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Modelling for the UK's Utility-Scale Solar Regulation Change: Lessons for Transdisciplinary Engineering in Policy Practice

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Abstract. Meeting the UK's net-zero greenhouse gases target by 2050 requires transdisciplinary engineering, it requires efficient exchange and collaboration between engineering and social science, between engineers and policy makers within the national government. Based on ethnographic fieldwork conducted within the UK's department for Business, Energy and Industrial Strategy (BEIS), this paper explores how technical and policy expertise were mobilized and combined in a recent change in utility-scale solar policy. Taking a model developed by BEIS' engineering advice team in collaboration with the established renewable policy team, this paper looks at what it means to give and receive engineering advice in the context of utility-scale solar regulation. Looking at the model design process from both the engineer's and policy advisor's perspectives highlights how concepts of expertise, disciplinarity compatibility and opposition impact policy and outcomes. The modelling process was successful in helping the negotiation and reconciliation of technical and social concerns to enable a change in utility-scale solar regulation satisfactory to industry and constituents. By drawing on this case, this paper ends on a wider discussion about how the generation of mutual trust and development of interactional knowledge between engineers and policy advisers enables TE in policy practice.

Keywords. Transdisciplinary engineering thinking and practice, managing cultural & disciplinary differences, engineering advice for policy, modelling, utility-scale solar

Introduction

Meeting the UK's net-zero greenhouse gases target by 2050 will not happen without transdisciplinary engineering (TE), without efficient exchange and collaboration between engineering and socio-political experts. But concretely, how does TE happen in policy practice?

This paper answers this question by exploring how technical and policy expertise were mobilized and combined in a recent change in utility-scale solar policy in the UK designed to increase the amount of renewable energy put into the grid. Using ethnographic interview data and document analysis, this article looks at how the engineer

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and policy adviser in charge of the project collaborated to create a model and answer the policy question.

After a detailed explanation of the case complete with quotes describing the modelling and policy process from both the engineer and policy adviser's points of view, this paper discusses the expertise required in this case and the skills needed to process it. The engineer and policy adviser mobilized and processed, respectively, technical or socio-political expertise, by drawing on their engineering or political science backgrounds. The difference in the type of expertise gathered and differing backgrounds however posed challenges when both had to combine technical and policy expertise to answer the policy question. The engineer and policy adviser had to figure out strategies to manage their stakeholders' competing interests, to communicate technical data in non-technical ways and summarize complex model results in a convincing fashion.

Exploring the strategies deployed by the engineer and policy adviser to overcome their disciplinary differences and manage the hurdles faced in this case allows us to see what enables TE in policy practice more broadly. The paper ends on a wider discussion about how the generation of mutual trust and development of interactional knowledge enables TE throughout the policy process.

1. Methodology

The following results are based on interviews and document analysis carried out in the UK government's department for Business, Energy and Industrial Strategy (BEIS) from January to September 2021. I started by interviewing the head of BEIS' in-house engineer team tasked with "supplying technical information on energy-related issues to the policy units that sit within the department's directorates"[2]. The head of the team put me in touch with the engineer in their team who worked on the project who in turn put me in contact with the policy adviser they worked with, gaining a view of the same project from different perspectives. The semi-structured interviews were held online, lasted one hour each and were subsequently transcribed and added to NVivo for a thematic analysis following Charmaz's grounded theory framework [1] . The interviews were complemented by an analysis of the Draft National Policy Statement for Renewable Energy Infrastructure (EN-3) in which the outcome of the project is presented. The work shown here is a small subset of my PhD project ethnographically investigating how engineering advice and related modelling insights are deployed in energy policy practice at BEIS.

A final disclaimer should be added before the results of the study. Methodologically, the results presented here can provide a picture of only a limited range of reality. I cannot claim that the data I obtained are representative of the entire body of British civil servants, let alone of other actors (inside and outside government) who play a part in engineering policy [2]. I hope, however, that this study reveals at least some of the mechanisms that characterize TE in the context of policy. I am currently using ethnographic methods across BEIS to complement this case's findings and gain a wider view of how TE happens in policy practice.

[2] Description taken from the letter sent by BEIS to UCL to approve my fieldwork

2. Results

2.1. The policy problem: setting out the case

Utility-scale solar facilities are composed of several arrays of solar panels that generate electricity as direct current (DC). These arrays then feed an external inverter which converts the electricity from DC to alternative current (AC). After inversion, a transformer steps up the voltage to export the electricity to the grid. Because the inverters are separate from the solar panels, the total electric production capacity of a utility-scale solar facility can be measured either by adding up the capacity of the panels (measured in DC) or by combining the capacity of the inverters (measured in AC).

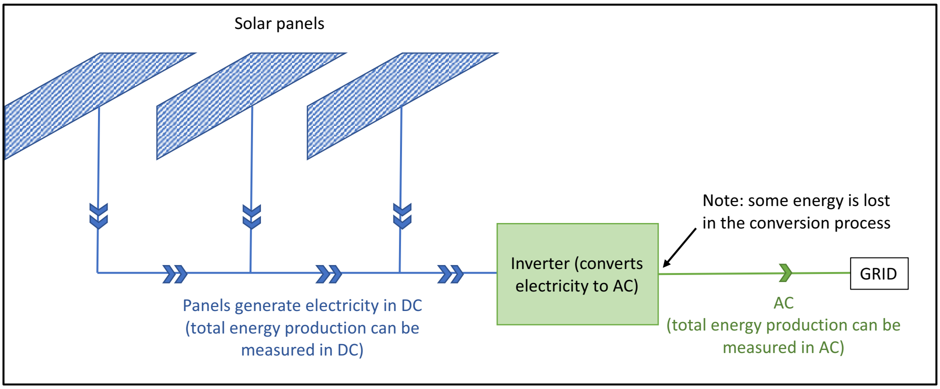

Figure 1. Total production of a utility-scale solar facility can be measured in DC or AC.

It used to be the case until this year that, in the UK, the capacity of utility-scale solar installations would be measured in DC. Below 50-megawatt (MW) DC facilities would fall under local council authority whereas above 50MW DC installations were considered Nationally Significant Infrastructure Projects (NSIP) and fell under the national government's jurisdiction, meaning longer and more complicated contracts [3] .

In January 2021, the minister for BEIS considered changing the 50MW DC threshold to 50MW AC allowing developers to plant more panels on their installations (to account for the energy lost in the DC to AC inversion process) without them being considered NSIPs. The trade-off, as seen in the EN-3 [3], was as follows: the DC to AC change would bring utility-scale solar regulation in line with other types of electricity production measured in AC, would put more renewable energy into the grid and would reduce the cost of solar-derived electricity. However, the change meant that developers could plant more panels on existing facilities with local residents being unhappy about the visual and environmental impacts of bigger utility-scale solar facilities.

For the ministerial team, the policy question could therefore be phased as follows: should the threshold be changed to 50MW AC, how much more energy would be put into the grid and how many more panels would developers plant on average?

2.2. Initial steps: translating the question

The ministerial team asked the ministry's established renewable policy team to come up with an answer, the project was given to a policy adviser within that team (henceforth referred to as pol 1). The adviser had been working at BEIS for a year, having worked in another ministry for a year prior to that, on a different topic. The adviser held an undergraduate degree and postgraduate diploma in political science.

Clearly this policy problem was a matter of TE, it required knowledge from a diverse range of perspective, technical as well as social. The policy analyst therefore sent an email to the ministry's in-house engineering advice team outlining the issue and asking for technical advice.

The initial email was sent to the head of the engineering team (eng 1), an engineer by training who had work in the private sector for 20 years after completing their PhD and had been at the ministry for 6 years. The head of the team gave ownership of the project to an engineer in their team (eng 2) who had been in the team for a year and a half and had work on UK energy models as part of their PhD. The head of the team remained engaged in the project to lend some help to their team member when needed.

The first step in the project was for eng 2 and pol 1 to get together to clarify what information was needed to answer the policy question. The outcome of the meeting was to breakdown the question as follows - as the result of the threshold change from DC to AC:

- What would be the impact on land use?
- What would be the impact on energy production?
- What would be the impact on load factor?
- What would be the impact on cost/levelized cost of energy?

Eng 2 suggested that that they tweaked a model written in Python they already had to answer the questions above. The model was on renewable energy generation and storage and used historic weather and electricity demand data to understand where the grid imbalances were. The model used publicly available weather data, BEIS energy data and assumptions underpinned by academic literature and calculations. Pol 1 stressed the importance of the possible visual impact of the change.

2.3. Model building: overcoming challenges

Model building lasted for three weeks, eng 2 tweaked the existing model to add costs of solar panels (based on industry data), land footprint data published by the government and consultation with academics. During those three weeks, eng 2 checked-in with pol 1 to check their assumptions and explain how lower and upper bounds for the model variables were selected. Pol 1 had some feedback about developers already overplanting panels which they gathered through a consultation with the developers about the proposed policy change. The model was updated accordingly. Throughout the process the policy adviser was also exposed during several consultations to the minister and constituents concerns about the visual impact of the policy change.

The first challenge faced by the engineer and policy adviser was balancing different stakeholders with competing ideas and interests. As we previously stated the policy problem is a matter of TE and draws on social and technical knowledge held by different groups and actors. Just in the creation of this model, academia, industry, local residents and ministerial team were consulted and ministerial and industry energy, land use and pricing data was used.

Both the engineer and the policy adviser explained that even if balancing stakeholders views was challenging, it was an essential part of their role – worth noting that the engineer dealt with technical stakeholders whereas the policy adviser worked with socio-political data:

> *"Industry and academia's motivation is for their technology to get more funding and more interest, whereas my motivation is for public money to be spent for the public good.* ***So, part of our role is to ensure that we remain unbiased" –*** *Eng 2*

> *"And our role is to try* ***to objectively put together the [stakeholders'] views we have gathered from other policy teams, ministers and [public] consultations and what our view might be within that.*** *" – Pol 1*

The engineer and policy adviser working on the project also noted that they knew the stakeholder balancing exercise their colleague was involved in, which created mutual trust:

> *"I wouldn't know the first thing it turns out about how to develop policy,* ***there's like regulation as well as all these kind of social issues to balance out and [the policy advisers] actually know what they're doing on that side****." – Eng 2*

> *"We didn't end up using any of the industry figures because we thought that some of them were probably not accurate* ***and so having [engineer's] model gave the recommendation much more credibility than if we had relied on industry data only****." – Pol 1*

The second challenge mentioned by the engineer and policy adviser working on the project was about the internal communication of technical information:

> *"****I don't think, coming from an engineering background, [communicating technical information] is a skill as valued as it could be****. I think really good engineers do have that skill, but I think it's very much seen as a premium thing, whereas in policy it is like absolutely the core thing.* ***Like you know, really thinking depending on your audience. It's hard, because you need to be able simplify and compress complex technical information into 2 lines*** *or something that someone non-technical will get." – Eng 2*

> *"I mean there was a point where* ***I was getting lost in very technical details****"– Pol 1*

Both the engineer and policy advisor overcame this issue by developing visuals and meeting up more regularly. The engineering added that the visual was a good way to establish a shared language between the two teams:

> *"What really helped in the end was to* ***have some visuals which is something that eng 2 is used to as [they] work with policy advisors.*** *I tried to make those visuals my own to some*

extent, write upgrades on those, and come back quickly to eng 2 like 'could you just please better explain to me how this part is supposed to be working'" – Pol 1

*"In the end, the final product has to be shared between our teams, so **it is important that we speak the same language if you know what I mean**." – Eng 2*

2.4. Policy outcome: generating narratives

After the modelling was completed, the policy adviser worked with the engineer to understand the results and wrote a six-page policy memo for the ministerial team. When drafting the memo, due to space constraints, the policy adviser and engineer had to select what part of the model and results to present. A five-minute presentation of the policy memo was delivered by the adviser to senior staff on the policy board, the engineering team was in attendance.

The model results were presented as graphs showing land use and energy output of current DC threshold versus AC threshold for different regions (the more north you go, the less sunlight). Results showed a potential 30% increase in energy production overall and, with now more efficient technology, a limited impact on land use. The policy team's recommendation was to go ahead with the threshold change.

When drafting the policy memo, the engineer and policy adviser worked together to create a narrative using the model data to convince the policy board that going ahead with the change was the right move:

*"[The policy board] wouldn't appreciate an introduction to physics course on a 50sq millimeter cable that carries 564 amps at a voltage of 12000 volts. But **a discussion on the bigger you make the cable the more power it can transmit, the more expensive it is, that's what they wanted to see. There is a line to walk in there, you have to generate some sort of narrative so that it makes sense.**" – Eng 1*

*"To convince the board, we had to provide them with the background, **and policy options set out in really simple stories**. **They love what they call a one pager, it's always a challenge to get anything substantial into one page though"**– Pol 1*

3. Discussion

By definition, a problem that requires TE is a problem where the expertise required to solve it is distributed, it is held by several actors from different disciplinary backgrounds. Now what does TE mean in a policy context? How do you mobilize and combine the technical and socio-political expertise necessary to solve complex policy problems? The aim of this section is to answer these questions by drawing on the case detailed above. By looking at utility-scale solar regulation change in the UK this paper illustrates what type of expertise can be drawn upon in a TE policy context, what skills are needed to properly mobilize this expertise, the challenges this brings about and the strategies deployed to overcome these hurdles and solve the policy issue.

3.1. A policy landscape with distributed expertise

When looking at the question of distributed expertise and how it is handled by the UK government when making policy, it is key to mention Page's work [4]. In his article, Page defines expertise as "a high level of familiarity with a body of knowledge and/or experience that is neither widely shared nor simply acquired" [4]. With this definition in mind, the author identifies different kinds of expertise for policy: technical expertise and policy expertise. Technical expertise refers to scientific, or in our case engineering, expertise. Policy expertise is the knowledge of policies and their socio-political content.

In the case of utility-scale solar regulation change, both types of expertise had to be mobilized to answer the policy question at hand. Technical expertise, in the form of industry energy, land use and pricing data, was mobilized. Policy expertise, if the form of socio-political arguments put forward by residents, ministerial team and industry also came into play.

3.2. Mobilizing different types of expertise requires different skillsets

Given the amount of expertise or knowledge required to answer this policy question, it is unlikely that one person within the civil service would be the sole "mobilizer of expertise" [4,5]. Instead, two different individuals handled a different type of expertise: the engineer mobilized technical expertise and the policy adviser mobilized policy expertise.

This should probably be nuanced slightly to say that technical expertise sometimes includes socio-political concerns, like the impact of the regulation change on energy costs, and policy expertise sometimes contains technical elements like the developers' panel overplanting practices. Perhaps the best way to conceptualize this point is a spectrum where the expertise mobilized by the engineer and the policy adviser is always a mix of technical and socio-political or policy expertise. The engineer however focused on expertise with a heavier technical component (leaning towards the technical end of the spectrum) and the policy adviser gathered expertise that is more socio-political in nature (leaning towards the policy end of the spectrum).

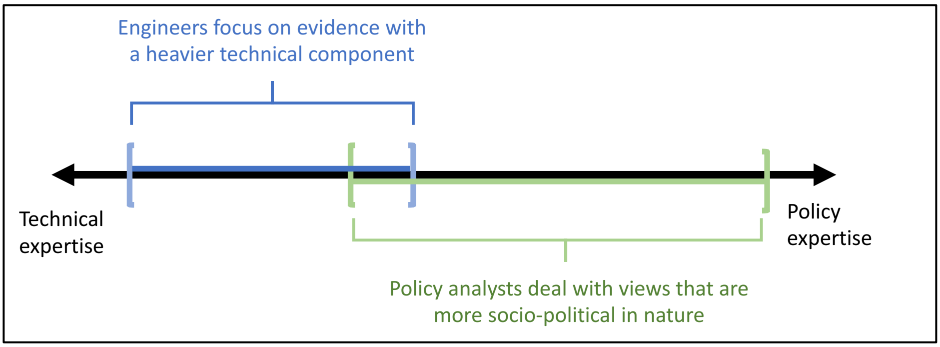

Figure 2. Mobilizing different types of expertise for policy.

To mobilize different types of expertise, the engineer and policy adviser need different knowledge and skillsets, informed by their backgrounds and experience. In mobilizing technical expertise, the engineer relied on their engineering knowledge and modelling know-how to gather and process quantitative data rooted in math's and physics. In mobilizing policy expertise, the policy adviser relied on their political science background and experience working with the ministerial team to process qualitative data gathered through consultations with various stakeholders.

3.3. The difference in skillsets brings challenges

The engineer and policy adviser mobilized different types of expertise and to do so possessed and used a different skillset. As the case shows, the difference in the type of information gathered and differing skillsets posed challenges when the engineer and policy adviser needed to combine technical and policy expertise to answer the policy question. The first challenge they faced was around balancing the competing ideas and interests of the various stakeholders they engaged. The second hurdle was the difficulty in internally communicating technical information caused by the lack of technical background of the policy adviser and the engineer's difficulty of explaining technical information to a non-technical audience. The third challenge was in summarizing complex model results in a convincing way for the policy board without overlooking key technical or policy information.

3.4. Overcoming challenges: enabling TE in a policy context

The challenges listed above limit TE in policy practice, they prevent the exchange of technical and socio-political knowledge between engineers and policy advisers to answer the policy question. Analyzing how the engineer and policy adviser overcame these hurdles is therefore not only valuable for the case at hand but to understand how to enable efficient TE in a policy context more broadly.

The first challenge faced was balancing the competing interests of the stakeholders engaged when collecting the expertise needed to answer the policy question. As theorized in policy literature and expressed by the engineer and policy adviser, there is no such thing as value-free technical or policy expertise [5–8]. Both engineer and policy adviser therefore critically engaged with the expertise they mobilized, comparing the different information received and in doing so created their own technical or policy knowledge. The engineer and policy adviser discussed the conclusions they reached (and how) between themselves, for example how the upper and lower bounds for the model were selected or summarized feedback from consultations with stakeholders.

By developing their own knowledge and opening up about the knowledge creation process amongst themselves, the engineer and policy adviser became experts in the eyes of each other . By critically engaging with the information they gathered, engineer and policy adviser became more than just mobilisers of technical or policy expertise but technical or policy experts in their own right [9]. The engineer considered the policy adviser as the policy expert and the policy adviser considered the engineer as the technical expert. Recognizing the expertise of each other, being aware that both gained new knowledge of the issue by critically engaging stakeholders, created mutual trust. This mutual trust is fundamental for the good exchange of technical and policy information, constituting one of the main building blocks of TE in policy practice.

The second hurdle was the difficulty in internally communicating technical expertise. Both the engineer and policy adviser admitted that this was a challenge at first, the engineer felt like their background did not prepare them to communicate well with non-technical audiences and the policy adviser felt like their background had not prepared them well to understand technical information. The modelling process however provided a forum for both to exchange their view and understanding of the policy issue [10–12], and led to the development visuals to help explain the technical limitations of the regulation change.

In developing visuals together, the engineer pointed out that the policy adviser and themselves were progressively speaking the same language, a concept known as "interactional knowledge" [13]. Interactional knowledge is the mastery of the language of a domain that enable different experts to communicate, reflect upon their subject matter and articulate their findings in a way that makes sense to their counterparts. Worth noting that, in this case, interactional knowledge was created through the development of visuals, but it can be created in other ways too, through analogies for example. The engineer and policy adviser developed interactional knowledge to be able to communicate technical information in a way that worked for both parties, allowing the effective combination of technical and policy expertise later in the policy process. The development of interactional knowledge therefore enabled successful TE in policy practice.

The third challenge faced was summarizing large amounts of complex information in a convincing way for the policy board. As the policy literature points out, "telling policy stories", creating a coherent policy narrative that leads the reader to the conclusion that the suggested policy makes sense, is how policy proposals are accepted in the UK civil service [2,5,14,15]. In line with the literature's findings, the engineer and policy adviser explained that they collaborated to create a narrative that obscured as little as possible the technical and policy expertise used to answer the policy question. The mutual trust and interactional knowledge developed during the policy process enabled TE at the final and key stage of the policy process; it allowed the engineer and policy adviser to collaborate to create a convincing policy story. The policy board followed the engineer and policy adviser's recommendation and incorporated the change in the Draft National Policy Statement for Renewable Energy Infrastructure (EN-3) published last September.

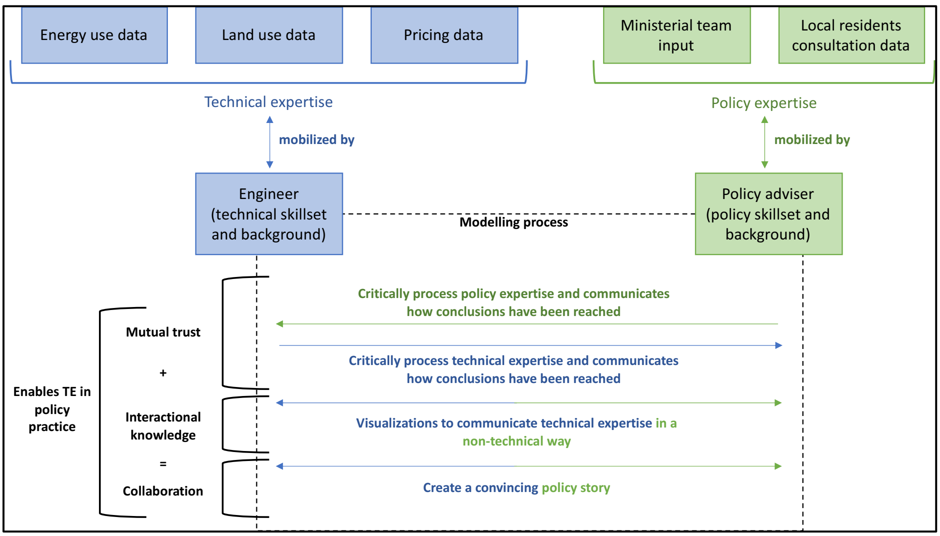

Figure 3. Enabling TE in a policy context.

4. Conclusion

Through the prism of utility-scale solar regulation change in the UK, this paper illustrates what TE means in policy practice, how engineers and policy advisers mobilize and combine technical and policy expertise to solve complex policy problems. Analyzing the strategies deployed by the engineer and policy adviser to overcome the hurdles faced in the process and manage their disciplinary differences allows us to see what enables TE in the policy context.

By critically engaging with and weighing the information provided by their stakeholders and communicating on this balancing act the engineer and policy adviser developed mutual trust. Both civil servants also developed interactional knowledge, by creating visuals together the engineer and policy adviser learned to speak the same language and communicate technical expertise. Mutual trust and interactional knowledge enabled TE throughout the policy process ending in the engineer and policy adviser collaborating to create a convincing policy story to see their recommendation go through.

These findings are useful to inform learning and development opportunities for engineers and policy advisers already involved in policy practice. Courses and workshops to learn how to critically engage with stakeholders, communicate the results of this engagement, develop interactional knowledge (through visuals or analogies for example) will improve TE in policy practice. These insights should also be incorporated into academic training for future engineers and policy advisers.

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