Climate service prototyping activities for the UK energy and transport sectors

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Met Office

UK CLIMATE RESILIENCE PROGRAMME

Document history

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UK CLIMATE RESILIENCE PROGRAMME

Contents

Executive summary

This report outlines work undertaken in WP3 of the UK Climate Resilience Programme, over the period 2019-2022, on co-development of climate service prototypes for the energy and transport sectors. It also reflects on what was achieved in the prototyping work and the lessons learned from the process.

For **transport**, work was undertaken with the Department for Transport (DfT) and its agencies to:

- Extend an existing set of present-day climate scenarios into the future
- Provide overview information about future climate extremes, for awareness-raising
- Co-develop a fact sheet about weather and climate impacts on UK transport

For **energy**, work was started – with input from a group of energy stakeholders (from academia, industry, and data organisations) – to temporally downscale data for energy-relevant climate variables in an internally-consistent way. This work did not progress to a full prototype, but a better understanding of the users' requirements has been gained, and the learning has been captured for future reference and will be shared with the co-development group.

As a result of these two prototyping activities, the following **overarching points** were noted:

- Climate service providers may become involved with developing a service at different stages – there may be a clear requirement from the outset, or the requirements may need to be defined as part of the process. Similarly, the development of a climate service may require considerable scientific analysis to be undertaken before the service can be provided (this was the case for both energy and transport) – and the magnitude of such a task is not always clear at the outset
- Sometimes, the creation of a new climate service may not be what is actually required to address a user need. For the energy case, the need for the prototype has arisen from a gap between what users want from climate model data and

what current climate modelling experiments provide (i.e. a wish to have data at a high temporal resolution). In this particular case, if the relevant variables were simply output from the climate model runs at the right resolutions, the need for downscaling would be much reduced and the task would be more focused

- Co-development is important for creating services that are useful, usable, and used. Although it is resource-intensive for both users and providers, it can:
    - Ensure that development progresses in a way that maximises the usefulness of the service(s) being co-developed
    - Strengthen working relationships, and
    - Lead to support for continued collaborations
- There are many balances to be struck when prototyping climate services, such as:
    - Good initial understanding of needs within the scientific team enables a quicker focus on relevant topics, if there is potentially broad scope; however, it also may mean that fewer initial options are considered in depth at the outset
    - A more "distant" user group means less input from users, but with a very engaged group, some very technical users can have high expectations or fixed ideas of what could/should be achieved
    - It is rare to be able to meet the needs of all members of a user group. Compromise is likely needed, which means that inevitably some users will be disappointed

The following **overarching recommendations** arose from the work undertaken:

- A clear driving force for a climate service prototype is needed from the outset, in order to make it easier to develop the vision as the prototyping process occurs
    - This vision should originate from a user or users – however, where there is more than one user, it is helpful to avoid trying to "be all things to all people" – e.g. by agreeing what will and will not be included in the task
    - On a related note, user expectations may be high (e.g. that "the ideal solution" will be provided by a comparatively short and lightly-resourced

    activity, when in reality what can be provided may simply be a step towards “the ideal solution”); this can be challenging to manage
  - On the other hand, users may sometimes be too flexible about their requirements (i.e. unwilling or unable to specify a particular avenue of enquiry to pursue), which can hinder the process of co-developing a useful output
- As early as possible in the process, a clear statement of the problem that the prototype seeks to address should be agreed between users and providers, in order to ensure that the prototyping process is – and remains – focused. Any changes in scope that occur as co-development takes place should be limited to those that relate to learning from the co-development, rather than those driven by other factors
- There is sometimes value in “learning by doing” – i.e. providing a “version 0” of a potential service that can feed back into the discussion and scoping
  - For the transport work, “learning by doing” was achieved to some extent – essentially, the draft scenarios were a “version 0” which then led to refinement of the final outputs
  - For the energy work, a “version 0” was discussed and there was iteration of this idea with the users, but time and funding constraints prevented its provision

1 Purpose of document

This document discusses some of the work undertaken in WP3 of the SPF UK Climate Resilience (UKCR) Programme at the Met Office. The work focused on co-development of climate service prototypes for the energy and transport sectors, over the period 2019-2022.

Section 2 introduces the work, and Sections 3 and 4 provide an outline of the work undertaken for each sector. Outcomes and lessons learned are presented in Section 5 with overarching recommendations being made in Section 6.

2 Introduction

In WP3 of the UKCR programme, climate service prototyping activities have been undertaken for several different sectors (health, coastal, urban, energy, transport). This report focuses on work for the energy and transport sectors. The transport work was undertaken with approximately 1.5 FTE of staff time, and the energy work with approximately 1 FTE of staff time.

The co-development aspect of this work is especially important (e.g. Vincent et al. (2018) – "Co-produced climate services are increasingly recognised a means of improving the effective generation and utilisation of climate information to inform decision-making and support adaptation to climate change"). In this report we therefore focus on learnings from the co-development process (Figure 1), including how effectively it was applied in the work with each sector and how well it succeeded in generating the desired outcomes.

For the transport sector, we have worked with the UK Government Department for Transport (DfT) to deliver some technical climate information to support internal DfT conversations about climate, complemented by a high-level factsheet about weather and climate impacts on UK transport.

For the energy sector, we have worked with a diverse group of energy-sector users, spanning academics, industry professionals and data curators, to explore user needs and make progress towards defining a specific climate service requirement for bias-adjusted, high temporal frequency data for key energy-relevant climate variables.

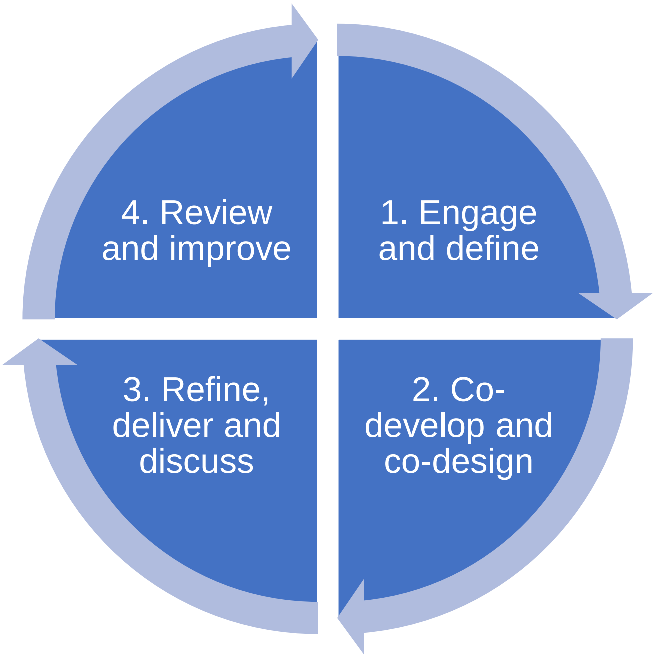

Figure 1: Co-development cycle – adapted from Vincent et al. (2018)

3 Transport sector

3.1 Approach

DfT co-funded the work for the transport sector, as they had established a requirement for support with climate information in parallel with the plans for transport sector engagement in UKCR. Figure 2 outlines the approach taken to the work with DfT.

Figure 3 links the stages of the process with the co-development cycle.

An initial user workshop to provide input for proposing possible tasks (Stage 1) was an effective way to capture initial thoughts on topics such as risk assessment approaches, decision timescales and future scenarios, and weather impacts on transport modes. These initial thoughts were used in constructing options for further work, for discussion with DfT.

The workshop was followed by delivering work against one of the proposed options – namely, to provide a set of text-based scenarios designed to support conversations about the future climate and possible impacts. However, not all of the scenario development work at Stage 2 was strictly co-development (hence dotted line on Figure 3), as DfT had limited involvement in the scientific work underlying the draft scenarios report.

The Oct'20 workshop to present and discuss the draft scenarios did seek feedback on what had been provided to date, and this feedback informed the next workshop (Nov'20, Stage 3) to discuss the direction of the work following the provision of the draft scenarios report.

The Oct'20 workshop captured more detailed feedback, on topics such as

- Who envisaged using the draft scenarios, and for what purposes (e.g. policy planning; emergency exercises)
- Barriers to usage (e.g. too generic/high-level for some; not clear how the scenarios fitted with other available information)
- Ranking the relative importance of the scenarios for different hazards – flooding was deemed the most important by those who expressed an opinion; others were reluctant to do so, as they did not feel they had sufficient knowledge
- Desired timescales (e.g. mid-century)
- Other spatial information that would be useful (as the scenarios are UK-wide) – e.g. transport routes, catchment areas)
- Other climate data/information that would be useful (information aimed at the lay person vs. deep technical information)

While the feedback was useful, it presented challenges for any co-development:

- **Diverse and complementary needs**: a rich diversity of needs was captured but some were contradictory, meaning that they could not be met in a way that pleases all stakeholders. To use a simple example, some people viewed the scenarios as too technical, while others felt they needed more technical detail.
- **Gap feasibility**: it would not have been possible to address all the identified needs in the available project time.
- **Sector-wide vs. organisation-specific needs**: Balancing meeting the needs of individual organisations (i.e. DfT and its agencies) with a wish to develop

unifying or consistent information across transport modes would require deeper engagement that was not feasible within the project.

Following the Nov'20 workshop the feedback was considered, and DfT agreed that a suitable compromise would be to create material related to extremes (Stage 4) alongside the co-developed fact sheet (Stage 2). The extremes information was largely technical and thus delivered with relatively little user input. On the other hand, the fact sheet was a successful example of co-development, with an intensive period of discussion and exchange regarding the content, tone, visual style, etc. The delivery of the finalised reports and fact sheet then followed (Stage 3). More detail about the work undertaken can be found in the Appendix, and outcomes and lessons learned are discussed later in Sections 5.1 and 5.3.

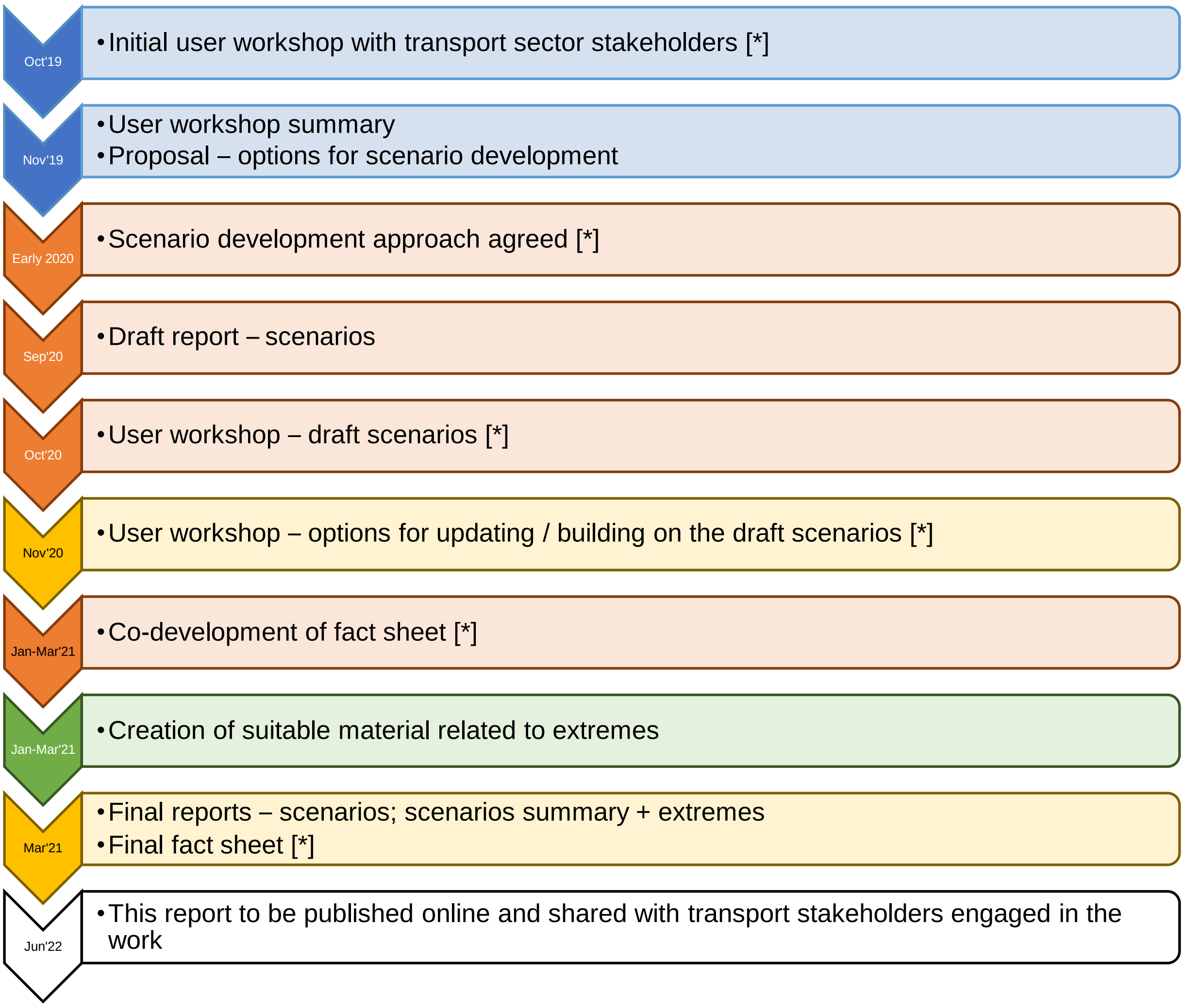

Figure 2: Outline of approach taken for the transport sector work. The colour of each entry indicates to which stage of the co-development cycle it pertains, and corresponds with those colours used in Figure 3. [*] denotes parts which involved particular input from DfT and/or its stakeholders.

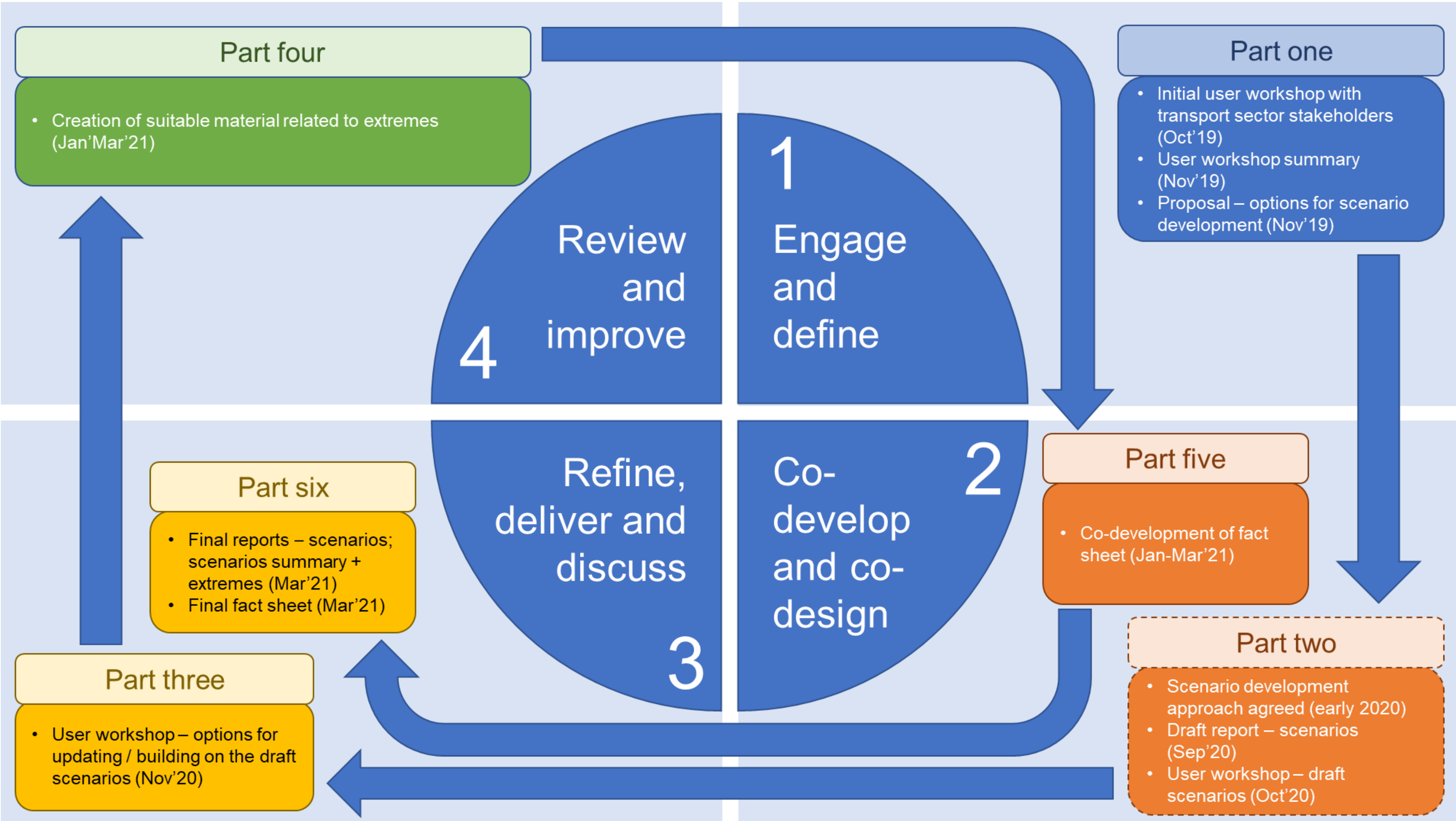

Figure 3: Position of the transport tasks in the co-development cycle.

3.2 Impact of the work

The impact of the work has been relatively difficult to assess. It is worth noting here that impact metrics were not discussed at the start of the work, and that doing this might have facilitated the impact assessment. DfT have described the outputs as "really valuable" and indicated that they have used them to inform internal conversations about climate adaptation policy as relevant teams work through the department's science and technology requirements.

Web analytics information from the UKCR website team found that there were relatively few downloads of the fact sheet. However, engagement about it on Twitter has been positive:

- The fact sheet was tweeted from @MetOffice_Sci in Nov'21 and achieved an engagement rate[1] of 3.7% at the time. This was a higher engagement rate than for most other posts from @MetOffice_Sci in Nov'21.
- The fact sheet was then tweeted again from @MetOffice_Sci in Mar'22 and retweeted from @UKCRP_SPF. The engagement rate for the @MetOffice_Sci tweet (based on one week of data) was 3.1%.

There is no consensus on what constitutes a "good" engagement rate on Twitter, but rates above 1% are described as "very high" (https://scrunch.com/blog/what-is-a-good-engagement-rate-on-twitter) or "great" (https://postfity.com/blog/twitter-engagement-rate/).

[1] Engagement rate of a tweet = 100% × (number of engagements / number of impressions). Impressions = times a user is served a tweet in timeline or search results. Engagements = total number of times a user interacted with a tweet – e.g. likes, replies, follows, retweets etc. [Source: https://help.twitter.com/en/managing-your-account/using-the-tweet-activity-dashboard]

4 Energy sector

4.1 Approach

The energy work started somewhat more slowly than the transport work, as for transport there was a requirement identified from the outset of the work, while this was not the case for energy.

Figure 4 outlines the approach taken to the energy work. There were two tranches of effort: scoping work during 2020, and follow-up during 2021-22.

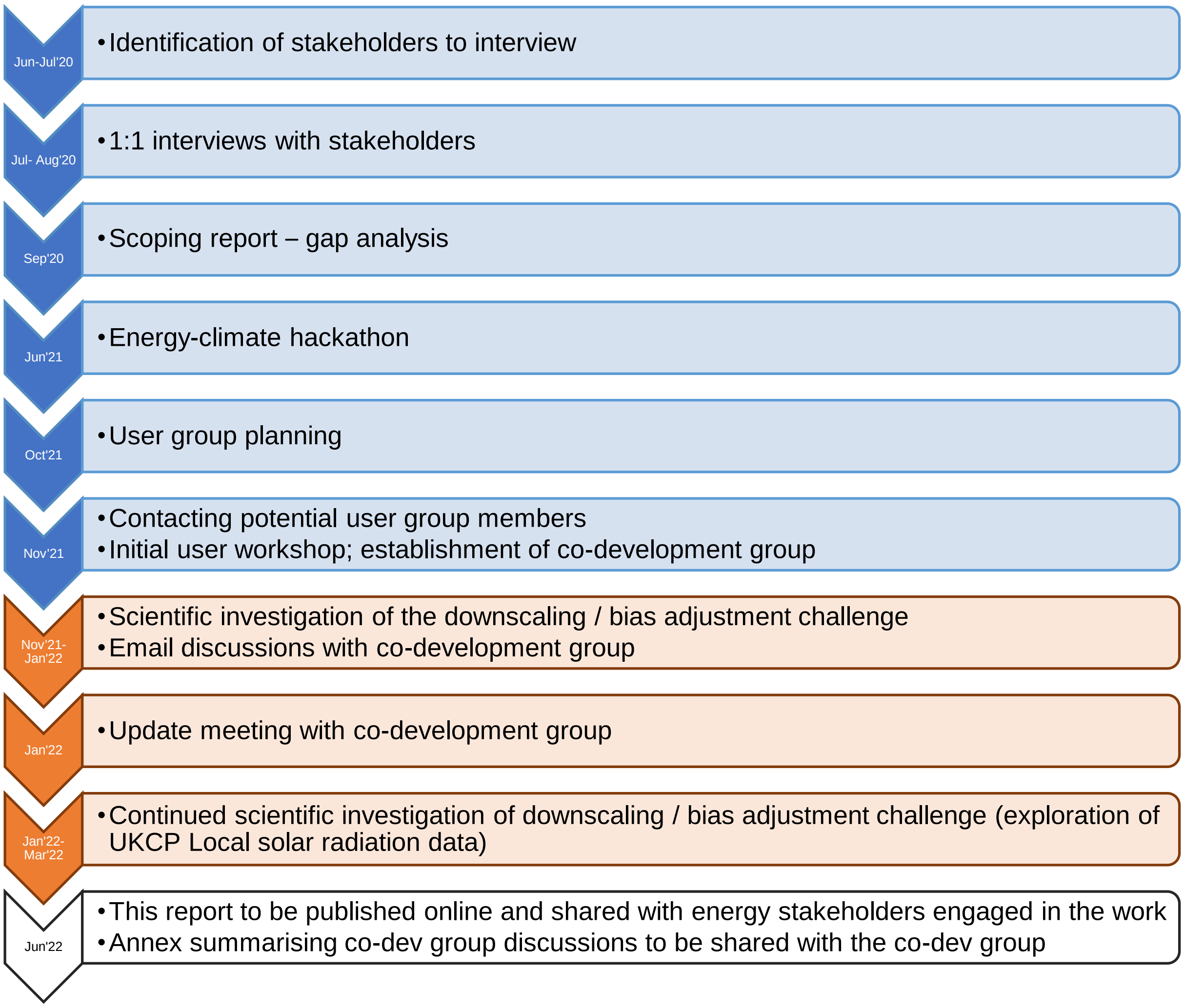

Figure 4: Outline of approach taken for the energy sector work

Figure 5 links the stages of the process with the co-development cycle. By contrast with the transport work, a much greater part of the work focused on the definition / scoping stage (stage 1), and in creating a co-development group and exploring the initial idea with them (stage 2). Due to funding constraints, and the gap between undertaking the scoping and choosing a gap to focus on, the work did not reach the stage of delivering a prototype product (stage 3) nor reviewing it with the co-developers (stage 4).

In terms of the scoping element, the interviews with stakeholders provided rich background information, though the direct relevance of this to energy climate services was not always clear. Conversely, the hackathon, which happened at a much later date, provided a more focused opportunity for engagement and the formulation of a clearer idea to be explored for the potential climate service.

Spending more time at the co-development stage meant that there was more user input at that stage, and thus more learning (see Section 4.2). Nonetheless, it was quite challenging to create and maintain momentum with a new group of contacts, especially as it took us a long time to absorb and understand their various needs and interests, and in turn to understand how the proposed work could help with this. Additionally, in the absence of COVID-19, some meetings with stakeholders might have worked better in person; that said, attendance may have been better (and therefore more views gathered) in the virtual setting.

More detail about the work undertaken can be found in the Appendix.

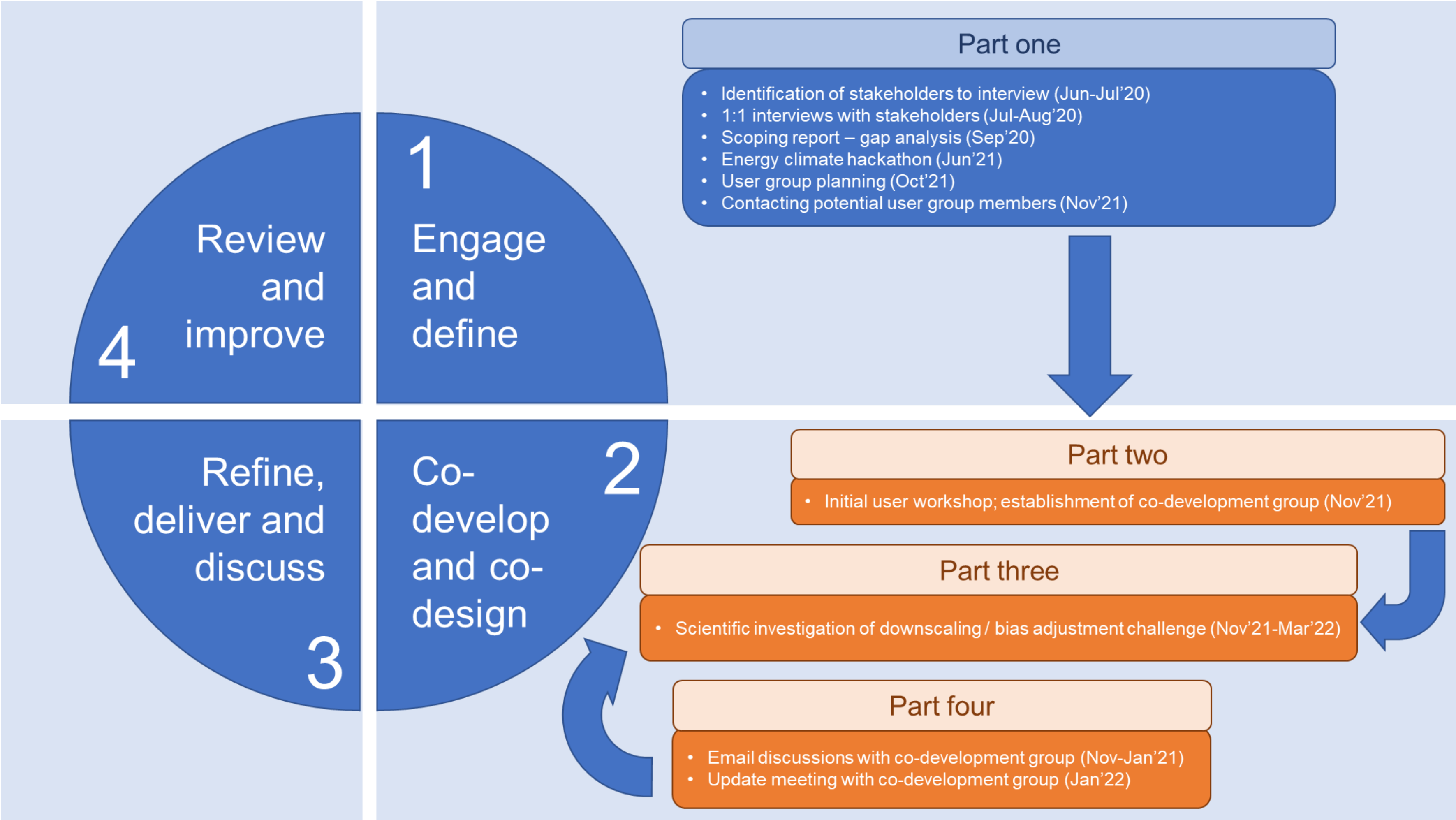

Figure 5: Position of the energy tasks in the co-development cycle.

4.2 Impact of the work

One of the key benefits of the work was to establish the co-development group and to progress our understanding of what the group would ideally like from this kind of data prototype. Figure 6 illustrates how the initially proposed, high-level idea has evolved in response to feedback from the co-developers (and via the preceding hackathon; Fallon et al. (2022)).

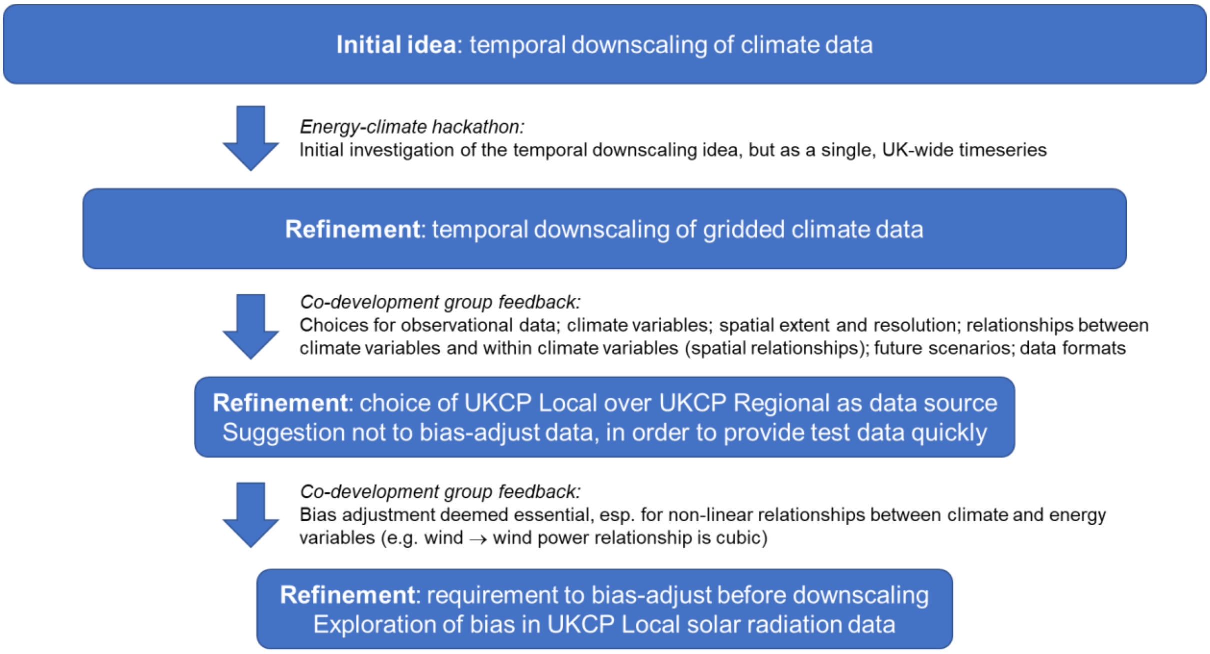

Figure 6: How feedback from others informed the evolution of the climate service prototype idea

In addition, working with the co-development group has strengthened our working relationships with several members thereof and led to support for a continued activity on this topic (e.g. via studentships within academia), and enthusiasm for potential onward collaborations.

Finally, a fundamental aspect of the work is that the requirement for mathematical downscaling of data to a higher temporal resolution exists mainly[2] because climate model output is not saved at the resolution at which users would like it.

5 Outcomes and lessons learned

5.1 Transport

Outputs of the work were:

- Internal reports, describing the scientific work undertaken for DfT:
    - Technical report
    - Summary report + extremes supplement
- Draft conference poster giving an overview of the work
- Fact sheet

Outcomes of the work were:

- Greater knowledge within the project team of the current "reasonable worst case" scenarios used internally by DfT (with specific focus on those related to weather/climate)[3]
- Learning regarding engagement with a government department. There are possible parallels here with work elsewhere in UKCR on upscaling of climate services, in which the importance of the "enabling environment" for upscaling is considered.
    - In this work, it was difficult to trace the use of outputs through the department's decision-making processes
    - When planning subsequent work with government stakeholders, there is potentially value in thinking about how all relevant stakeholders in a department(s) could be engaged at an earlier stage. (For instance, although we engaged with a representative group of stakeholders very early in the work, not all transport modes were represented.)

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[2] It is likely that even if model data were saved at (say) hourly resolution there would still be users who would like it at sub-hourly resolution; however, for this community there is still a gulf between what is desired and what is currently provided.

[3] These are confidential to DfT and thus not discussed further here.

- Consideration is now being given to how we can make better use of the co-developed fact sheet, e.g. whether it could be included in other fact sheet packs such as the city packs being produced in the urban prototyping work.

5.2 Energy

Outcomes of the work were:

- A more detailed understanding of the requirement for data for energy-relevant variables to be used in energy-climate modelling, e.g.:
  - A clear indication from users that bias adjustment of the climate data is essential – and therefore that any continuation of this work must include this step
  - Currently, where bias adjustment is done it is typically via univariate approaches, yet it ideally needs to be multivariate in order to preserve statistical relationships between variables, and for a given variable, appropriately. Multivariate approaches are relatively novel, and quantifiable methods would thus need to be established for using multivariate approaches so that (for example) these could be compared with the univariate bias correction of several variables.
- Establishment of an engaged co-development group of energy professionals:
  - Initially (Nov'21), 11 people volunteered to join the co-development group: 6 from academia, 4 from industry and one data manager
  - The most active participants in the co-development group came from the academic participants. Similarly, at the time of writing (Mar'22), the interest in continuation of working relationships also comes mostly from the academic colleagues
  - The outcomes of establishing this group were thus (a) a stronger steer from energy experts and (b) continuing relationships with energy experts.

5.3 General lessons learned

The complementary approaches to the work in these two sectors provide opportunities to compare and contrast them and thereby learn from the co-development experiences (see Table 1 for a summary).

For transport a full cycle of co-development was completed, but for energy the time taken in the early stages of the work (coupled with funding constraints) limited the progress beyond formulating the idea for what users wished to be delivered. In the early part of the energy work, time was expended in scanning the space for gaps and exploring which gap(s) could potentially be addressed, whereas for transport a specific requirement for work existed and therefore was more easily and promptly addressed. Given the amount of time required at each step in the co-development cycle, the transport case – where there was already a specific need identified – seemed more efficient.

That said, the intensive co-development discussions undertaken for energy felt more in-depth (Figure 4, Parts two to four), and Figure 6 has already demonstrated the way in which the co-development informed the scientific thinking for the task. For transport, there was much less involvement of the users in defining the science to be undertaken (Figure 3, Part two), although there was a defined checkpoint when users were consulted about the draft scenarios developed. Without being able to continue the energy work, it is difficult to evaluate which was the "better" approach (i.e. which stage(s) in the co-development cycle is/are the "best" stage(s) at which to concentrate the effort); however, instinctively the timing of the intensive engagement with the energy group seems to have been better than for the transport group. While the draft scenarios produced for transport were deemed useful[4] by many of the users, they also had many comments about what would be <u>more</u> useful[5] –

[4] At one of the user workshops, we ran a live "instant feedback" survey, with one question asking users about the potential usefulness of each of the draft scenarios (1=least useful, 5=most useful). There were 11 respondents to the survey. There was very little difference between overall assessments of the usefulness (range: 4.2 to 4.6), with all scenarios scoring either 4.5 or 4.6, except heatwaves (4.2). If individual sectors are considered then the rail sector had a lower mean usefulness score (4.0) for the draft scenarios, compared to the other sectors. Aviation had the highest usefulness scores (4.8) followed by local road (4.7).

[5] Such as higher spatial resolution (rather than just at the UK level); assessment of uncertainty; information aimed at the layperson; changes to return periods of rare (extreme) events; information at shorter timescales (i.e. for operational/seasonal planning as well as climate timescales).

suggesting that more intensive co-development at an earlier stage might have steered the work in a subtly different direction, where the focus was more clearly driven by users rather than relying on the approach proposed by scientists.

One overall lesson learned was that in both pieces of work it would have been better to set expectations (on both sides) from the beginning, and then manage these as the work progressed. This could include agreeing impact metrics, for instance. However, it is not always easy to take this approach in practice, especially with common project challenges such as scope creep (and indeed the fact that these are prototyping projects, in which the task naturally evolves to some extent as it progresses).

Topic	Transport	Energy	Relevance
Existing sector knowledge in project delivery team	Expert knowledge of transport sector, gained through prior work	Little background knowledge of renewable energy sector	Having sectoral experience can mean: • Greater knowledge of stakeholders, and thus their interests, needs, and knowledge • Easier to decide between possible gaps to address
Initial understanding of needs for climate service information	User requirement, driven by users, existed from the outset	Scoping work needed to find potential gaps	If the project team already has an initial understanding of needs, this enables a quicker focus on relevant topics, if there is potentially broad scope
Establishment of the task	Quicker to get into detail, as more defined brief	Slower to get into detail, as less defined brief	
Level of user engagement	User group more distant from the work	Deeper discussions with user group	Deeper engagement means that more of the technical detail can be explored, though this is contingent on the engagement involving users with knowledge of such detail

			A more distant user group means that there is less steering from the users, but the flipside of this is that some very technical users can have high expectations or fixed ideas of what should be achieved
Extent of co-development	Full co-development cycle completed	Limited progress around co-development cycle	Co-development is important for creating services that are useful, usable, and used
Use of outputs	Very high-level impact/usage information provided by DfT Unknown use of outputs by end users (e.g. DfT's agencies)	N/A	Knowing how outputs **will be** used is helpful for steering the development of such outputs while they are being created Knowing how outputs **are being** used, once created, is helpful for creating future services or expanding on the current one

Table 1: Comparing and contrasting the activities undertaken for the two sectors

6 Overarching points and recommendations

Considering the co-development work undertaken for both of these prototypes, the following overarching observations and recommendations can be made.

6.1 Overarching points noted

- Climate service providers may become involved with developing a service at different stages – there may be a clear requirement from the outset, or the requirements may need to be defined as part of the process. Similarly, the development of a climate service may require considerable scientific analysis to be undertaken before the service can be provided (this was the case for both energy and transport) – and the magnitude of such a task is not always clear at the outset

- Sometimes, the creation of a new climate service may not be what is actually required to address a user need. For the energy case, the need for the prototype has arisen from a gap between what users want from climate model data and what current climate modelling experiments provide (i.e. a wish to have data at a high temporal resolution). In this particular case, if the relevant variables were simply output from the climate model runs at the right resolutions, the need for downscaling would be much reduced and the task would be more focused
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- There are many balances to be struck when prototyping climate services, such as:
    - Good initial understanding of needs within the scientific team enables a quicker focus on relevant topics, if there is potentially broad scope; however, it also may mean that fewer initial options are considered in depth at the outset
    - A more “distant” user group means less input from users, but with a very engaged group, some very technical users can have high expectations or fixed ideas of what could/should be achieved
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6.2 Overarching recommendations

- A clear driving force for a climate service prototype is needed from the outset, in order to make it easier to develop the vision as the prototyping process occurs
  - This vision should originate from a user or users – however, where there is more than one user, it is helpful to avoid trying to "be all things to all people" – e.g. by agreeing what will and will not be included in the task
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- As early as possible in the process, a clear statement of the problem that the prototype seeks to address should be agreed between users and providers, in order to ensure that the prototyping process is – and remains – focused. Any changes in scope that occur as co-development takes place should be limited to those that relate to learning from the co-development, rather than those driven by other factors
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7 References

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Appendix: description of the work undertaken for each sector

Transport

Preliminaries

At the start of the work, the primary interest was in creating scenarios that would support risk assessment activities within DfT. A requirement was that these scenarios should refer to existing “reasonable worst case scenarios” (RWCS) used for the present-day management of weather. These scenarios are confidential and hence not reported here.

An initial user workshop was held to scope out the requirement in October 2019. Representatives of DfT and several of their agencies (Network Rail, Maritime and Coastguard Agency, and Highways England[6]) attended. Following the workshop, a proposal containing several options for scenario development was provided to DfT.

Scenario drafting

An approach to scenario development was agreed with DfT in early 2020 and a draft report describing the resulting scenarios provided in September 2020.

The approach taken was to explore the RWCS using historic observations and current climate data, extending them to consider the future climate using UK Climate Projections[1] (UKCP18) and other methodologies (Figure 7).

Three key questions were considered:

- Has the RWCS ever occurred in the past?
- What is the evidence for the associated hazard in the current climate?
- What is the evidence for the associated hazard in the future climate?

Different strands of evidence from UNSEEN and UKCP18 were combined to provide a set of text-based scenarios designed to support conversations about the future climate and possible impacts.

[6] Now National Highways

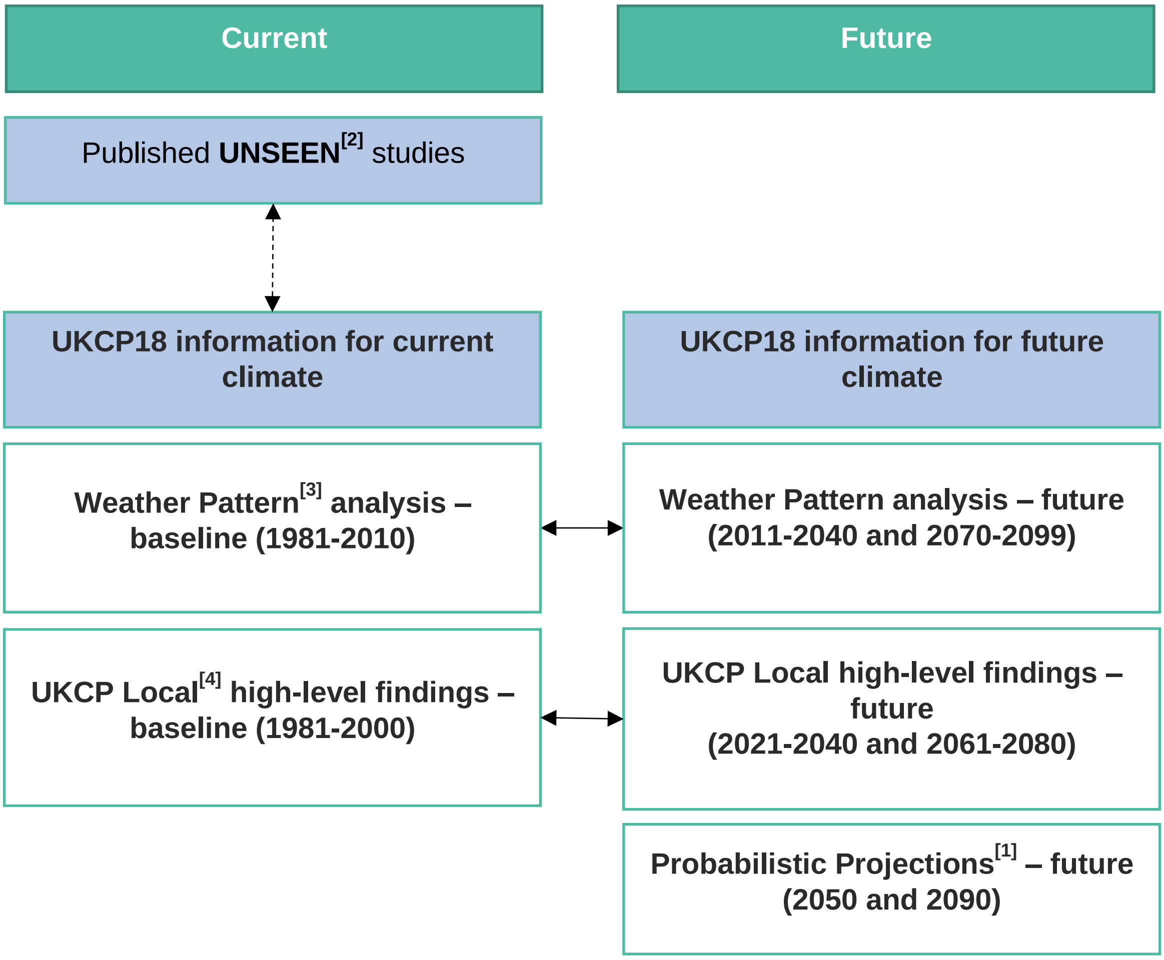

Figure 7: Methodologies used for exploring hazards in current and future climates. Dashed arrow indicates complementary information for assessing the current climate. Solid arrows indicate consistent methods for assessing current and future climate hazards. References: [1] UKCP Science Overview Report; [2] Thompson et al., (2017), McCarthy et al., (2019), Dunbar et al., (in preparation); [3] Pope et al. (2021); [4] UKCP Convection-permitting model projections: Science report.

User feedback and follow-up

In October 2020 these draft scenarios were presented to transport stakeholders (15 attendees, again from DfT and its agencies) via an online workshop, to gather initial feedback. Based on this feedback, a later workshop (November 2020; 14 attendees from DfT and its agencies) was held to discuss two potential development options for the scenarios:

- Expanding the technical content of the scenarios
- Preparation of communications material around the scenarios

It was agreed to pursue the latter, in the form of a fact sheet. A document summarising the scenarios report was also requested by DfT.

At the November workshop, some users also requested information about extremes. Although the methodologies used in preparing the draft scenarios had attempted to consider some aspects of extremes, a specific UKCP18 report focusing on extremes was not published until late 2020 (UKCP Additional Land Products: Probabilistic Projections of Climate Extremes – "PPCE"). It was therefore decided to provide an additional report summarising the scenarios and also offering information about extremes from the PPCE report.

Material for this report was developed in tandem with an intensive co-development process for creating the fact sheet. DfT requested a fact sheet that could be used by people with little knowledge of weather, climate and its impacts on transport.

A four-page fact sheet was co-developed with one DfT colleague, who acted as a single point of contact for the co-development process. The fact sheet provides information about:

- Observed and possible future climate changes – to set context
- Case studies of past impactful weather events – to help the reader make the link between current weather impacts and how these might change in future, and to demonstrate the magnitude of impacts in real terms (e.g. costs or numbers of impacts)
- Risk assessment – to explain how risk is a function of hazard, vulnerability and exposure, and what these terms mean
- Systemic risks, interdependencies and indirect impacts – to emphasise the connectedness of the transport system with other systems
- Climate change governance in the UK – to support those needing an entry-level resource about this – e.g. links between Climate Change Risk Assessment (CCRA), National Adaptation Programme (NAP), Adaptation Reporting Power (ARP), etc
- Further reading – e.g. links to CCRA reports, NAP documents, and UKCP – to allow engaged readers to easily find out more

Once signed off by DfT, the fact sheet was made available online at https://www.ukclimateresilience.org/projects/climate-services-for-the-transport-and-energy-sectors/. See Section 3.2 in the main report for more information.

Energy

Scoping

The scoping work involved discussions with various stakeholders across the energy space (Government, umbrella organisations, industry representatives, academics). Met Office colleagues working in the energy sector were also consulted. Approximately 20 external stakeholders were interviewed about perceived gaps in provision. A gap analysis report was prepared for internal Met Office use.

Energy-climate hackathon & initial research idea

By coincidence, colleagues at the Universities of Reading and Oxford – in partnership with the Met Office – organised an energy-climate hackathon which took place in June 2021 (Fallon et al., 2022). Ahead of this hackathon various conversations were held directly with colleagues at Reading about their perceptions of gaps in the energy climate services space. As a result, a joint hackathon topic was put forward, on methods for temporal downscaling of climate model data for use in energy-relevant applications such as energy systems modelling. The topic was popular with hackathon participants and the outcomes of the event provided further food for thought regarding how best to address this topic – for example, which machine learning methodologies could possibly be used in temporal downscaling.

While the preceding engagement, undertaken as part of the scoping process, spanned a broad range of stakeholders, the engagement related to the hackathon provided a more focused opportunity for obtaining information about potentially tractable gaps. Nonetheless, the hackathon was essentially a first step, using a very simplified version of the true scientific challenge in order to make some initial progress.

User group and co-development

The relevance of the hackathon topic for the UKCR work was that it provided "food for thought" in terms of the potential development of a climate service data prototype, whose intended aim would be to start providing to energy-climate modellers the climate data that they need for their models – i.e. considering factors such as spatial extent of data, spatial and temporal resolution, variables and time horizons of interest, file format, and so on.

As such, in autumn 2021, we scoped and created a user group to support the co-development of such a prototype. A contact list of potentially interested parties (approximately 60 external contacts) was collated and contacted by email about the work.

First workshop

An initial user workshop was held on 21st November 2021 and around 20 external contacts attended.

The aims of the workshop were threefold:

- To provide an overview of the planned work in developing an energy climate service prototype
- To obtain an initial steer from the potential users of such a prototype
- To prepare for setting up a user group for co-developing the prototype

During the meeting participants were encouraged to complete a poll offering them different options for interacting with the project – either joining a co-development group, or maintaining an interest via a "notified" group (the default option). 11 people volunteered to join the co-development group: 6 from academia, 4 from industry and one data manager.

Participants added information to virtual Post-It note sessions about such topics as observational data used, meteorological variables of interest, spatial scales and resolutions of interest, preserving relationships between different weather/climate variables and data formats used.

A workshop summary was circulated to all invitees, including those unable to attend.

Post-workshop discussion

A key element of the workshop follow-up was establishing the group's spatial interests – higher spatial extent at lower resolution, or the opposite. This was to determine whether data would be downscaled from the UKCP Regional (12km, whole of Europe) or UKCP Local (2.2km, UK only) product.

Users' preferences expressed about this were split, with a moderate preference for the higher-resolution, lower-extent option. Two drop-in discussion sessions were offered to the co-development group, in case clarification was needed, but only one participant attended one of these.

Having decided to work with the UKCP Local data, and bearing in mind the common variable requests of temperature, wind speed and solar radiation, it was found that the UKCP Local data already contained temperature and wind speed at hourly resolution for three available timeslices. Solar radiation data were available at three-hourly resolution, providing some simplification of the downscaling task: (a) required for only one variable, rather than three, and (b) a somewhat more tractable challenge, methodologically, to downscale from three-hourly to hourly data than downscaling from daily to hourly.

Second meeting (co-development group)

Planning then began for a further co-development group meeting in late January 2022. This meeting aimed to:

- Prepare the co-development group for eventual testing of the prototype data
- Outline our proposed approach to creating the data
- Seek co-developers' input to creating the data
- Seek co-developers' feedback on all of the above

At this stage, mindful of the need to create – in a timely fashion – some initial data for testing, it was proposed to skip bias adjustment of the data and proceed straight to downscaling the solar radiation data. However, the co-development group found this an unpalatable suggestion, highlighting the need for bias correction in particular for cases where the relationships between weather/climate and impact are non-linear.

Following this feedback, an initial exploration of potential biases in the UKCP Local solar radiation data was conducted. The purpose of this was to assess whether the UKCP Local solar radiation data could be used in energy modelling without bias adjustment.

The findings from the preliminary work within this area are as follows.

- There are differences between the hourly mean solar irradiance for specific 3-hour periods between ERA5 and UKCP Local, and these differences vary with location and season.
- Only hourly mean differences were studied. It is possible that other percentiles of the distribution may vary more or less than the mean difference and this may be particularly relevant when looking at extremes or when equipment is sensitive to weather thresholds.
- The differences observed between the ERA5 and the re-gridded hourly mean solar irradiance from UKCP Local may be a result of a number of different factors; such as the re-gridding of the UKCP18 Local data to the ERA5 spatial resolution, biases in ERA5 re-analysis compared to observations as suggested by a limited study by Urraca (2018), or the smoothing of the ERA5 data to match the temporal resolution of the UKCP Local data. Further work would be required to confirm and understand these differences better.
- Whilst finer resolution datasets are available for univariate data – such as the SARAH solar radiation data (NCAR 2015) for solar irradiance – ERA5 is one of very few datasets available that contains all the parameters wanted by the users, in a manner that means the variables are physically consistent with one another. As a result, it is desirable to understand how well this dataset represents the “observed” climate. Our brief review of the literature for solar

irradiance, suggests that apart from the limited study by Urraca (2018) which looked globally and at Europe, very little work has been done in this area.

- Gridded observation datasets based on observed meteorological variables tend to focus on temperature and rainfall at daily resolutions. These variables are used often for climate model verification. However, given the trend towards helping customers assess the potential impact that climate change has on their business, perhaps there is a need to widen the scope of the variables available in gridded observational datasets, as well as increasing the temporal resolution (subject to suitable data being available).

Cessation of funding and closure of tasks

It was indicated in February 2022 that due to other priorities, funding would not continue via UKCR for the energy work during FY22/23. The focus then switched to:

- Documenting the work undertaken;
- Ensuring that lessons learned were captured for future work; and
- Ensuring that appropriate relationship management activities were undertaken so that any adverse effects on the relationships with users were minimised

The decision was communicated to users by email in late February 2022. Four of the user group responded to express their disappointment and confirmed an interest in continuing collaborations on this and other energy-climate topics.

References cited in the appendix

National Center for Atmospheric Research Staff (Eds). Last modified 21 Oct 2015. “The Climate Data Guide: Surface Solar Radiation Data Set – Heliosat (SARAH) – Edition 1.” Retrieved from https://climatedataguide.ucar.edu/climate-data/surface-solar-radiation-data-set-heliosat-sarah-edition-1.

Urraca R, Huld T, Gracia-Amillo A, Martinez-de-Pison FJ, Kaspar F, Sanz-Garcia A. (2018). Evaluation of global horizontal irradiance estimates from ERA5 and COSMO-REA6 reanalyses using ground and satellite-based data. Solar Energy, 164, 339–354. https://doi.org/10.1016/j.solener.2018.02.059