project outputs such as datasets and GIS maps. The types of outputs which are most useful can be established through good engagement to enhance the compatibility with end-user needs.

Packaging model outputs e.g. GIS based maps, GIS toolkits and online visual tools can also be useful to stimulate discussions. Where presented well, the use of maps which summarise data e.g. through colour coding can help extend the outreach of research to non-technical audiences.

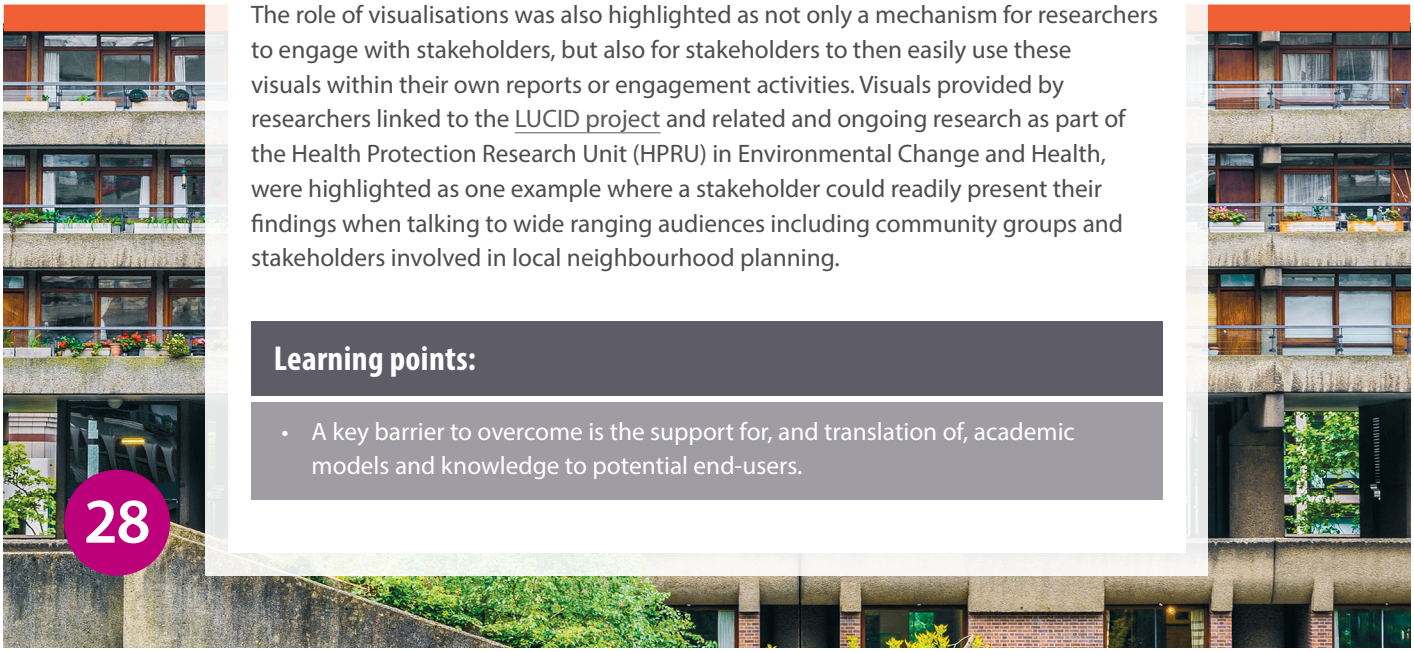
> "...it's not just the model, it's the visualisation of the results that engages people."

This was true of the experience with ARCADIA where online maps visualising outputs, using map formats people were familiar with, and that could easily be investigated and manipulated helped to engage different audiences who could then see a clearer link to model outputs and datasets that could be provided in a format familiar to them.

The role of visualisations was also highlighted as not only a mechanism for researchers to engage with stakeholders, but also for stakeholders to then easily use these visuals within their own reports or engagement activities. Visuals provided by researchers linked to the LUCID project and related and ongoing research as part of the Health Protection Research Unit (HPRU) in Environmental Change and Health, were highlighted as one example where a stakeholder could readily present their findings when talking to wide ranging audiences including community groups and stakeholders involved in local neighbourhood planning.

Learning points:

- A key barrier to overcome is the support for, and translation of, academic models and knowledge to potential end-users.



- While impact focused activities, and additional impact funding, are beneficial to support further engagement and discussion and highlight key collaborative opportunities, there is still a resource constraint in delivering final products.

- Projects need to do more to clearly and simply articulate to participants how outputs could be useful to them, share outputs and fully engage to get feedback. For example, it may be that potential users highlight other beneficial aspects of the research models or data.

Recommendations:

- As part of the proposal think through from the outset the intended audience and how information will be disseminated to overcome this barrier. For example, a model to download, use as a learning tool and drive conversation, data, or visual aids? (**1**)

- Cost and resource for these aims appropriately. For example, if a tool is to be provided will it require online resources to support its use or workshops or engagement events to facilitate end-user training as a part of the project itself? (**1**)

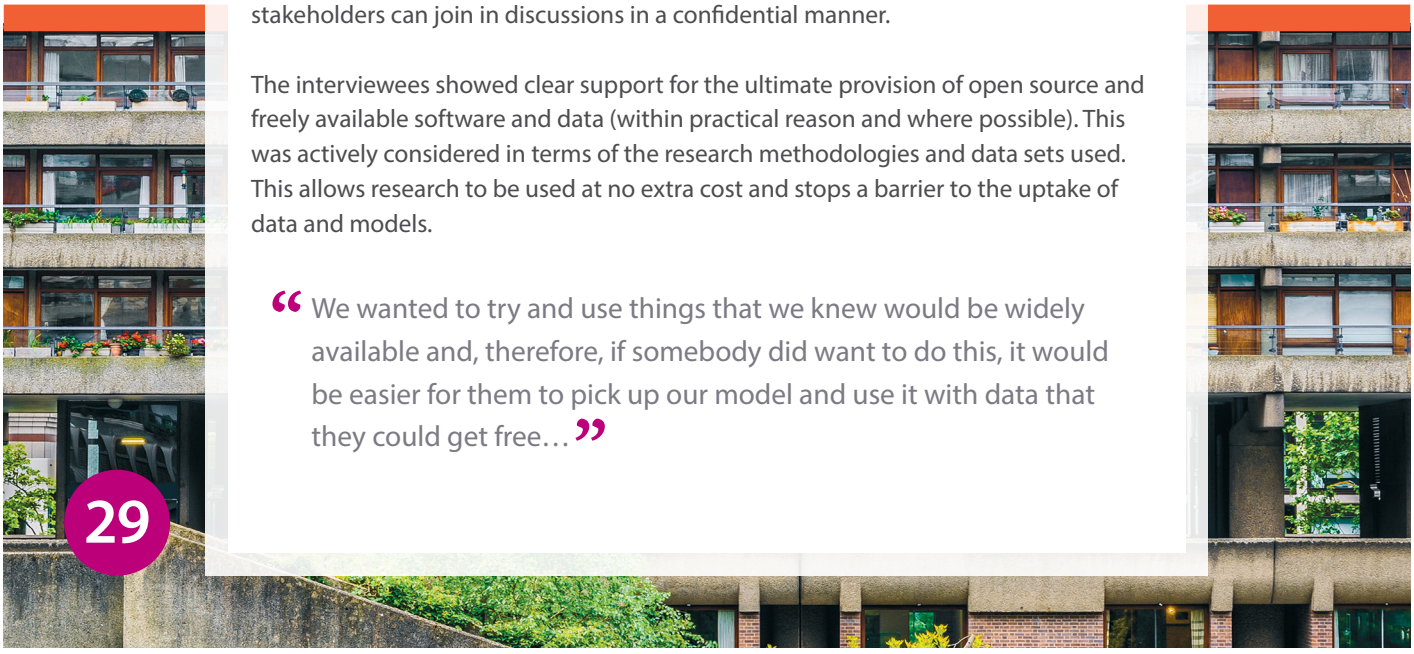
- Provide researchers with support or training on how to format outputs for different audiences, e.g. could better or different ways of visualising data help, and how to present to different audiences. (**4**)

11. Restrictions to sharing models, tools and data

There are numerous reasons that may restrict the sharing of data, including data privacy laws, commercial sensitivity and academic intellectual property rights. Researchers may also fear sharing a valuable resource that is part of future research, fear errors being discovered, or analysis / results being questioned (Hamilton *et al*. 2015). Additional constraints can be due to the period under which data for a particular project may have been licensed, or ethical issues where information was gathered through participatory workshops or focus groups where it is important that stakeholders can join in discussions in a confidential manner.

The interviewees showed clear support for the ultimate provision of open source and freely available software and data (within practical reason and where possible). This was actively considered in terms of the research methodologies and data sets used. This allows research to be used at no extra cost and stops a barrier to the uptake of data and models.

> “We wanted to try and use things that we knew would be widely available and, therefore, if somebody did want to do this, it would be easier for them to pick up our model and use it with data that they could get free…”



No interviewee highlighted major issues which they felt would hinder their collaboration and sharing of tools completely, particularly where mutually beneficial in terms of impact and showcasing the work and demonstrating its utility. However, other constraints were linked to issues of resources, the stage and level of development of models, longer-term support for their use, issues of quality control, or where data could be used for marketing purposes it was not intended for.

In certain cases, data sets used were restricted by licensing agreements between Universities and data providers. Other issues related to the scale of data or model outputs. This was pertinent for those projects focused at a building level where household level data could not be shared because of the need to anonymise it.

However, possible solutions to this include the development of derived data sets, the aggregation of data to different scales, or anonymisation of data. This can require additional work to post-process data and generate derived data that is still useful and meets the purpose of stakeholders. Alternatively, models and/or tools can be provided in isolation along with details of the data required to use them. While this is one approach, it can also act as a hindrance to uptake as potential users will need to access or potentially pay for data to use the tool unless already available to them.

Other approaches include the provision of a 'light' model version. For example, DECORUM-Light, showing the spatial distribution of benefits of different Blue-Green infrastructure scenarios, was developed as the full version can be time and data intensive. This was facilitated under a project called LEMUR (Local Energy Mapping for Urban Retrofit) which linked DECORUM to publicly available data. It is based in ArcGIS so by downloading the toolbox it is readily usable and uses OS data which can often be downloaded for free.

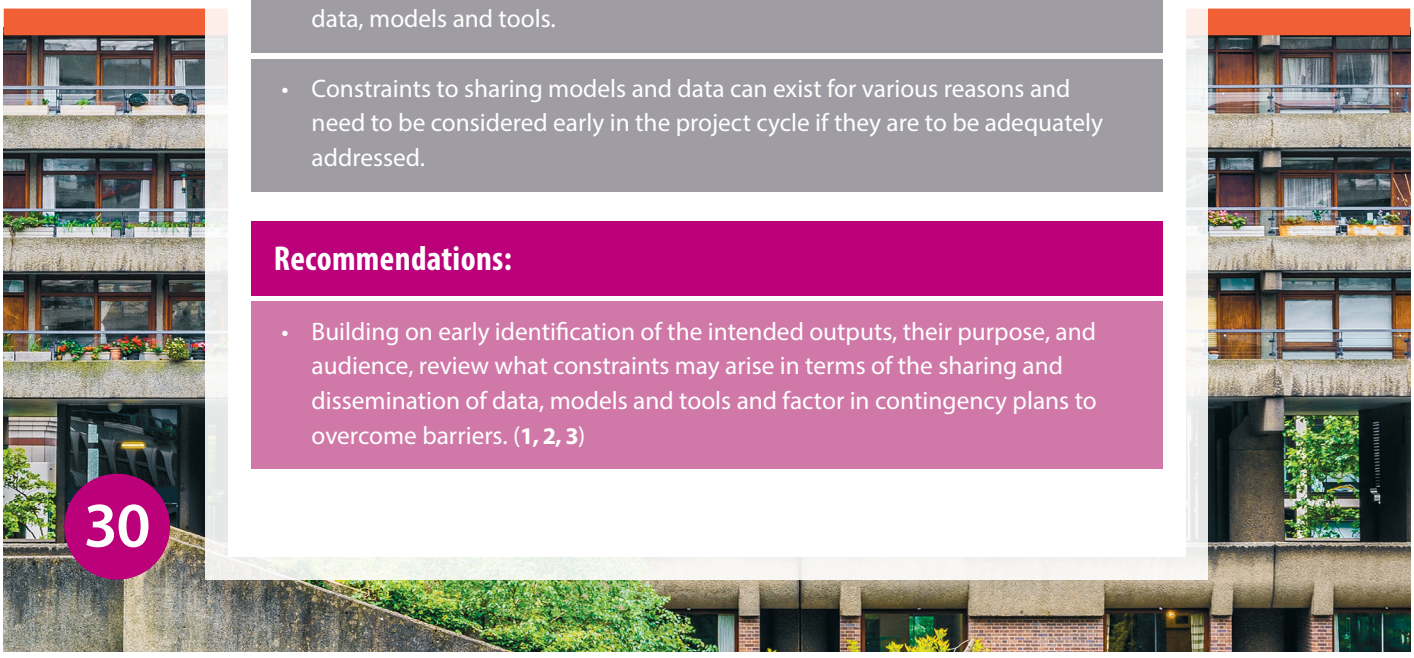
Identifying potential restrictions early on, and learning from past projects, can help to ensure that appropriate data management and dissemination strategies are put in place from the outset, as well as developing methodologies which would facilitate future sharing of models and data as much as feasibly possible.

Learning points:

- There was clear support for the provision of open source and freely available data, models and tools.
- Constraints to sharing models and data can exist for various reasons and need to be considered early in the project cycle if they are to be adequately addressed.

Recommendations:

- Building on early identification of the intended outputs, their purpose, and audience, review what constraints may arise in terms of the sharing and dissemination of data, models and tools and factor in contingency plans to overcome barriers. (**1, 2, 3**)



- Identify alternative options and assess their usefulness with end-users e.g. if aggregate or derived data is to be provided will this still be useful for stakeholders and address their needs? Can 'light' versions be developed to reduce the level of complexity? (**2, 3**)

- Investigate stakeholder requirements and working processes e.g. do they have access to data that could be used alongside the models, will they spend time running them or be willing to pay for data? (**1, 2, 3**)

12. Data management

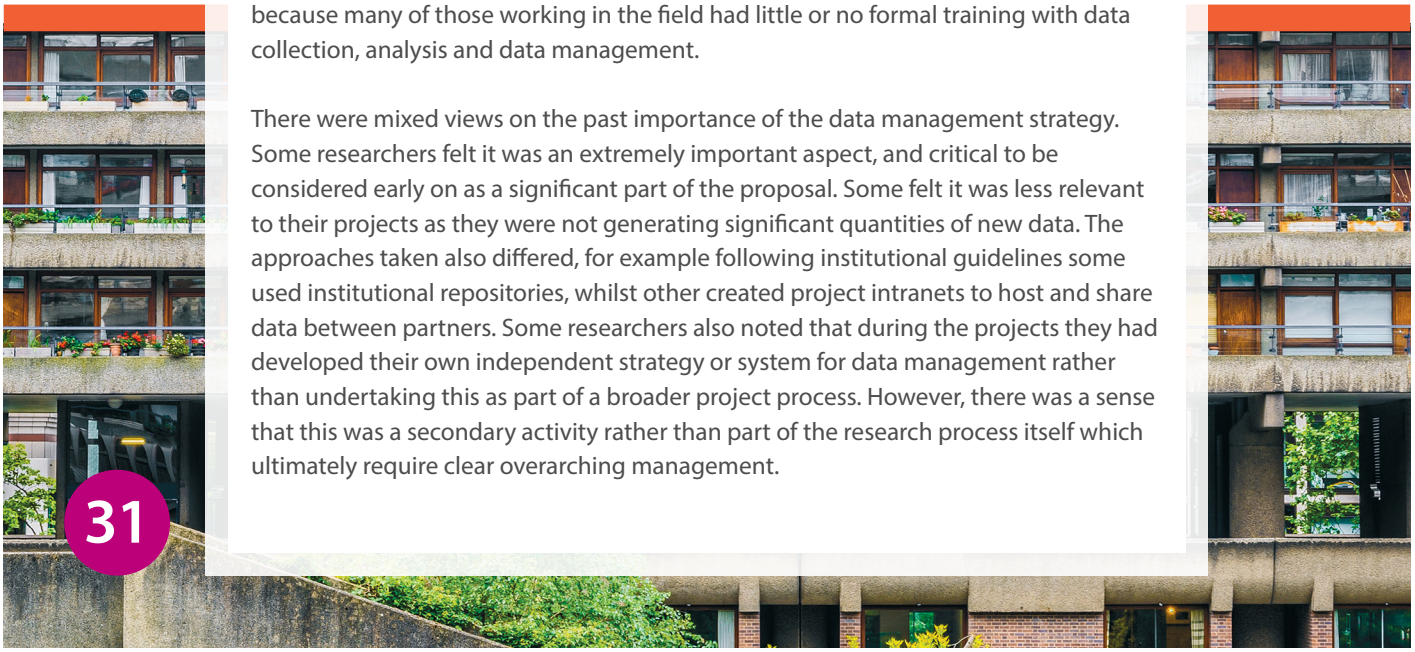
The majority of the ARCC research projects reviewed by this study preceded the most recent data management requirements of EPSRC and RCUK as well as changes at institutional levels. EPSRC is the RCUK council which places most responsibility for data management with the institution, as opposed to the Principal Investigator. However, this should align with EPSRC expectations. Namely that:

1. EPSRC-funded research data is a public good produced in the public interest and should be made freely and openly available with as few restrictions as possible in a timely and responsible manner

2. EPSRC recognises that there are legal, ethical and commercial constraints on release of research data. To ensure that the research process (including the collaborative research process) is not damaged by inappropriate release of data, research organisation policies and practices should ensure that these constraints are considered at all stages in the research process.

The potential benefits of high quality, well organised, and accessible built environment data will likely accrue to researchers, practitioners and institutions, extend the impact of research, and result in innovative findings where data is newly available or linked together. However, there was an impression of limited knowledge, or clear framing, of data management strategies for researchers to adhere too (although it is reiterated most projects reviewed preceded the most recent requirements by EPSRC and institutions). As Hamilton *et al*., (2015) highlights, in the energy and buildings field one of the main reasons why data is both difficult to access and poorly structured is because many of those working in the field had little or no formal training with data collection, analysis and data management.

There were mixed views on the past importance of the data management strategy. Some researchers felt it was an extremely important aspect, and critical to be considered early on as a significant part of the proposal. Some felt it was less relevant to their projects as they were not generating significant quantities of new data. The approaches taken also differed, for example following institutional guidelines some used institutional repositories, whilst other created project intranets to host and share data between partners. Some researchers also noted that during the projects they had developed their own independent strategy or system for data management rather than undertaking this as part of a broader project process. However, there was a sense that this was a secondary activity rather than part of the research process itself which ultimately require clear overarching management.



> “The primary part for us was how to get the outputs and then we worried about how to manage all the data afterwards.”

Projects which clearly illustrated accessible data outputs were found to have proactively developed web interfaces and data stores during the research stage, which were made freely available. Dissemination of this nature was integrated into the project plan from the outset, rather than being considered as a follow up activity on completion of the research.

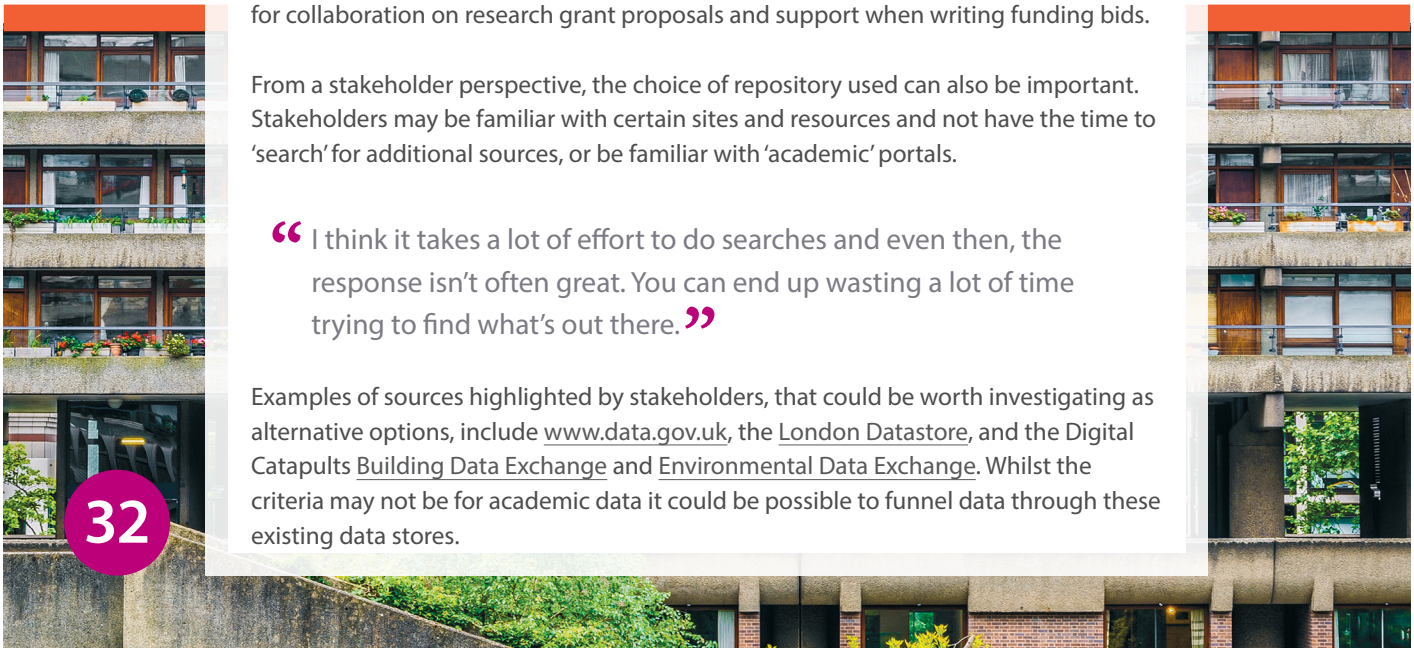
Suggestions from academics and practitioners gathered through the ARCC Urban microclimate: overcoming obstacles to high density resilient cities workshop (2017), also included calls to move beyond issues of simply being able to access data to improving data consistency and standardising the format of this. This would encourage and open new possibilities for cross-examination, combining different datasets, and support collaboration. The EPSRC-funded TEDDINET (Transforming Energy Demand through Digital Innovation), includes the project Data Management for TEDDINET (D4MT) to help teams collectively construct a data legacy across the set of TEDDI projects, focusing on building knowledge and experience of appropriate ways to collect and curate data. This has involved the creation of a tool, MetaMaker, to add metadata to .csv files for building energy data so that queries can be carried out across different datasets and from different sources. Likewise, other key repositories and data sharing portals could be identified early on e.g. the European Climate Adaptation Platform (Climate-ADAPT) established to help users to access and share climate related data and information. The identification of such tools and support at early stages of projects could help to enhance the data management process, support researchers, and enhance the usability of data by developing strategies to actively promote the outputs and encourage their use.

Universities also host repositories for the archival store for digital data produced as a result of research by academics. Benefits of utilising these include DOIs for datasets so they can be cited, the long-term preservation and curation, and data will be assigned a licence and can be made publicly available. Systems may also support addition of metadata to help with understandability and make items discoverable. Where costs are expected, support can be provided to account for these within cost codes when developing budgets. Other online resources include e.g. the Open Data Institute which provides online resources and support for open data initiatives as well as the potential for collaboration on research grant proposals and support when writing funding bids.

From a stakeholder perspective, the choice of repository used can also be important. Stakeholders may be familiar with certain sites and resources and not have the time to ‘search’ for additional sources, or be familiar with ‘academic’ portals.

> “I think it takes a lot of effort to do searches and even then, the response isn’t often great. You can end up wasting a lot of time trying to find what’s out there.”

Examples of sources highlighted by stakeholders, that could be worth investigating as alternative options, include www.data.gov.uk, the London Datastore, and the Digital Catapults Building Data Exchange and Environmental Data Exchange. Whilst the criteria may not be for academic data it could be possible to funnel data through these existing data stores.



For example, information on London's Urban Heat Island during a heatwave has been uploaded by researchers as an online resource on the London Datastore. Having data easily identifiable and in a workable format will be key to its subsequent uptake. It was noted by one stakeholder that if this process was simplified then uploading and using different sources of data could be embedded by stakeholders as part of daily tasks without much additional effort.

Conversely sub-optimal data management can also be a barrier for researchers as well as stakeholders. Stakeholders, such as local authorities, may hold data that could be useful but can have their own internal data standards and management strategies. For example, there can be large differences in the quantity, accessibility, and age of data that local authorities put online.

A further key issue was there was a lack of clarity over who had / or should have responsibility for the development and management of the data management strategy, although it was generally felt by interviewees that this should be implemented and imposed in a top-down manner as part of the management process to ensure such a strategy was adhered to by researchers. It was highlighted by researchers that they would benefit from someone with specific expertise to manage this, ensure it is happening efficiently, and being planned for alongside research tasks to be most effective. Another potential benefit of having a clear data management process in place for academics to follow throughout the project is that it can save time and reduce the need to redo or update work later in the project when next steps are being considered.

Learning points:

- In past projects, it was felt that data management was often left to researchers to incorporate within their own research agenda and was undertaken in an ad hoc manner.
- There was a lack of clarity over who had/or should have responsibility for the development and management of the data management strategy.

Recommendations:

- Specific expertise and knowledge of the most appropriate ways to manage, store, present and publicise available data may be required. Experts in this area could offer support and facilitate such management practices. When developing proposals investigate and incorporate resources to support adequate data management. (**1**)
- Data management strategies are part of good research management, and as such further training for researchers or project managers could be sought to help enhance expertise in this area. (**2**)
- Invest time in researching tools and mechanisms to support data management. What is available, how could it enhance cross examination of data, compatibility, collaboration and uptake in the future? (**1, 2, 3**)

13. Ongoing software support for tools/models/data

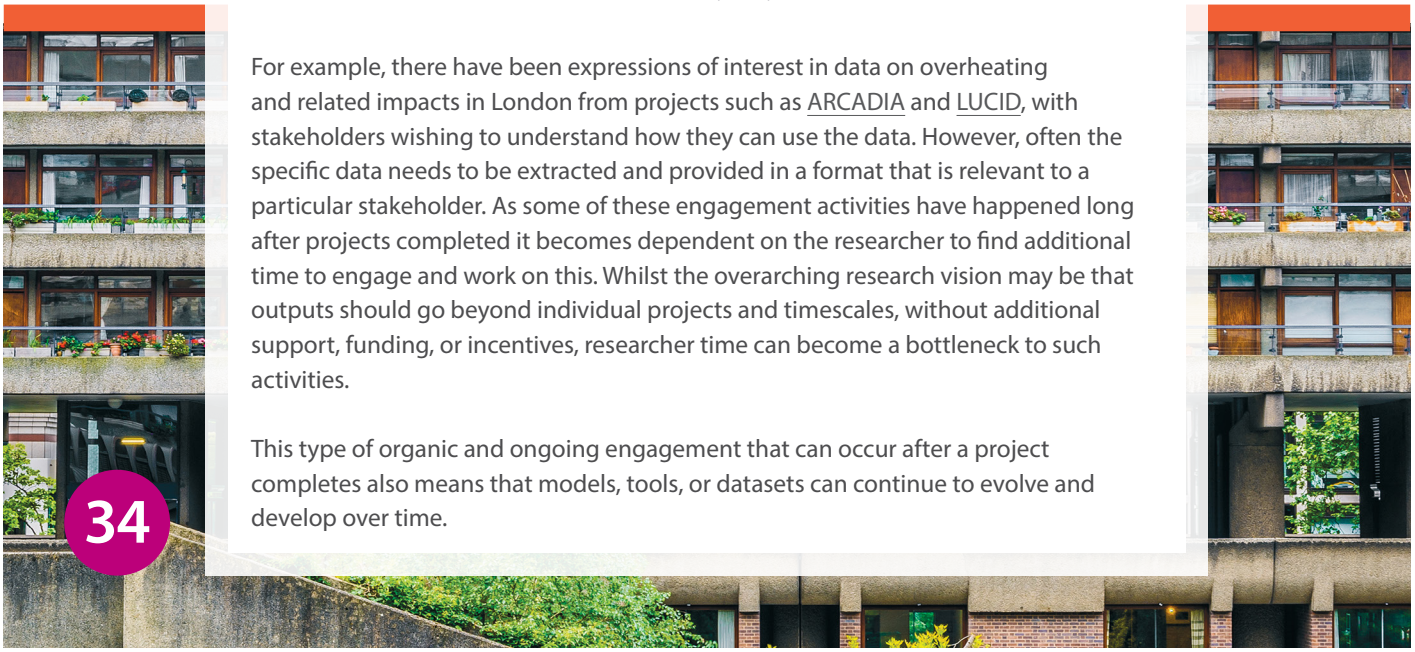
The issue of ongoing resources to enhance the longevity of models and tools was raised by many of those interviewed, particularly that researchers and their institutions often do not have the capacity to provide ongoing support for the software e.g. web-hosting and updates beyond the lifetime of the project itself.

Many of those interviewed commented that they were interested and active in pursuing collaborative work and happy to devote their own time, where reasonable, to providing data and model runs beyond the scope of the project. However, unless there is some framework for ongoing support for these activities such work can be slow, eventually come to a stop, and is often dependent on a few researchers retaining links with the work. This itself can be difficult as contract researchers may move institutions and the models and tools they have developed become difficult to access and use by others.

Similarly, there is often a need for the provision of external support from those experienced with the models, tools, and data beyond the lifetime of the project. For example, support to answer questions or providing guidance and/or training in using the model or data. The need for some form of managed quality control was also highlighted as an issue to ensure that people using the tools, and referencing them as sources, are using them correctly and not misrepresenting outputs.

Part of this issue can stem from requiring some level of research experience or particular expertise to understand the model and outputs. It can also be related to the level of completion of tools, models and datasets within the project timeframe, and level of documentation, which can require the researchers to continue to work as operators, often in parallel to new research responsibilities.

> “…changes and updates were required to include updated information and provide the relevant outputs. It was quicker for the original researcher who developed the code to do this rather than someone else try and understand and edit the code, which would have probably resulted in a long series of questions and need for assistance from the researcher anyway.”



For example, there have been expressions of interest in data on overheating and related impacts in London from projects such as ARCADIA and LUCID, with stakeholders wishing to understand how they can use the data. However, often the specific data needs to be extracted and provided in a format that is relevant to a particular stakeholder. As some of these engagement activities have happened long after projects completed it becomes dependent on the researcher to find additional time to engage and work on this. Whilst the overarching research vision may be that outputs should go beyond individual projects and timescales, without additional support, funding, or incentives, researcher time can become a bottleneck to such activities.

This type of organic and ongoing engagement that can occur after a project completes also means that models, tools, or datasets can continue to evolve and develop over time.

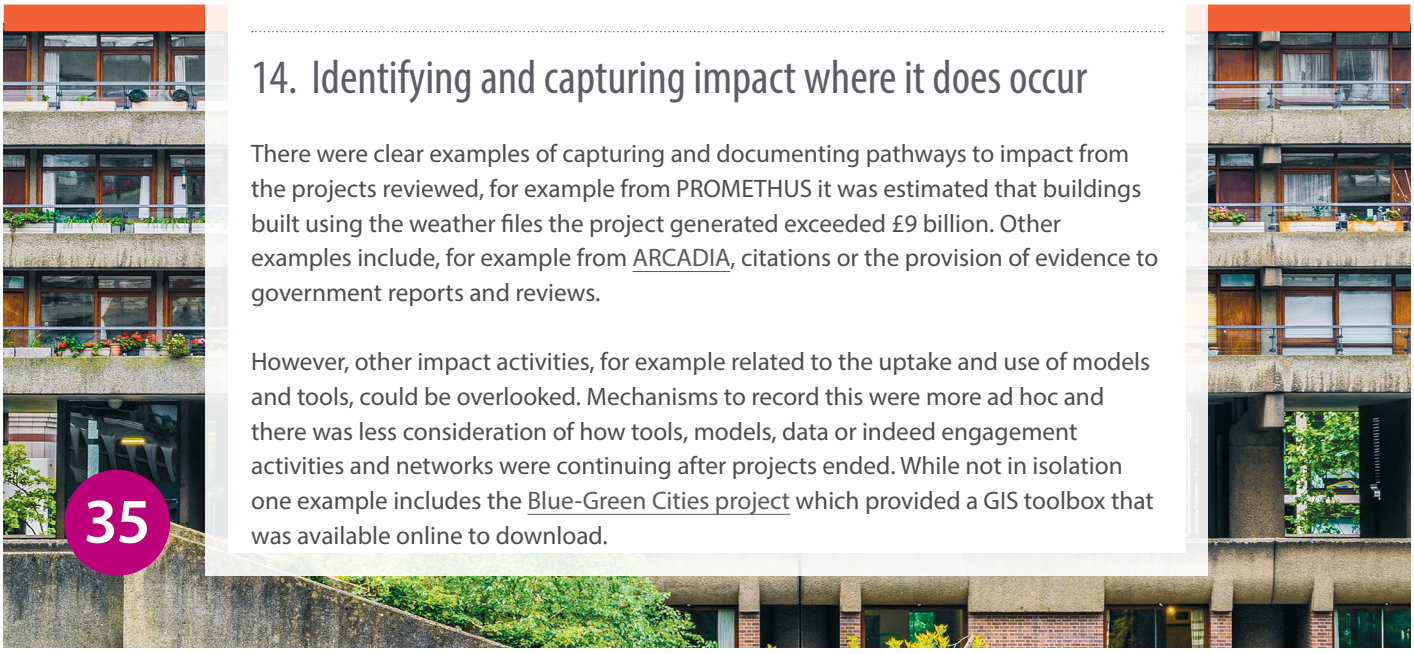
Edits and modifications may be added for various stakeholders or projects but the documentation of this can be difficult as this work is often done in addition to core researcher responsibilities. Yet, it is often this form of ongoing development that continues to build model capacity, strengthens the reputation of models, and supports their longevity. This is key for the legacy of such models, tools and data, with examples seen of how long-standing models or datasets such as from DECORUM and PROMETHEUS have benefitted from their legacy and longevity and the reputation and trust that has built up around their continued use and evolution.

Learning points:

- A key barrier that can restrict the availability and usability of models and tools is the competing or new research responsibilities of those experienced with the models, tools, and data beyond the lifetime of an individual project.
- Secondly, limited capacity to provide ongoing support for the software e.g. web-hosting and updates beyond the lifetime of the project itself can also restrict the availability and usability of models and tools.
- Continued use and ongoing development can be beneficial to build model capacity, support model longevity, build a good reputation and trust in their use, and ultimately the legacy of the work.

Recommendations:

- During the project proposal and planning stages consider the additional expertise or support that may be required to ensure longevity of outputs and investigate options, such as working with institutional staff or stakeholders to address this, including resources for such activities. (**1**)
- Develop a clear legacy plan for research outputs from the outset, that can be modified throughout the course of the project. This may include identifying grants or funding that could be used on completion of projects to continue with the dissemination and support of models and tools. (**2, 5**)



14. Identifying and capturing impact where it does occur

There were clear examples of capturing and documenting pathways to impact from the projects reviewed, for example from PROMETHUS it was estimated that buildings built using the weather files the project generated exceeded £9 billion. Other examples include, for example from ARCADIA, citations or the provision of evidence to government reports and reviews.

However, other impact activities, for example related to the uptake and use of models and tools, could be overlooked. Mechanisms to record this were more ad hoc and there was less consideration of how tools, models, data or indeed engagement activities and networks were continuing after projects ended. While not in isolation one example includes the Blue-Green Cities project which provided a GIS toolbox that was available online to download.

However, there was no mechanism put in place to record how widely this has been downloaded, how it's been used in practice, or formal feedback from those who downloaded the tool on its usability. This type of information, if recorded, would be valuable for understanding potential users, benefits and limitations of using the resource and help to provide feedback and lessons for future developments or projects. Recording this information could also support project reporting, e.g. supporting pathways to impact on Researchfish, and could help to incentivise researchers to undertake such activities where their contributions and impacts are recorded and properly reported.

Learning points:

- When placing models, tools, or data online this should not be viewed as a final step, but instead can be used to provide valuable feedback in terms of users, planned uses and potential and real impact of the resource.
- Recording such information can provide valuable lessons on what did and didn't work well. Sharing such insights honestly could benefit future developments or projects.

Recommendations:

- When developing data management and impact strategies build into these mechanisms for identifying and measuring success. This may stretch beyond models, tools, and data to engagement activities and networks. (**2**)
- Build into online repositories measures to capture information on e.g. the number of downloads, the users sector, and the purpose of the download. (**6**)
- Talk openly about what worked well, what went wrong, and what was done about it. (**6**)

15. Future funding and next steps

For certain projects reviewed the subsequent value of Impact Acceleration Award Accounts (IAA) was evident. Decisions on how this funding is invested is made by the 33 participating Research Organisations, with the aim to plan how their research is going to be communicated, translated and accelerated to users and moved further along the line towards use. Not all universities have an IAA account and can apply for this type of funding, and those researchers that do will be competing against any other projects that fall under the remit of the specific research council involved. However, where applicants were successful it was found that IAA grants were useful for promoting the existence of tools and models, disseminating information, supporting further engagement, understanding how to tailor this to end-user needs, and investigating next steps for further development.

However, some projects benefitting from IAA accounts also highlighted that there can still be a barrier to overcome between the outreach activities undertaken to showcase research, data and tools, the enthusiasm and interest of different stakeholders in the

tools presented, and then the final step in terms of ability to provide access and use of the tools and data. To reach this stage it was highlighted that the IAA projects need to be very focused and dependent on the initial research being at a very advanced stage in terms of the outputs that can be provided. At this stage, other options for funding may become more appropriate, with researchers exploring wider EPSRC / RCUK funding for related projects, Innovate UK funding, commercialisation funding, and institutional funding. Projects also highlighted more innovative ways of being funded, e.g. through crowd sourcing or trying to get buy-in from industry, but the overall feeling was this was very difficult to attract and as such model development often ended abruptly as projects ended.

Small collaborative grants provided another avenue that could be used to support this type of development, towards the end or on completion of projects. In many cases, it was not felt the resources in terms of time and cost to provide final models/tools/data, and access to these were very high, but the key was to identify and attain support and work with the correct person with the correct skills. This could include working with web developers or other academics with different skill sets to package outputs. Benefits of this approach were highlighted through this project as part of the ARCADIA case study (see Annex 2).

A second example would be to work with external software engineers to reduce the software-development costs in the supply chain and allow multiple suppliers to offer the solution. This approach is being pursued by the University of Bristol with the Manufacturing Technology Centre (MTC, one of the 7 High Value Manufacturing Catapult centres) in a pilot of the MTC's new Algorithm Deployment Support Service (ADSS).

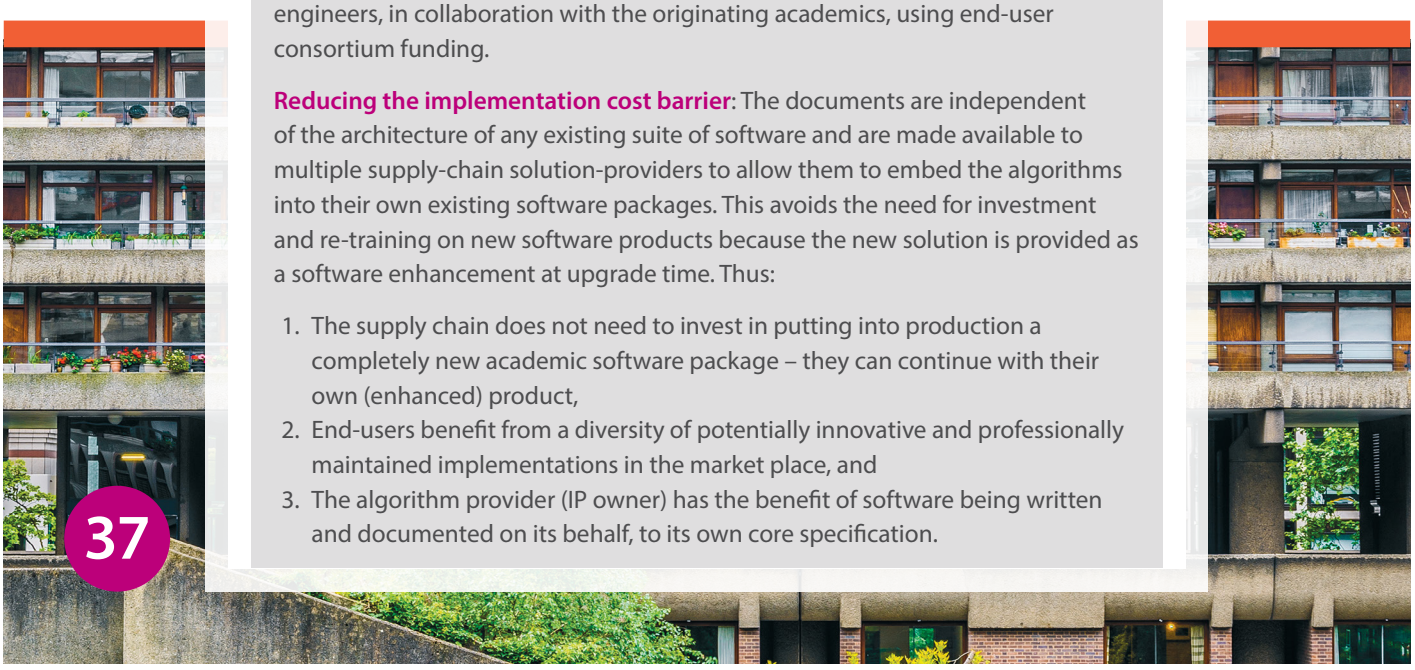
Case study: Algorithm Deployment Support Service (ADSS)

ADSS was specifically established to support the transition process from academia to multiple suppliers for public-domain (published) algorithms, providing solutions to common issues arising at the end of a research project.

IP: The intellectual property (IP) that is transitioned does not rest in software itself but in industry-standard software-engineering documents (generally Requirements, Design and Test Documents) generated by MTC's software engineers, in collaboration with the originating academics, using end-user consortium funding.

Reducing the implementation cost barrier: The documents are independent of the architecture of any existing suite of software and are made available to multiple supply-chain solution-providers to allow them to embed the algorithms into their own existing software packages. This avoids the need for investment and re-training on new software products because the new solution is provided as a software enhancement at upgrade time. Thus:

1. The supply chain does not need to invest in putting into production a completely new academic software package – they can continue with their own (enhanced) product,
2. End-users benefit from a diversity of potentially innovative and professionally maintained implementations in the market place, and
3. The algorithm provider (IP owner) has the benefit of software being written and documented on its behalf, to its own core specification.



Enabling an academic-independent legacy: The ADSS scheme will also provide a test facility to prove to end-users that the software achieves the requirements of the Software Requirements Document using a range of reference inputs, appropriate to the nature of the algorithm. In due course, software support is expected to be solely provided by the supply-chain, without further reference to the academic algorithm-developers, addressing the potential problem of a key researcher or student leaving and becoming uncontactable.

Lastly, in terms of project and model longevity a key frustration raised was also that EPSRC does not fund follow on projects. While models or further developments to models have been taken up by new projects there is a trade-off between what researchers are willing to include in proposals so that research is different enough, whilst also building on current capacity and resources. If models, tools, and data have not reached an advanced stage and development is still required, or if a clear distinction cannot me made to previous projects, then they may be omitted altogether in place of proposing completely new tools. Yet, there may not always be a need for new or more tools, but finding and using what is already there and pushing their development further. This will be important if the call to facilitate a move from the current focus of many tools on analysis to a more solution focused approach is to be effectively achieved.

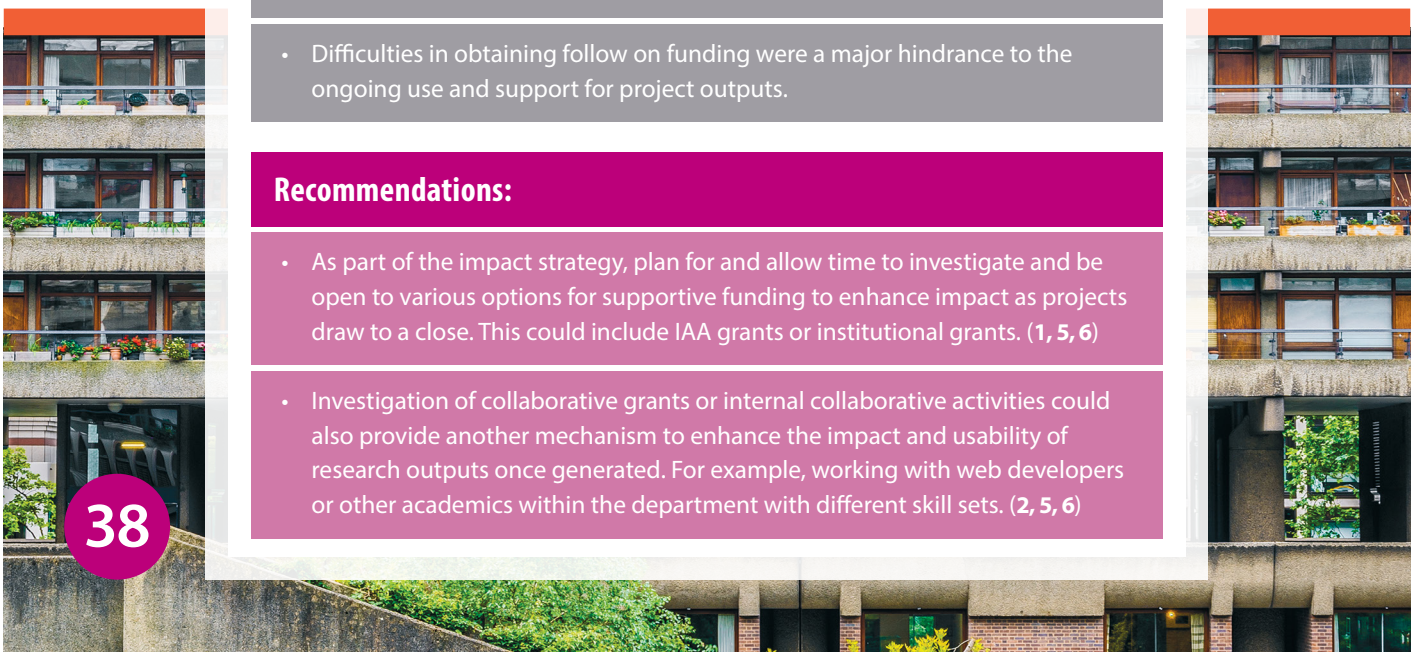
> "Otherwise it can be a case of re-inventing the wheel but ending up at the same stage with a different model which does the same thing but doesn't reach a further stage of development."

Learning points:

- The step from research tool or prototype models to final shareable resources or commercial products was often seen as something that would happen outside of the remit of the initial project itself.
- Different types of funding were investigated to enhance the dissemination and interest in using project outputs, but the final step in terms of the ability to provide access and use of the tools and data often remains problematic.
- Difficulties in obtaining follow on funding were a major hindrance to the ongoing use and support for project outputs.

Recommendations:

- As part of the impact strategy, plan for and allow time to investigate and be open to various options for supportive funding to enhance impact as projects draw to a close. This could include IAA grants or institutional grants. (**1, 5, 6**)
- Investigation of collaborative grants or internal collaborative activities could also provide another mechanism to enhance the impact and usability of research outputs once generated. For example, working with web developers or other academics within the department with different skill sets. (**2, 5, 6**)



Moving forward

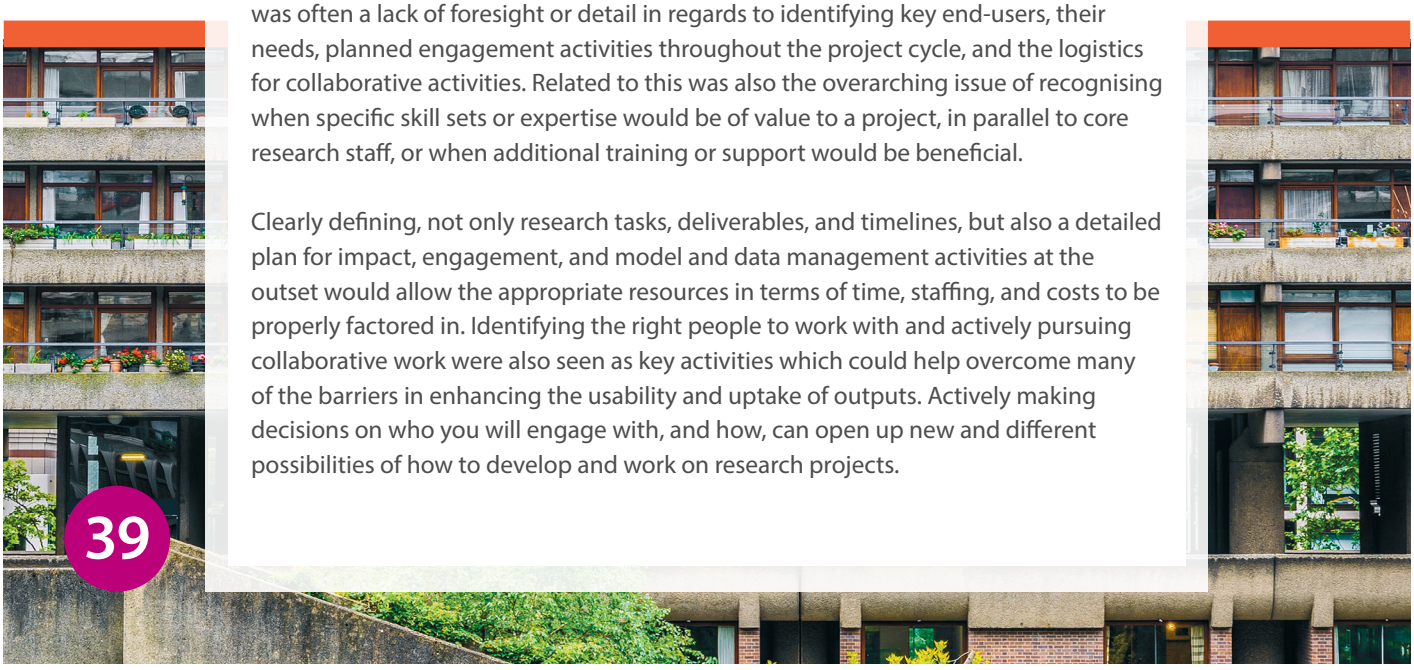
The above section reflects on some of the main themes discussed when trying to understand the current challenges, barriers, limitations, and benefits to researchers and stakeholders of sharing, accessing and using research outputs. While the review focused on building to city scale projects under a built environment and climate change theme many of the findings, lessons learned and recommendations will be relevant and transferable across research projects which aim to provide research models, tools, or datasets as key outputs.

The review has highlighted that whilst achievements are high, many projects have potential for much greater policy and practice application beyond their past / current impact and stakeholder interest, but addressing the barriers to this is still a real, ongoing, and frustrating challenge to those researchers and stakeholders involved.

Many of the barriers and limitations faced resulted as an oversight of specific project considerations at the project inception and commencement stages. Encouraging and supporting researchers and stakeholders to actively engage from the outset, and considering how lessons learned from past projects could be proactively addressed going forwards, could help to alleviate problems which would otherwise arise later in the project.

Many of the issues highlighted stemmed from the same underlying problem that there was often a lack of foresight or detail in regards to identifying key end-users, their needs, planned engagement activities throughout the project cycle, and the logistics for collaborative activities. Related to this was also the overarching issue of recognising when specific skill sets or expertise would be of value to a project, in parallel to core research staff, or when additional training or support would be beneficial.

Clearly defining, not only research tasks, deliverables, and timelines, but also a detailed plan for impact, engagement, and model and data management activities at the outset would allow the appropriate resources in terms of time, staffing, and costs to be properly factored in. Identifying the right people to work with and actively pursuing collaborative work were also seen as key activities which could help overcome many of the barriers in enhancing the usability and uptake of outputs. Actively making decisions on who you will engage with, and how, can open up new and different possibilities of how to develop and work on research projects.



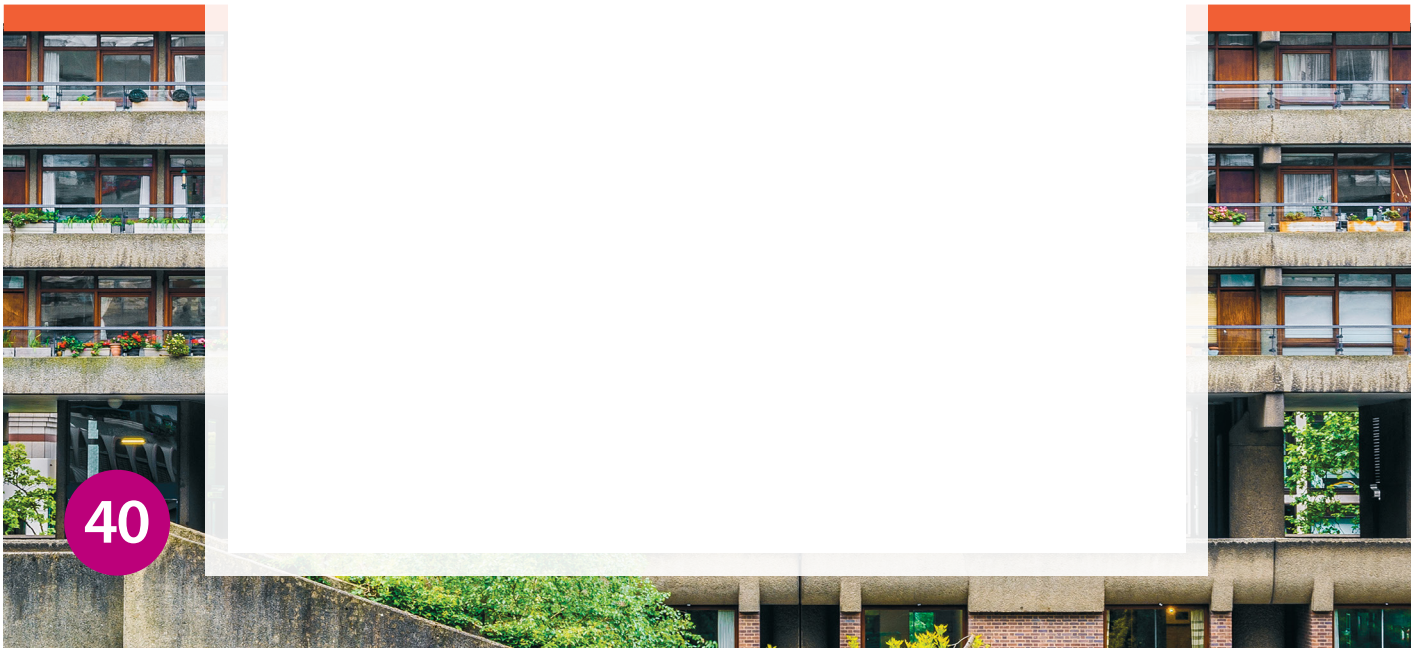
Finally, the review also highlighted some questions that may be more pertinent to funding bodies, in terms of the legacy and longevity of outputs. These include whether the current criteria for proposal applications, and emphasis on these, provide the right drivers to researchers in terms of what they actively consider, research, and plan for in advance.

For example, should they require additional information on why specific impact activities are proposed, including supporting evidence for these, and how they will be managed and taken forward throughout the project? Or, if a stakeholder model is proposed what infrastructure will be in place for the continued support and facilitation of this and any ongoing commitment to the development and use of it in the future.

Similarly, the case was made that if it was specified in certain calls that researchers needed to include specific and detailed information on how they would develop and facilitate an 'Action' alliance to support wider participation in the project and promote knowledge sharing, then this would provide an early incentive to consider, plan for and include such information.

> "Ask academics to do certain things and they will do it."

Lastly, researchers will need to justify any additional resource requests, e.g. for inclusion of specific expertise or to support the integration of stakeholder 'champions', and highlight the cost benefits of these. In parallel, funders need to acknowledge these needs as otherwise more forward thinking and integrative solutions, to e.g. engagement, may be seen as not being competitive financially compared to projects which overlook such aspects.



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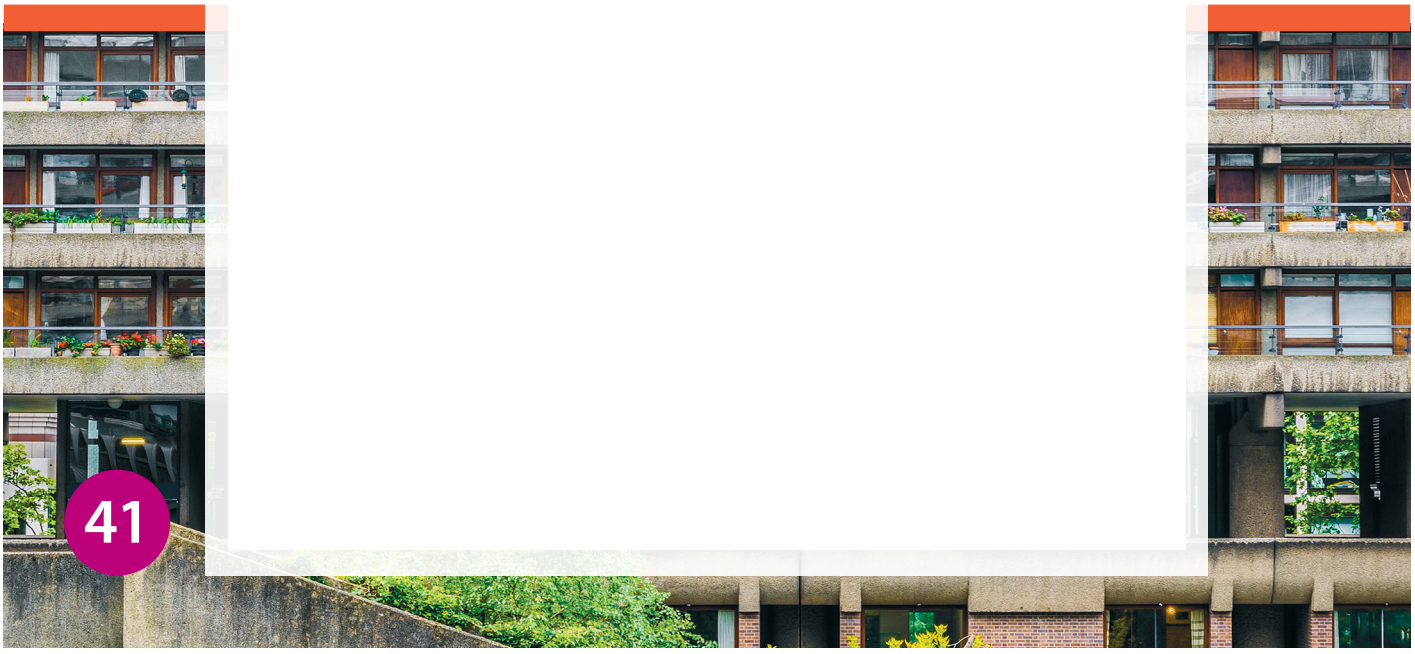
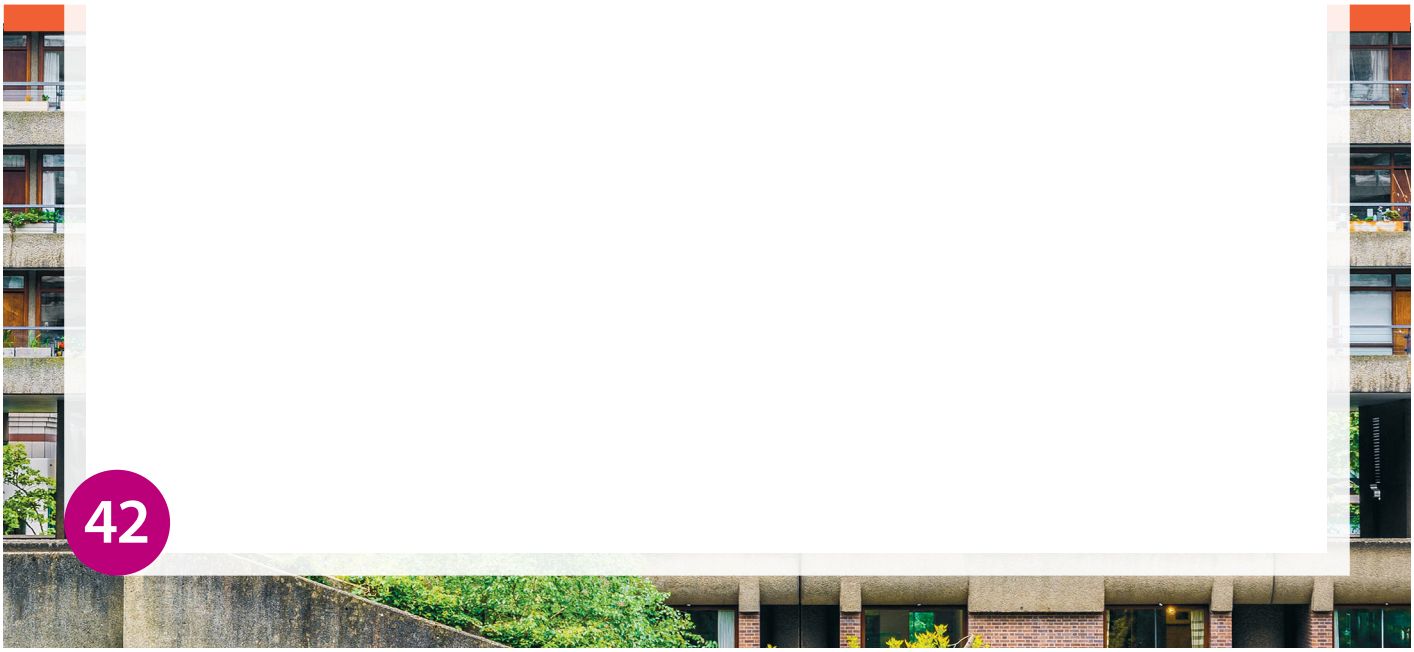


Annex 1: Overview of the ARCC projects referenced in the report



Building-level

ARIES – Adaptation and Resilience In Energy Systems

September 2011–October 2015 • University of Edinburgh • £771,708 • EP/I035773/1 • UK and regional

Aim

To capture the potential for changes in future energy supply and demand and the consequent impact on electricity and gas system resilience.

Specific models / tools / data

Downscaling models – new mesoscale weather synthesis model.

Models of renewable generation availability and regional and UK-wide impacts on renewable and thermal generation portfolios.

Suite of building physics models for domestic and commercial property producing gas and electricity profiles.

Enhanced models of gas and electricity systems with smart grid capabilities.

Purpose /stakeholder use

To identify climate risks for individual supply and demand factors and, through integrated modelling, allow examination of system-level risks and cumulative effects.

Low Carbon Futures – Decision support for building adaptation in a low carbon climate change future

December 2008–June 2012 • Heriot-Watt University • £624,272 • EP/F038240/1 • Case study buildings in various UK locations

Aim

To produce a general, deterministic and computationally efficient methodology for adequately sizing HVAC (heating, ventilating, and air-conditioning) plant and equipment in buildings.

Specific models / tools / data

Climate model, describing the UKCP09 sample-based outputs in a form widely applicable in models of building performance, as well as in other fields.

Low Carbon Futures Tool – A series of probabilistic design days for the future climate that can be employed in building services design.

A set of building performance metrics and associated risk levels acceptable to designers and building users.

Purpose /stakeholder use

Investigate and represent the outcomes of the UKCP09 climate scenarios in a manner appropriate to the building design community.

Explore how this data can be used to inform communication between design stakeholders.

Incorporate the findings in the development of the existing standard guidelines and building regulations.

PROMETHEUS – The use of probabilistic climate data to future proof design decisions in the buildings sector

July 2008–June 2011 • University of Exeter • £516,044 • EP/F038305/1 • 45 locations nationally

Aim

To develop a new set of probabilistic reference years that can be understood and used by building designers.

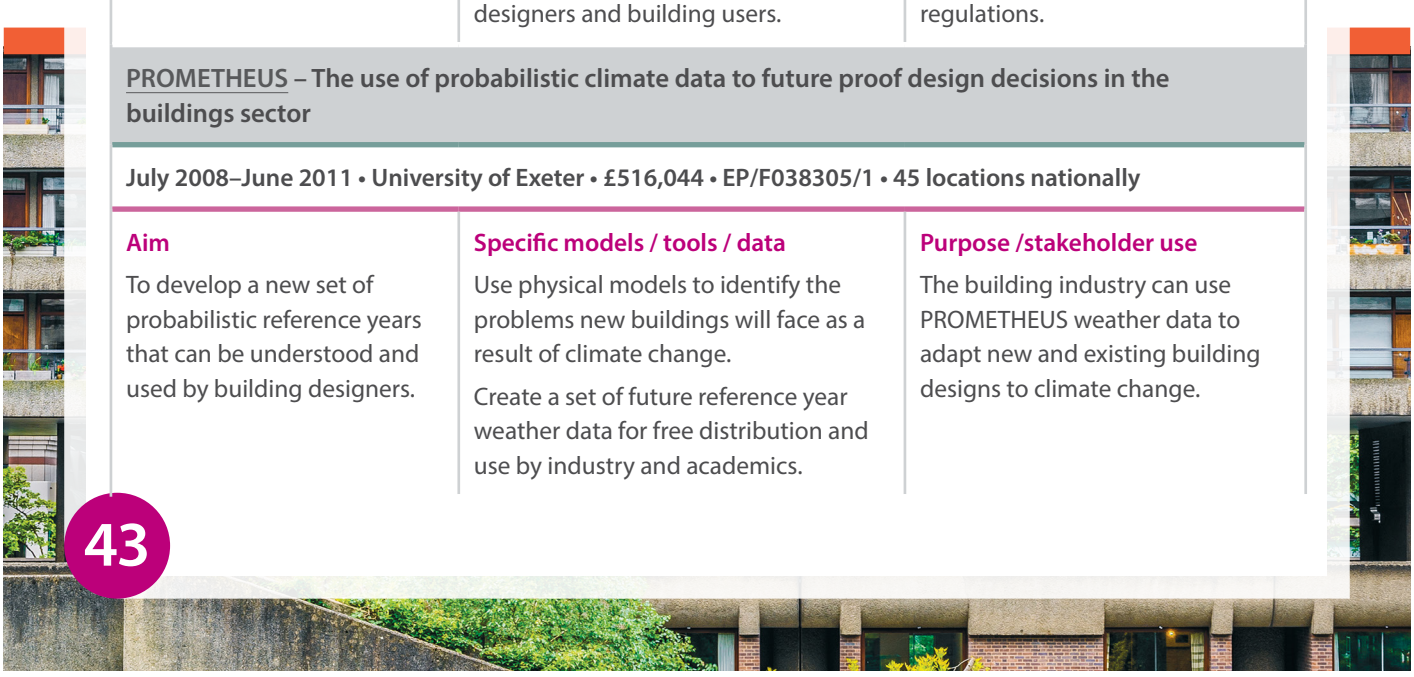
Specific models / tools / data

Use physical models to identify the problems new buildings will face as a result of climate change.

Create a set of future reference year weather data for free distribution and use by industry and academics.

Purpose /stakeholder use

The building industry can use PROMETHEUS weather data to adapt new and existing building designs to climate change.



City-level

ARCADIA – Adaptation and Resilience in Cities: Analysis and Decision-making using Integrated Assessment

July 2009–June 2012 • University of Oxford • £650,883 • EP/G061254/1 • Greater London & surrounding region

Aim	Specific models / tools / data	Purpose /stakeholder use
To provide system-scale understanding of the inter-relationships between climate impacts, the urban economy, land use, transport and the built environment and to use this understanding to design cities that are more resilient and adaptable.	Economic model; transport model; climate model; land use and demographic model.	To provide decision support tools for adaptation of urban areas, and to work with stakeholders to demonstrate how these tools can be used to develop strategies for transitions to resilience at a city scale.

Blue-Green Cities – Delivering and evaluating multiple flood risk benefits in Blue-Green Cities

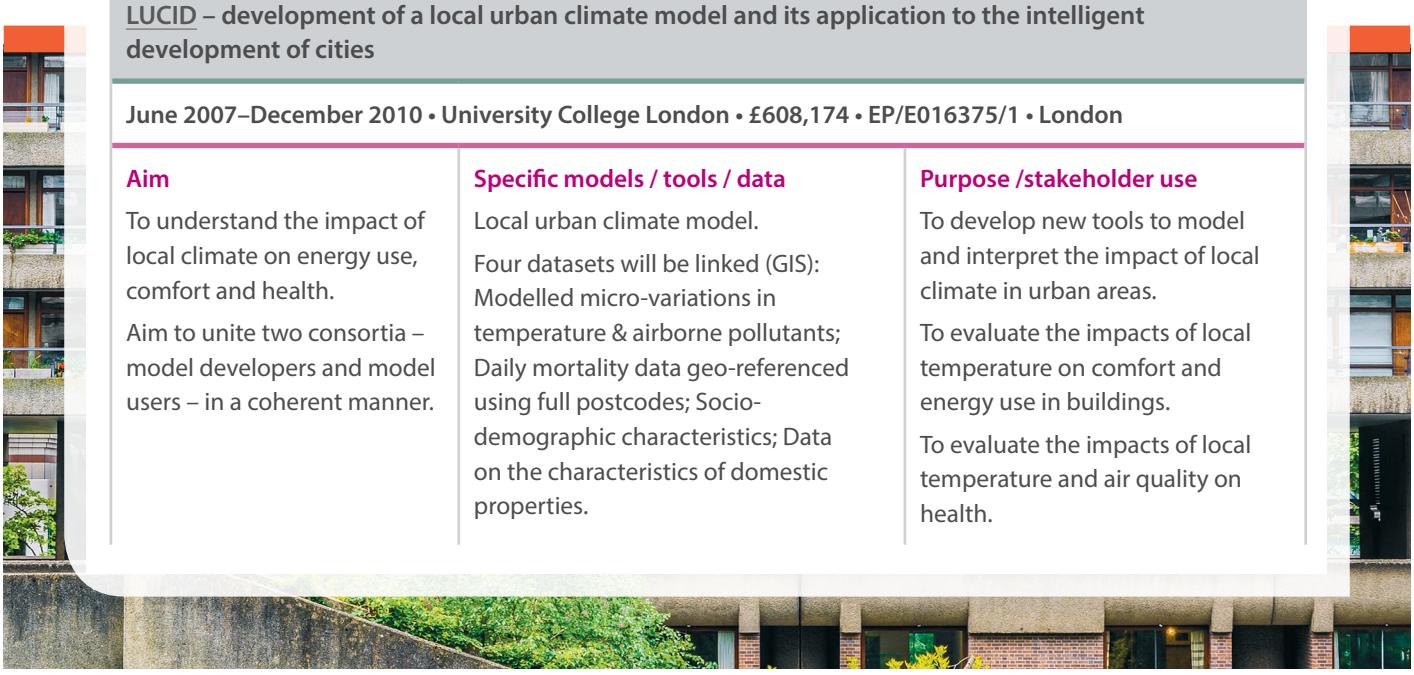
February 2013 – April 2016 • University of Nottingham • £1,434,824 • EP/K013661/1 • Newcastle

Aim	Specific models / tools / data	Purpose /stakeholder use
Develop new strategies for managing urban flood risk as part of wider, integrated urban planning intended to achieve environmental enhancement and urban renewal in which multiple benefits of Blue-green cities are rigorously evaluated and understood.	Hydro-dynamic model (CITY-CAT); flood-footprint 'tool'; GIS tool for infrastructure options for flood risk in blue-green cities. 2D hydro-morphodynamic model to predict flow and suspended sediment dynamics in urban rivers and investigate how restored floodplains and Sustainable Urban Drainage Ponds can attenuate the upstream flood peak and impact downstream flood risk.	Help practitioners understand the benefits, and spatial distribution of benefits, that accrue from Blue-green infrastructure schemes.

LUCID – development of a local urban climate model and its application to the intelligent development of cities

June 2007–December 2010 • University College London • £608,174 • EP/E016375/1 • London

Aim	Specific models / tools / data	Purpose /stakeholder use
To understand the impact of local climate on energy use, comfort and health. Aim to unite two consortia – model developers and model users – in a coherent manner.	Local urban climate model. Four datasets will be linked (GIS): Modelled micro-variations in temperature & airborne pollutants; Daily mortality data geo-referenced using full postcodes; Socio-demographic characteristics; Data on the characteristics of domestic properties.	To develop new tools to model and interpret the impact of local climate in urban areas. To evaluate the impacts of local temperature on comfort and energy use in buildings. To evaluate the impacts of local temperature and air quality on health.



Multi-level

SNACC – Suburban neighbourhood adaptation for a changing climate: identifying effective, practical and acceptable means of suburban re-design

September 2009–September 2012 • University of the West of England • £380, 454 • EP/G061289/1 • 6 Neighbourhoods from 3 cities as case studies: Bristol, Oxford & Stockport • Building-level to suburban-level

Aim

The proposed research answers the question: how can existing suburban neighbourhoods be best adapted to reduce further impacts of climate change and withstand ongoing changes?

Specific models / tools / data

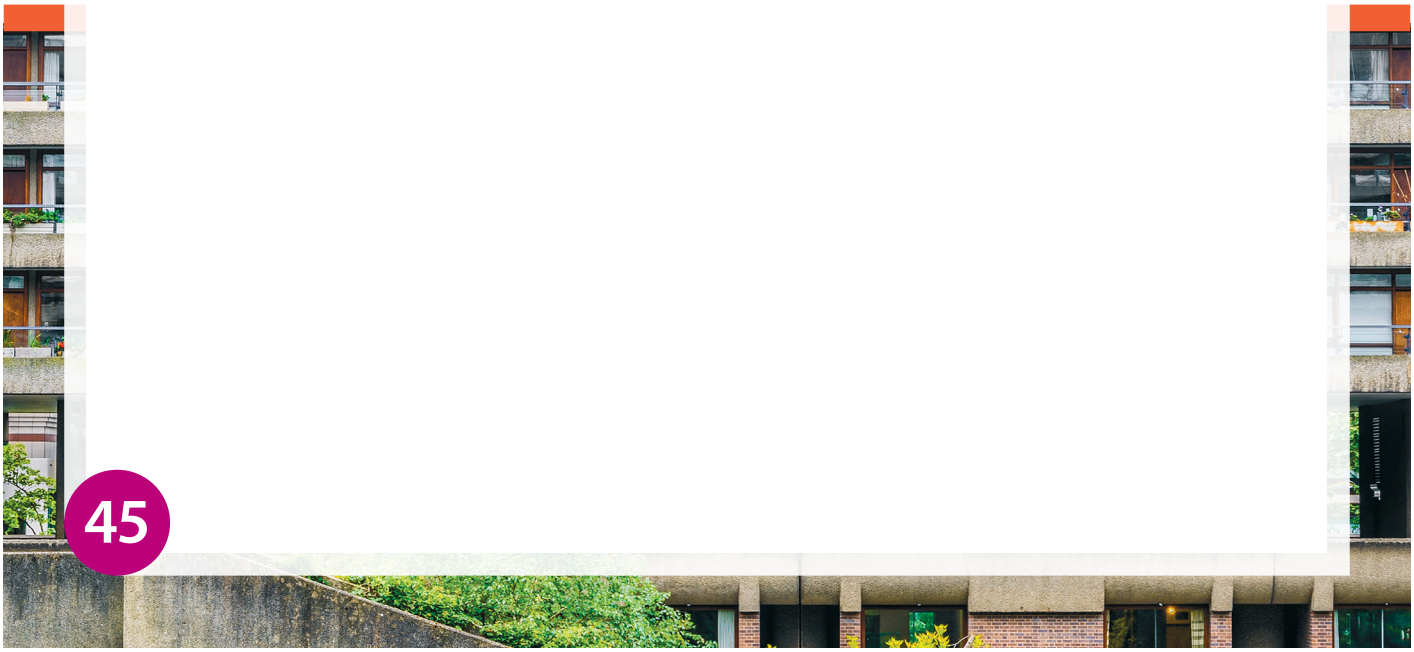
Tools that allow the participants to visualise how 'adapted' neighbourhoods will look.

The project also provides more sophisticated and tested versions of the VEP and DECORUM existing models, as well as a new model of hedonic pricing for climate change.

Purpose /stakeholder use

Determine which neighbourhood adaptation strategies perform best in terms of technical performance, and practicality and acceptability for the stakeholders implementing them.

The outcomes will contribute, practically, to securing a sustainable future for the UK's suburbs in the face of climate change.

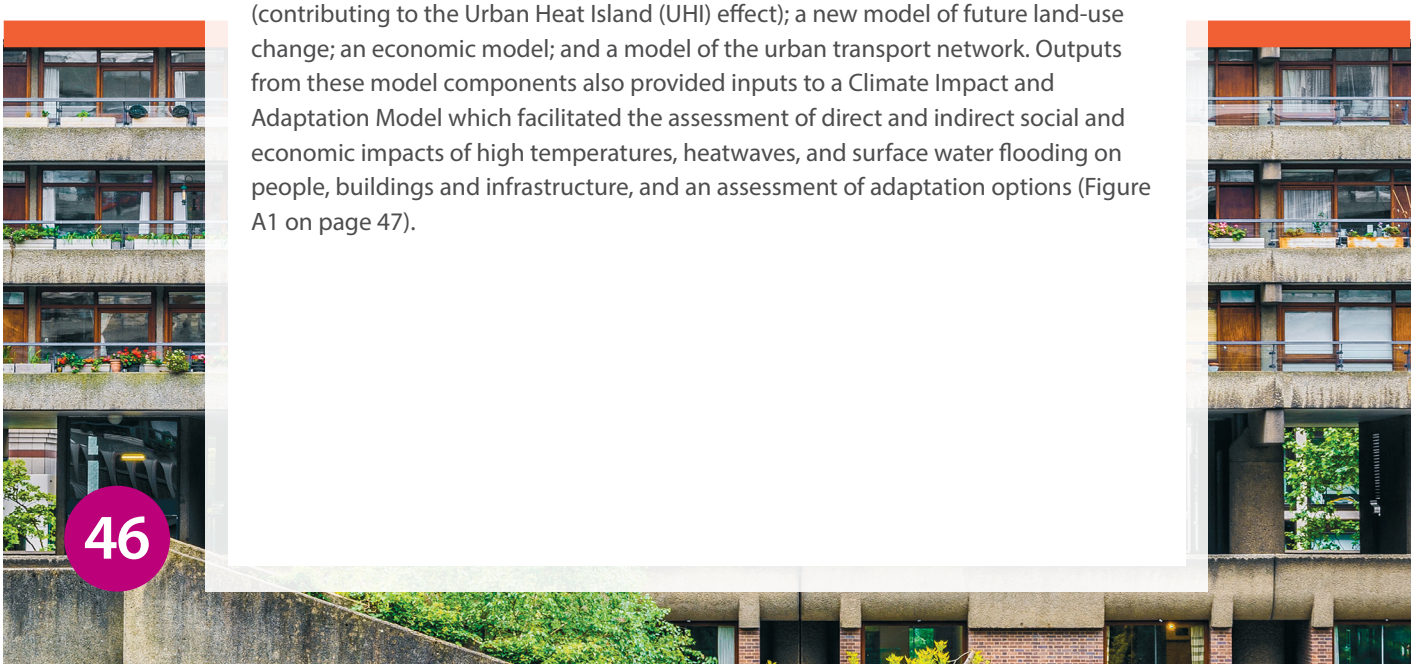


Annex 2: The ARCADIA case study – Findings, steps forward, and future work.

Overview of the ARCADIA project

The development of adaptation strategies for urban areas requires integrative thinking to understand and model relationships between the built environment, land-use, infrastructure systems, the urban economy and climate. Such considerations underpinned the EPSRC funded ARCADIA project, which aimed to provide system-scale understanding of the inter-relationships between climate impacts, the urban economy, land use, transport and the built environment and to use this understanding to design cities that are more resilient and adaptable. Specifically, the proposal aimed to do this through the integration of a suite of models within an Urban Integrated Assessment Framework (UIAF) aimed towards stakeholder use, and with the ultimate goal to provide a decision support tool for adaptation of urban areas.

The UIAF incorporates a spatial model of climate change in London, which includes the additional effects of waste heat and urban land cover on temperatures (contributing to the Urban Heat Island (UHI) effect); a new model of future land-use change; an economic model; and a model of the urban transport network. Outputs from these model components also provided inputs to a Climate Impact and Adaptation Model which facilitated the assessment of direct and indirect social and economic impacts of high temperatures, heatwaves, and surface water flooding on people, buildings and infrastructure, and an assessment of adaptation options (Figure A1 on page 47).



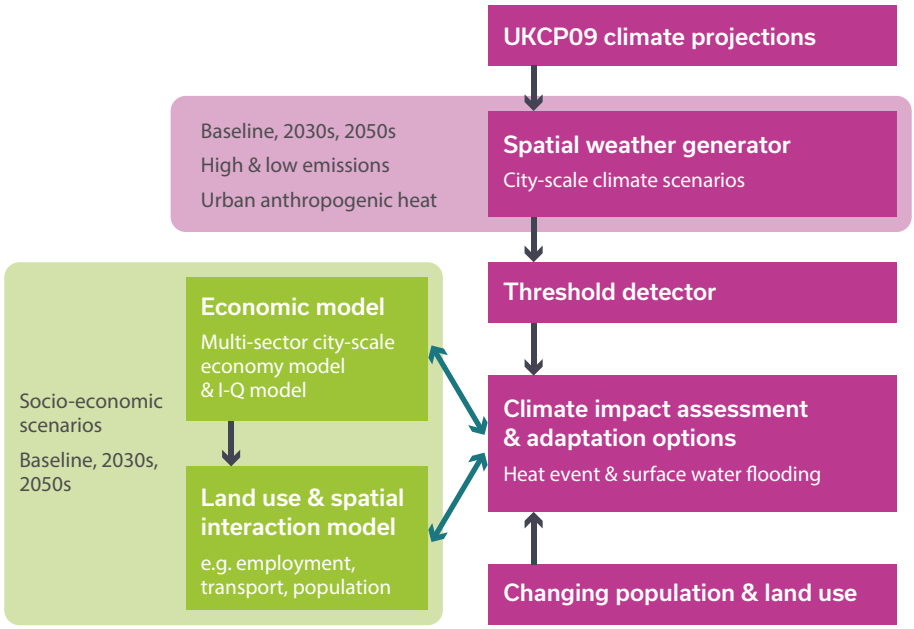
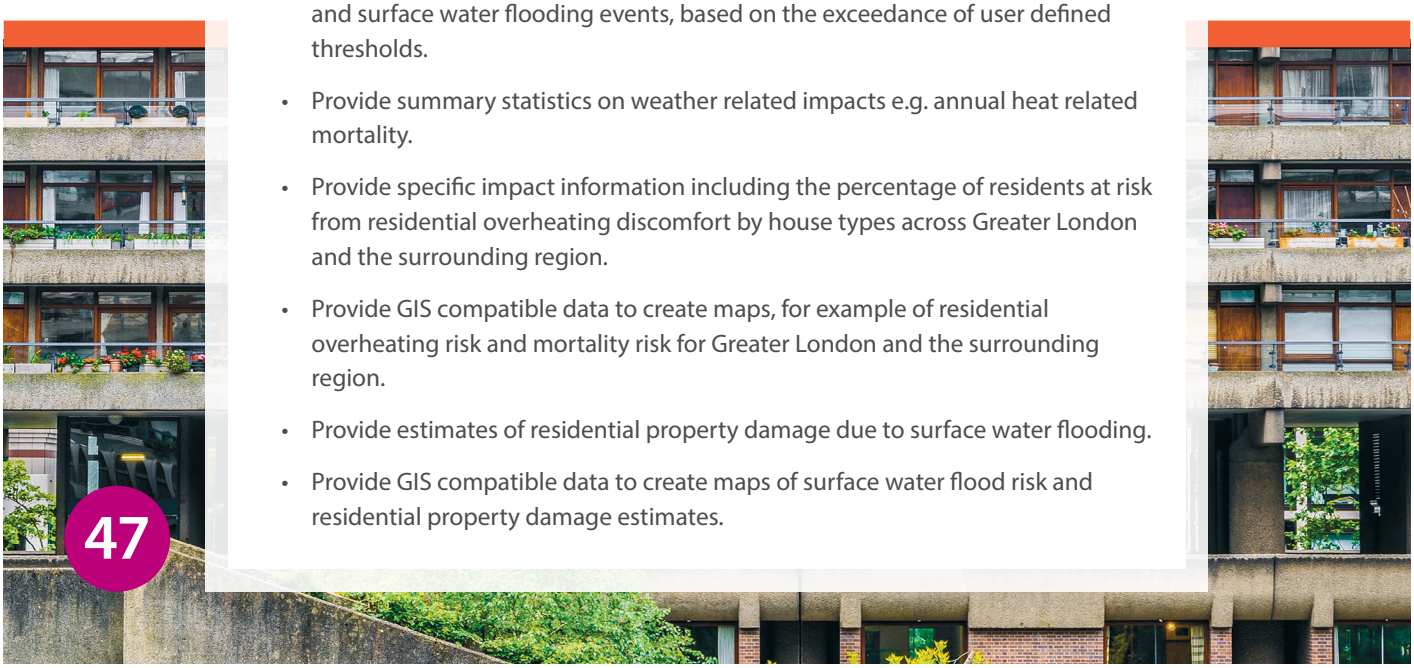


Figure A1: Overview of the UIAF and how the Climate Impact Assessment and Adaptation Options component sits within this.

Overview of the Climate Impact and Adaptation Model

The Climate Impact and Adaptation Model allows spatial patterns of risk to be identified and mapped, can provide information on the probabilities of extreme weather events, their characteristics, related impacts, and an assessment of the benefits and implications of adaptation policies. For example, the model can be used to:

- Post-process large climate files to more usable formats for subsequent use or to provide summary data on weather variables.
- Provide probabilities and characteristics of high temperatures, heatwaves, and surface water flooding events, based on the exceedance of user defined thresholds.
- Provide summary statistics on weather related impacts e.g. annual heat related mortality.
- Provide specific impact information including the percentage of residents at risk from residential overheating discomfort by house types across Greater London and the surrounding region.
- Provide GIS compatible data to create maps, for example of residential overheating risk and mortality risk for Greater London and the surrounding region.
- Provide estimates of residential property damage due to surface water flooding.
- Provide GIS compatible data to create maps of surface water flood risk and residential property damage estimates.



- Provide estimates of the number of days when rail buckles and disruption to railway passenger journeys could occur, and the associated economic impacts.
- Provide an assessment of heatwave frequency, duration and intensity for a range of different heatwave definitions.
- Highlight the benefits of different impact specific adaptation options in terms of reduced risks and impacts.

In the Climate Impact and Adaptation Model hazards are defined based on specific temperature and precipitation thresholds for each impact, which can be set via a user interface. These thresholds can be adjusted to represent and assess various impact specific adaptation options. In certain cases, the user can specify a range of different outputs and formats.

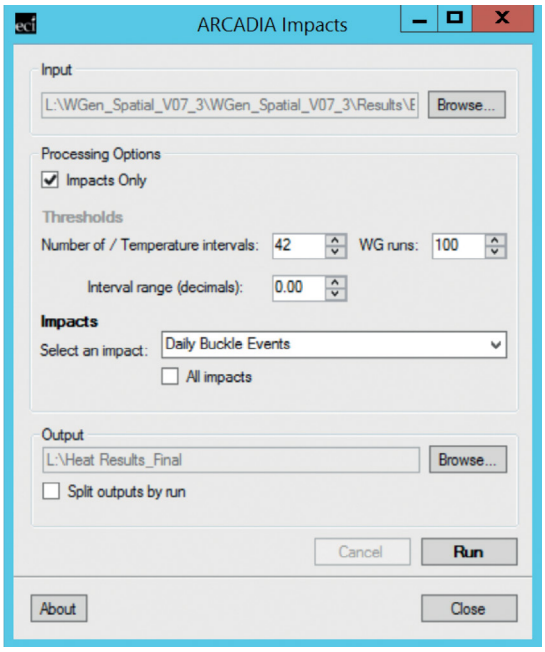


Figure A2: Example of the User Interface.

Issues with the usability and accessibility of model outputs

As part of the ARCADIA project findings from the research were predominantly presented in peer reviewed journal articles, project reports, and factsheets, as well as at national and international academic conferences and a final stakeholder event.

Following project completion there was also interest in accessing and using both the model code and the outputs from the impact model, from researchers and non-academic end users, as well as interest in the possibility to apply the model to look at different types of risk and adaptation options. This included using the model to support the analysis of different adaptation pathways and to provide different types of visual outputs and area specific outputs.

In this case the onus on updating and re-running the model fell to the original researcher as it was quicker to do this then try to explain the code, process for running it, and areas where updates would be required, as well as any subsequent steps to process outputs e.g. to create graphs or tables of average results.

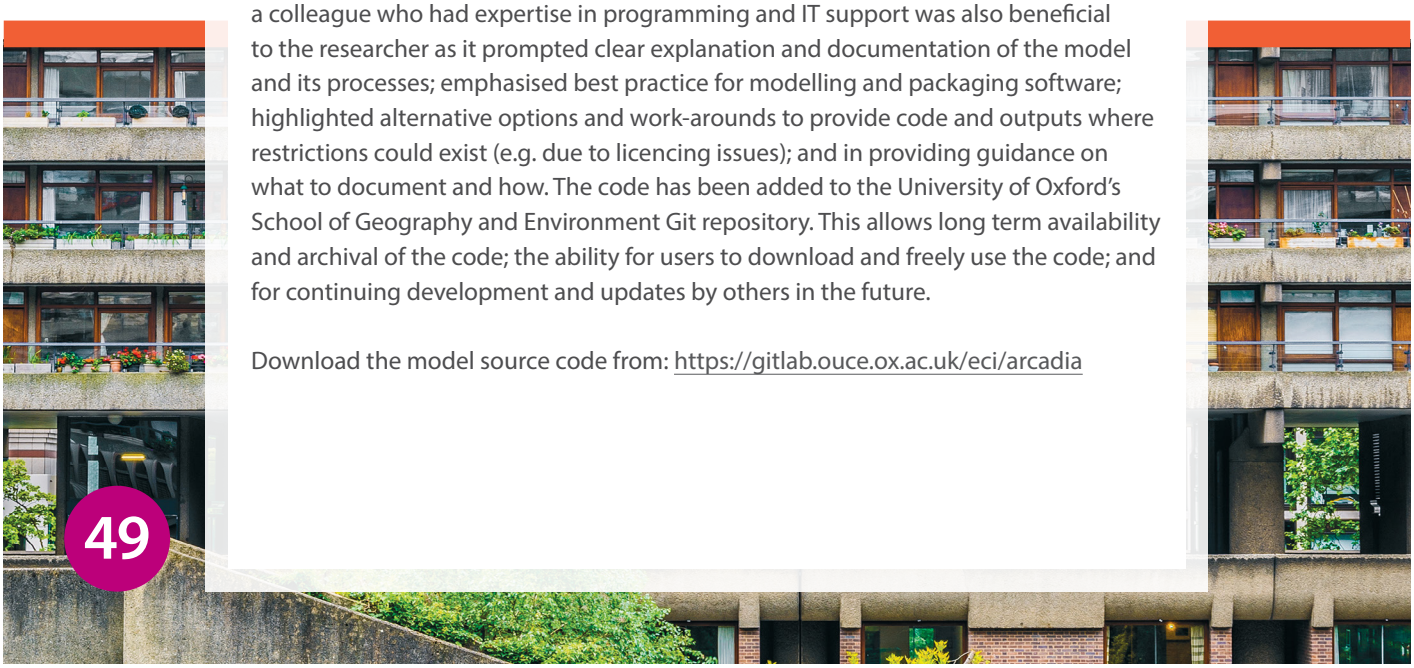
As such, the transition from a predominantly research based tool that was housed on a departmental PC to a packaged model that could be easily shared, re-run, and provide a range of user defined output files was not completed as part of the original ARCADIA project. Many of the barriers highlighted in this report were true of this case study. For example, the model was developed firstly as a tool to meet research objectives rather than considering the end user and mechanisms to provide a decision support tool from the outset; as the researcher had moved to a new project there were time constraints on the ability to continue working on updates and outputs when requested by different stakeholders; and updates were often reliant on the good will of other researchers who processed and shared additional information as required.

Furthermore, additional experience and skills were needed to professional package as well as improve the efficiency and share-ability of the model code. For example, due to large file sizes the code could be very slow to run for certain options. During the project for speed of processing, and following extensions or related work that happened subsequently, the code was fragmented in some places. This sped up the ability of the researcher to generate outputs but would also require explanation so that other users would understand how to run different pieces of code in sequence. Similarly, due to the need to update or output new / revised results quickly the code was amended manually, rather than via the User Interface, in certain cases with the intention to do a more efficient update when time permitted.

Solutions to enhance the usability and accessibility of model outputs

As such, the focus on this model as a project case study clearly highlighted advantages of securing departmental IT and programming support to help work through the code, update and improve the user interface, improve the standard of the code, efficiency and run time, and develop and package this for external use. Engaging with a colleague who had expertise in programming and IT support was also beneficial to the researcher as it prompted clear explanation and documentation of the model and its processes; emphasised best practice for modelling and packaging software; highlighted alternative options and work-arounds to provide code and outputs where restrictions could exist (e.g. due to licencing issues); and in providing guidance on what to document and how. The code has been added to the University of Oxford's School of Geography and Environment Git repository. This allows long term availability and archival of the code; the ability for users to download and freely use the code; and for continuing development and updates by others in the future.

Download the model source code from: https://gitlab.ouce.ox.ac.uk/eci/arcadia



The IT support also extended to ways in which the model outputs could be better managed and shared. This involved support from the ARCC network and Knowledge Exchange Manager to identify specific people to present the model outputs to one-to-one, to discuss and understand their needs and working practices, decide would type of outputs would be of most interest and practical use, and the formats for these.

Once it was understood what was most useful from a practitioner's point of view a plan of action was undertaken to create these outputs and disseminate them with relevant parties.

The most appropriate format was found to be providing the data via the University of Oxford's ArcGIS Online account. Output data from the Climate Impact and Adaptation Model was uploaded, along with a description of the data, attributes, and related links. As well as an overview, the user has the option to view the data in table form, as well as the data visualisation. This includes options to open the maps in Scene Viewer or ArcGIS desktop where the user can manipulate the maps and highlight areas of interest, and select different layers to view. There is also the option to download the data in different formats for example as .csv or .shp file, as well as to provide external links to the data. In this manner users could easily access the data or simply download it as a layer to use directly alongside their maps. Having the data stored in this format meant that outputs could be quickly and easily tailored to particular locations or layers relevant to a specific stakeholder, as well as supporting the overall data management.

The online version is available from oxforduni.maps.arcgis.com

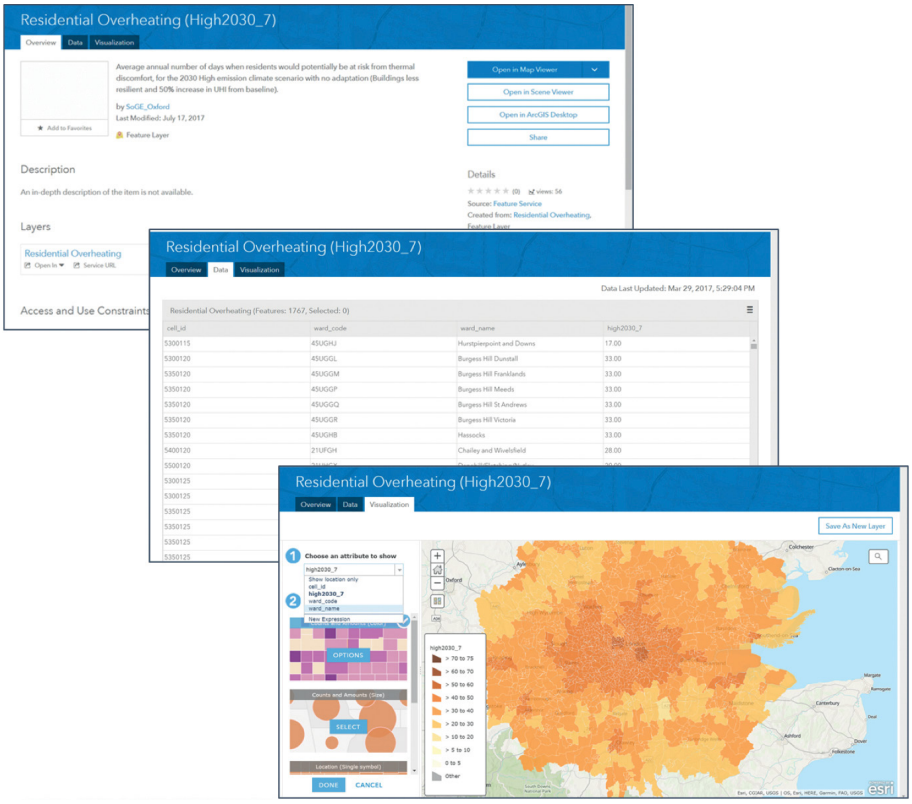


Figure A3: Example of online data and visuals.

Enhancing end-user engagement

A second area that the case study focused on was how to build more focused engagement around the model outputs and capabilities. As previously mentioned, support from the ARCC network and Knowledge Exchange Manager helped to identify specific people to present the model outputs to one-to-one, to discuss and understand their needs and working practices, decide which type of outputs would be of most interest and practical use, and the formats needed for such outputs.

The type of engagement activities differed to the standard approach used by the researcher during the ARCADIA project itself (i.e. more technical presentations, updates of progress, presentation of results and findings, and question and answer sessions). Instead, shorter non-technical presentations were prepared to outline the project in a succinct manner, focusing on the type of outputs that could be provided and ways in which these could support specific stakeholders needs.

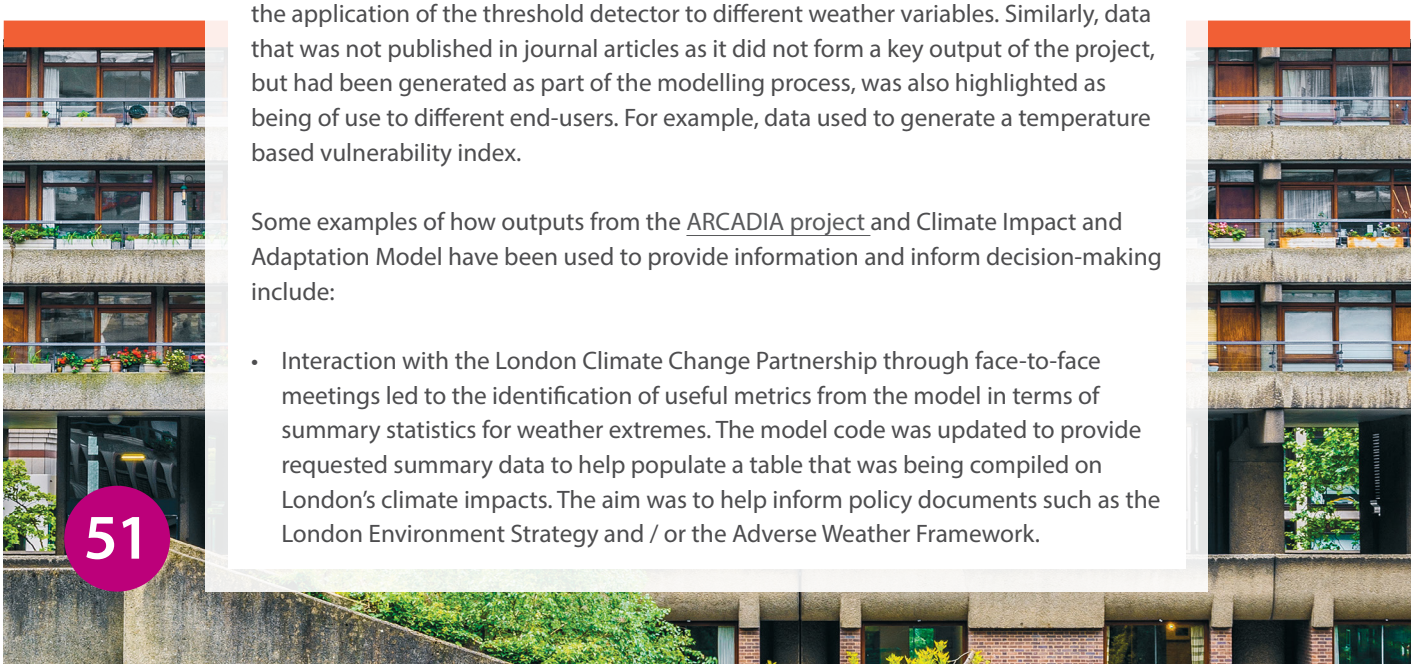
Secondly, the online visuals were presented as interactive tools at research and stakeholder based workshops and ARCC facilitated events engaging stakeholders, rather than presenting formal presentations. This was supported with short, non-technical flyers summarising the model. The interactive visuals were available to look at before and after the more formal portion of the events, and allowed people to 'play' with the model outputs, ask questions, provide opinions on how useful they found the visuals and ways they could use the information, as well as providing feedback. It provided a means to engage with potential end-users who would not have accessed the project information through academic channels such as journal articles and project websites, and open up the project outputs to a wider variety of end-users.

Providing information and informing decision-making

The benefits of this engagement in terms of increased uptake of outputs and impact were quickly evident. For example, through discussions and feedback different ways in which the model code and data outputs could be used were highlighted. This included an interest in some of the interim steps and outputs of the model, such as the post-processing of large weather generator files to simplify the format of existing data and the application of the threshold detector to different weather variables. Similarly, data that was not published in journal articles as it did not form a key output of the project, but had been generated as part of the modelling process, was also highlighted as being of use to different end-users. For example, data used to generate a temperature based vulnerability index.

Some examples of how outputs from the ARCADIA project and Climate Impact and Adaptation Model have been used to provide information and inform decision-making include:

- Interaction with the London Climate Change Partnership through face-to-face meetings led to the identification of useful metrics from the model in terms of summary statistics for weather extremes. The model code was updated to provide requested summary data to help populate a table that was being compiled on London's climate impacts. The aim was to help inform policy documents such as the London Environment Strategy and / or the Adverse Weather Framework.

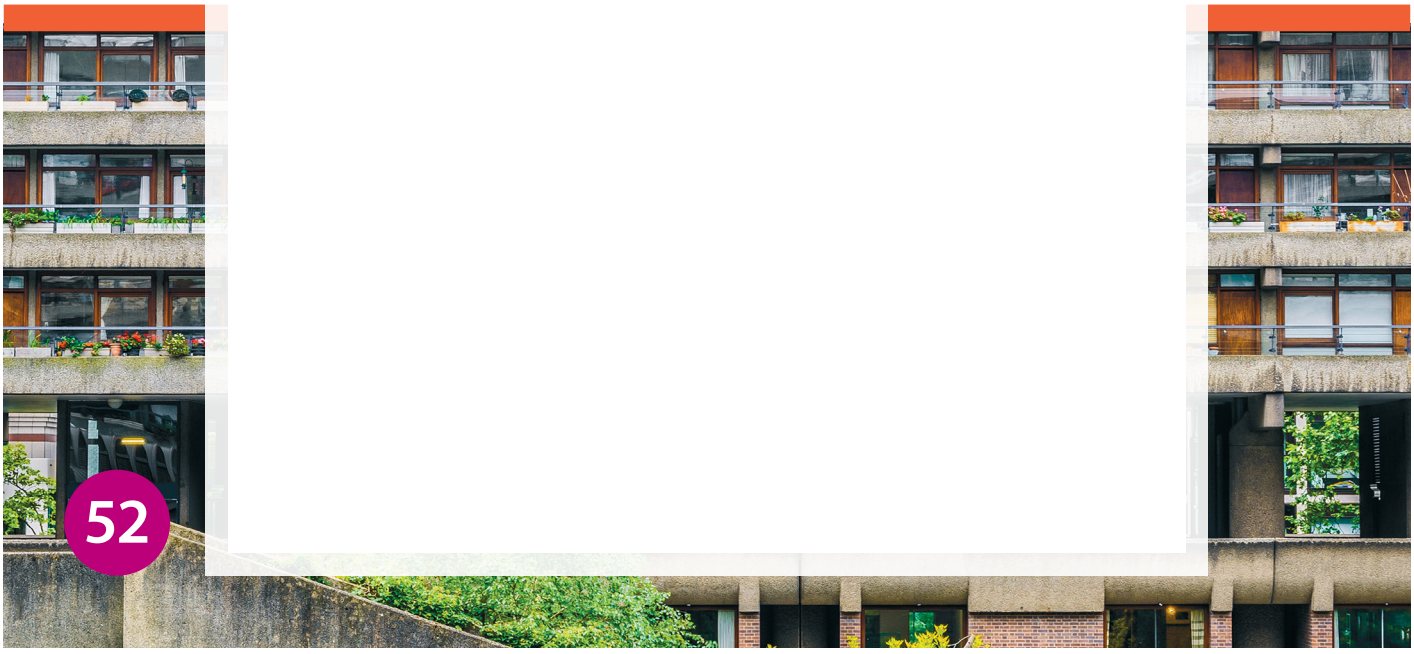


- Stakeholder engagement and networking that occurred during the project itself led to collaborative work being undertaken with Transport for London. The study focused on the implications of climate change for thermal discomfort on underground railways, integrating outputs from a passenger discomfort model within the Climate Impact and Adaptation Model.

- Face-to-face meetings with a consultant highlighted how other model outputs, such as the temperature vulnerability index, could be used within Neighbourhood plans. GIS based maps and data were provided for specified boroughs and incorporated within a local neighbourhood plan to support evidence on future heat related vulnerabilities.

- Lastly, academic research collaborations were also highlighted. For example, using outputs from other projects to update the modelling and provide more up to date and detailed estimates of residential discomfort and adaptation pathways relevant to those working in the built environment. Likewise, data generated on surface water flood risk was used as an input to another model that focused on flood risk management and insurance, which was subsequently cited as evidence within a Bank of England Report on Climate Change and Insurance.

Finally, there has been noted interest in the potential of the model and outputs for different applications in the future. This has become of more interest and relevance to potential end-users as the model code and data outputs will be accessible and freely available to use. By removing the barrier to access it is hoped that there will be ongoing interest, engagement, and application of the research by both researchers and stakeholders in the future.

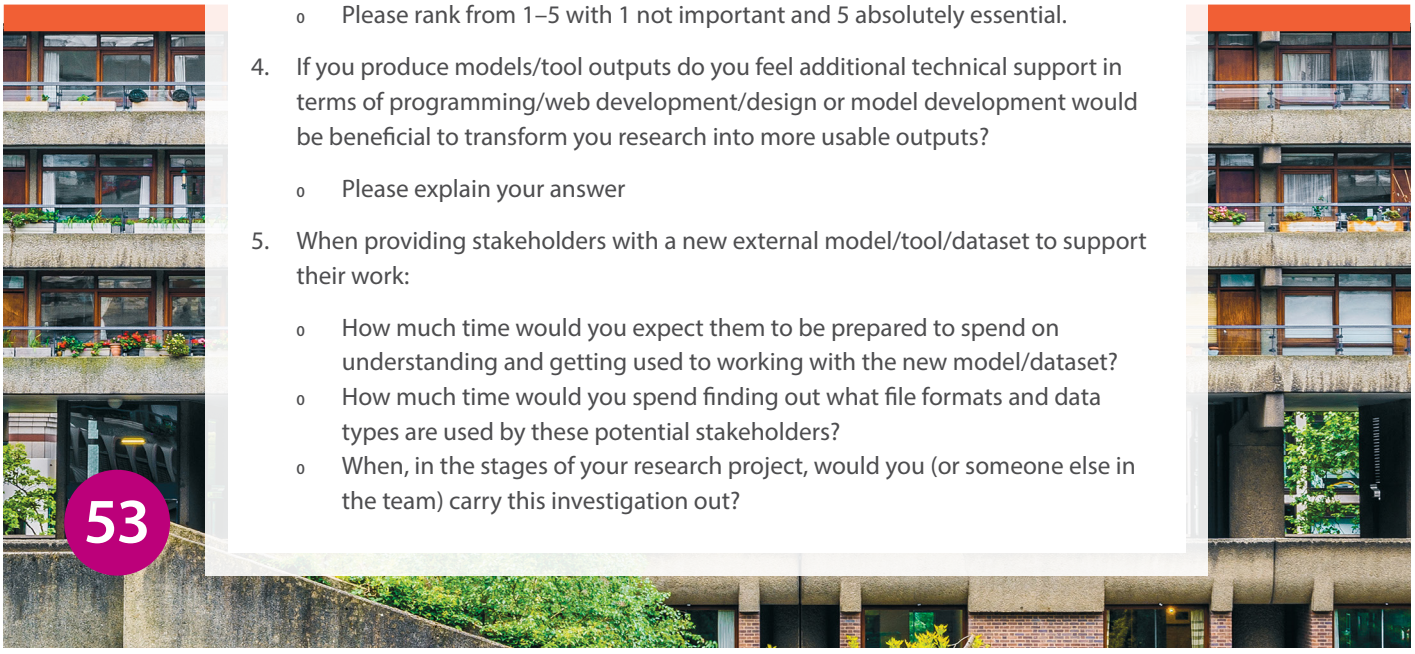


Annex 3: Survey questions

Researcher focused: Helping researchers to enhance the uptake and use of building-scale to city-scale decision support models

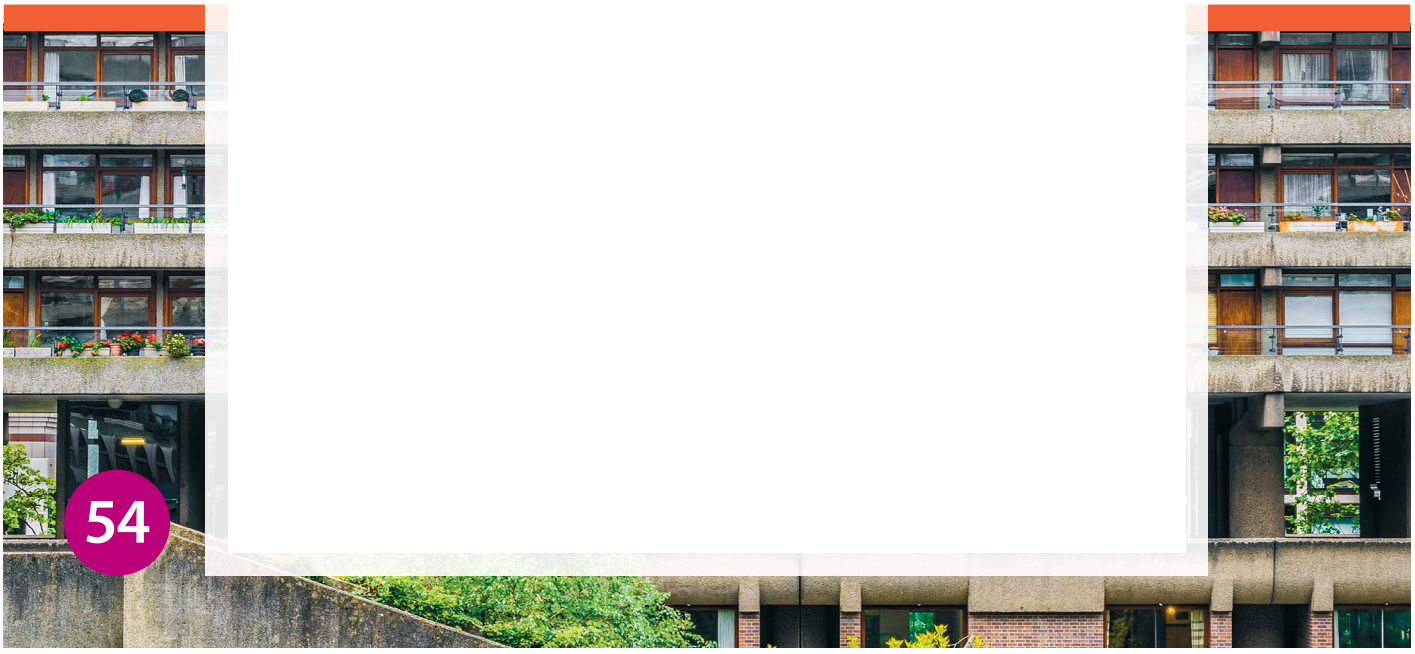
The purpose of this survey was to gather information and opinions from researchers on processes for working, the types of data and supporting systems used, and understand where they thought there were skills gaps or other barriers which are preventing research outputs from being more industry ready.

1. About your institution and you:
    - Name of institution
    - Are you in a department with a built environment focus? If so what is it called?
    - What is your main job role?
2. Have you ever prepared or been involved in delivering a data management strategy in a research project?
    - If you answered "YES", please explain what your role was in developing/ delivering the data management plan and if you helped create it, did you make use of online resources e.g. institutional guides, DMP Online?
3. How important would you rate data management as a component to your research task/role?
    - Please rank from 1–5 with 1 not important and 5 absolutely essential.
4. If you produce models/tool outputs do you feel additional technical support in terms of programming/web development/design or model development would be beneficial to transform you research into more usable outputs?
    - Please explain your answer
5. When providing stakeholders with a new external model/tool/dataset to support their work:
    - How much time would you expect them to be prepared to spend on understanding and getting used to working with the new model/dataset?
    - How much time would you spend finding out what file formats and data types are used by these potential stakeholders?
    - When, in the stages of your research project, would you (or someone else in the team) carry this investigation out?



- What are the specific file formats and data types used by potential stakeholders who may be interested in your research?
- Have you ever considered what operating system your potential stakeholders might use?
- What do you believe are the common operating systems used by built environment practitioners?

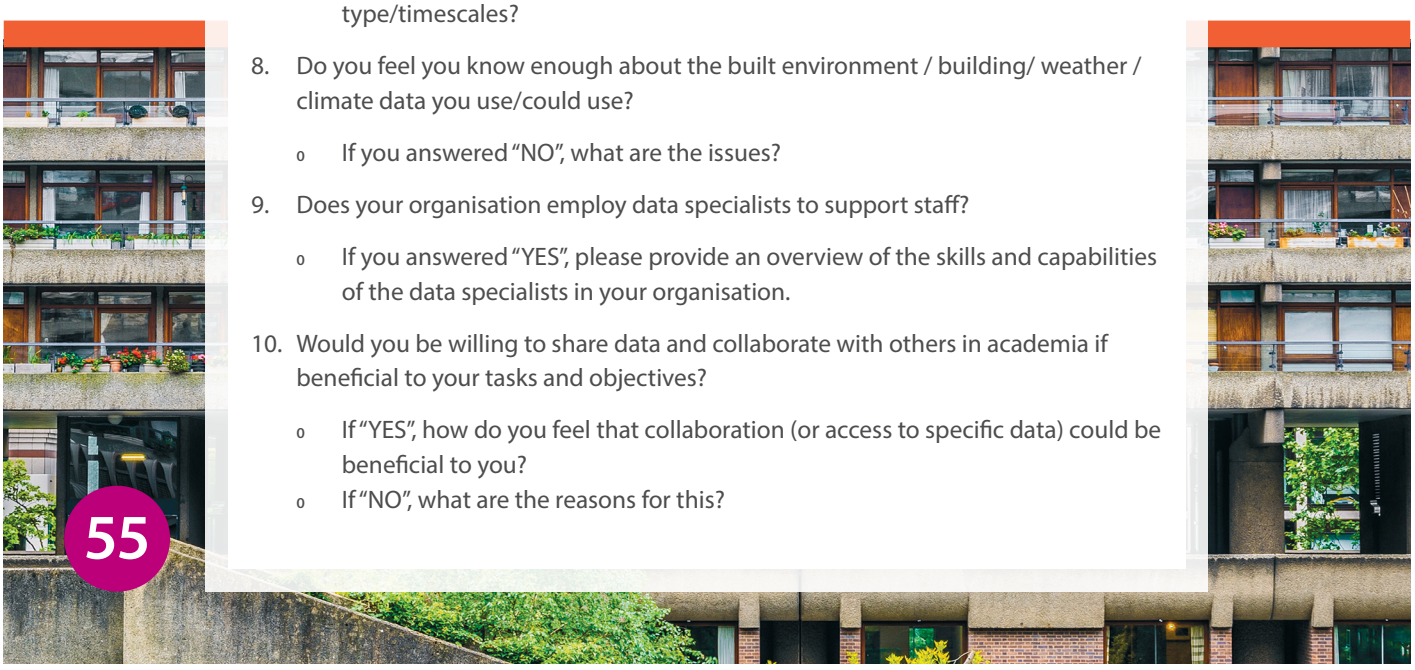
6. Have you ever experienced difficulties in sharing/transferring your research model/tool/data outputs to stakeholders?
    - YES, on your project or are you aware of situations when this has arisen on other projects, or NO?
    - If "YES", what was difficult and with the benefit of hindsight what might have been helpful to have known in advance.
7. Do you feel you have the necessary skills to maximise the impact from your research?
    - If "NO", what are the issues?
8. Do you feel you have the necessary support to maximise the impact from you research?
    - Please explain your answer.
9. Would you find additional training (such as consultancy brief writing or managing difficult stakeholders) useful in terms of improving ability to communicate with and, or, manage stakeholders/consultants?
    - If NO, please explain why? – something that should be left to project manager / not your job etc.
10. What would you list as the three greatest limitations to enhanced uptake and impact from your research?



Stakeholder focused: Enhancing the uptake and use of building-scale to city-scale decision support models developed by researchers

The purpose of this survey was to gather information and opinions about the types of data and supporting systems used in industry, and to understand where there are gaps or barriers which are preventing the built environment sector from using models developed by researchers.

1. About you and your organisation:
    - Name of organisation
    - Which best describes it: Public, private or third sector?
    - Are you aware of a data management strategy at your organisation?
    - Describe your job role?
2. As part of your day-to-day role do you require and work with built environment / building/ weather data? For example, CENSUS data, weather data?
    - If you answered "YES", please specify the data type(s) and briefly summarise the purpose of using this data.
3. Do you use standard formats for your data e.g. .csv, .shp?
    - If you answered "YES", please specify types of extension/s and let us know if these data formats are standard across your organisation or projects you may work on.
4. Which operating system(s) do you use at work?
    - Which system is used across your organisation?
5. How long would you consider to be acceptable in terms of the run time for a model/tool? E.g. 2 hours, 2 days?
6. If using a new external model/tool/dataset to support your work, how much time would you devote to understanding and getting used to working with the new model/dataset?
7. Do you feel that built environment / buildings data / climate data, currently available, meets your user needs?
    - If you answered "NO", please explain why not e.g. issues related to data scale/ type/timescales?
8. Do you feel you know enough about the built environment / building/ weather / climate data you use/could use?
    - If you answered "NO", what are the issues?
9. Does your organisation employ data specialists to support staff?
    - If you answered "YES", please provide an overview of the skills and capabilities of the data specialists in your organisation.
10. Would you be willing to share data and collaborate with others in academia if beneficial to your tasks and objectives?
    - If "YES", how do you feel that collaboration (or access to specific data) could be beneficial to you?
    - If "NO", what are the reasons for this?



Improving climate resilience in the urban environment: Enhancing the uptake and use of building-scale to city-scale decision support models by policymakers and industry

Published by the Adaptation and Resilience in the Context of Change network.

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