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Towards a Framework for Understanding Transdisciplinary Engineering in Policy Practice: Insights from the UK's Energy Ministry

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Abstract. The UK's energy ministry is an ideal site to understand transdisciplinary engineering (TE) in policy practice as effective net-zero policies require a mix of engineering and socio-political knowledge. Combining engineering expertise with other disciplinary knowledge for policy however is no easy feat and many barriers and facilitators exist at the structural, actor, and process levels. Based on two years of ethnographic data, this paper explores how the ministry's institutional set-up, experts and processes enable or hinder TE in net-zero policy practice. Using empirical examples, we explore how the ministry's policy culture and structural evolution over time influences the take-up of engineering advice in policy. We also analyse which actors within the ministry and outside collaborate and what knowledge is drawn upon. We then look at how differences in policy process influence how engineering advice is given, and how it is combined with other types of expertise. The paper ends with a framework, based on our case study, Engineering Studies, Science and Technology Studies and Expertise in Policy literature to understand TE in policy practice more broadly and its implications for experts' skills and governance structures.

Keywords. Engineering policy and practice in the public sector, Engineering advice for policy, UK government, Energy policy

Introduction

The UK's energy ministry is an ideal site to understand transdisciplinary engineering (TE) in policy practice as effective net-zero policies require a mix of engineering and socio-political knowledge[2].

This paper draws on a two-year ethnographic study of the ministry centred around its engineering advice team, uncovering the variables that impact TE in policy practice. The engineering advice team supports the ministry's various policy teams in creating energy policies, liaising with them to refine the policy question at hand and helping the policy teams gather and process the evidence needed to answer the question. Generally policy teams focus on socio-political evidence whereas the engineering team deals with more technical data. Once a policy answer has been found, the engineering team also supports the policy teams in drafting policy proposals submitted to the minister for final approval. For a more in-depth look at the UK policy making and implementation process

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[2] This echoes the ISTE definition of TE: "a holistic integration of knowledge and understanding from engineering, natural and social science disciplines and non-academic stakeholders"

please see Lioté's 2022 and Cooper's 2021 articles on the topic and Page's books on the UK civil service [1–4].

Combining engineering expertise with other socio-political knowledge in policy making however is a complex endeavour and many hurdles exist at different institutional levels. In this paper, we group these variables into three sets: structural, actor and process level variables which we explore in turn using participants' quotes. Structural level variables show how the structure and culture of the ministry impact TE in policy. Actor level factors highlight how TE in policy is shaped by what knowledge is needed and which actor is called upon. Process level variables focus on how engineering advice is given and how it is combined with other types of expertise.

These three sets of variables serve as the main components of our framework for understanding TE in policy practice. In the ensuing discussion, we link each component back to Engineering Studies, Science and Technology Studies (STS) and Expertise in Policy literature to reflect on the implications of our framework for experts' skills and knowledge coordination. We end our paper by using our framework to suggest what a TE enabling governance structure, team composition and engineering advice process could look like in policy practice.

1. Methodology

The following results are based on ethnographic data collected in the UK's energy ministry from 2021 to 2023, this included participant observation, 28 semi-structured interviews, 2 workshops and document analysis. My research has been focused on the ministry's engineering advice team tasked with suppling technical information on energy-related issues to policy teams within the ministry. Interviews have been carried with the engineers working in the ministry (abbreviated: eng), their policy counterparts (abbreviated: pol) and senior civil servants overseeing the ministry's engineering team in post and retired (abbreviated: sen). All the data was added to NVivo and thematically analysed, initially following Charmaz's grounded theory framework [5], and subsequently using Braun and Clarke's guidance [6]. The work shown here is a small subset of my PhD titled 'How is engineering advice deployed in energy policy practice? An ethnographic look at the UK's energy ministry' and supported by a UK Engineering and Physical Sciences Research Council grant (EPSRC Grant #2264956).

Before we move on to the results, a few caveats should be added. The results presented here are geographically bound and based on a specific institutional set-up. The research is focused on an intra-ministerial engineering advice team in a specific UK ministry and therefore only reflects a limited range of reality. We are not claiming that the framework presented below is universal however we still hope it can shed some light on how TE unfolds in policy practice. In the future, we aim to expand our research beyond the UK's energy ministry to grow and refine our framework.

2. Results

2.1. Structural Level Variables

The first set of variables that affect the combination of engineering and socio-political knowledge in policy practice can be labelled as structural, meaning they are linked to the

structure and culture of the ministry. The policy culture of the ministry, which is very similar across the whole UK civil service, sees policy advisers change teams frequently to further their career.

*"There's **a cultural thing** that if you come into a policy profession, **you need to move around** to get as broad experience as possible and **become a better generalist, that's what gets you promoted**." – Sen*

However, this logic of changing teams to hone policy skills in different topical areas and become a better generalist does not apply to the engineers working in the ministry.

*"The **turnover** in **policy** teams is probably about **18 months**. The turnover **in [the engineering team]** is probably more like **4 years**. We can typically accommodate one career progression for most people." – Sen*

*"The thing about bringing technical people in is you're bringing them in because of their expertise. **There isn't lots of other places in the civil service for [the engineers] to go**, there's not multiple versions of [the energy engineering advice team]. **So they do tend to stay longer.**" - Sen*

The high turnover in policy teams and lower churn rate in the engineering team impacts TE in policy practice in two connected ways. First, incoming policy advisers often do not have the tacit knowledge or corporate memory that their predecessors built over time. This generally means that the engineers, who stay in their role for longer, have to bring their policy counterpart up to speed on some details of the policy area and process, slowing down collaboration. Secondly, and linked to the previous point, by virtue of staying in their role for longer, engineers can become the knowledge holders in that policy area. This might create unfavourable power dynamics where the balance tilts too much in favour of the engineer, leading to friction in the engineer-policy adviser collaboration process.

*"We often **end up re-telling policy people the same thing because the last people we told it to have moved on**. And so, it's quite **hard to get continuity of policy**." – Eng*

*"If [engineer] constantly has someone in my policy role that hasn't been there for more than 18 months [they're] the one keeping it together. **[They've] got the institutional knowledge of what the thought processes were when designing the original policy**. It also means from a policy perspective that **its more complicated to negotiate because they know a lot more**." - Pol*

In addition to policy culture, the historical evolution of the ministry has impacted its engineering capacity and by extension engineering-policy collaboration. Going back to 2008, the energy ministry's remit of the time was to 'establish the UK as a world-leader in the fight against climate change'[3] and, to achieve this vision, the engineering advice team was created. The engineering advice team however was set-up support policy teams, creating a dynamic where the policy teams drive the policy, the engineers are not dictating what should be done, which can be a source of frustration.

[3] Department for Energy and Climate Change Annual Report and Resource Accounts 2008-09

> *"Back in the day, [the ministry's] vision was to 'make the world green' and* ***given the technical nature of the issue they formed a small team of engineers*** *to advise the ministers on what's sensible and what isn't. It was a team to support the policy work, so what they do is driven by the policy teams, it is not driven by the engineers.* ***[The engineers] are doing what they're asked to do, they're not saying what should be done.*** *" – Sen*

The engineering advice team's remit and aim also evolved overtime as a response to policy failure. Dating back to reforms of the 1970s and 80s the UK civil service has limited internal engineering capacity, outsourcing a lot of engineering research and work to arms-length bodies and private firms (as is still the case today). This became a serious issue for the energy ministry in the 2010s when a commissioned energy model contained engineering errors that no one picked up on in the ministry, due to a lack of internal engineering capacity. From then on, the engineering advice team's aim also includes acting as an 'intelligent customer', helping policy team phrase and understand outsourced engineering work.

> *"When you look back, you'll find that* ***outsourcing of engineering work*** *that became very fashionable in the* ***late 70s and early 80s*** *because that* ***enabled the politicians to slim down the administration and put a barrier between themselves and the instantiation where things might go wrong.*** *" – Sen*

> *"It was a* ***technical mistake in modelling*** *which led to a review of business-critical models.* ***Anyone who had any real-world experience*** *in building solar PV projects, when they looked at the modelling,* ***knew it couldn't be right,*** *but we didn't have enough of those in the department. So, the* ***aim of the engineering advice team*** *also* ***became making sure that this didn't happen again.*** *" – Sen*

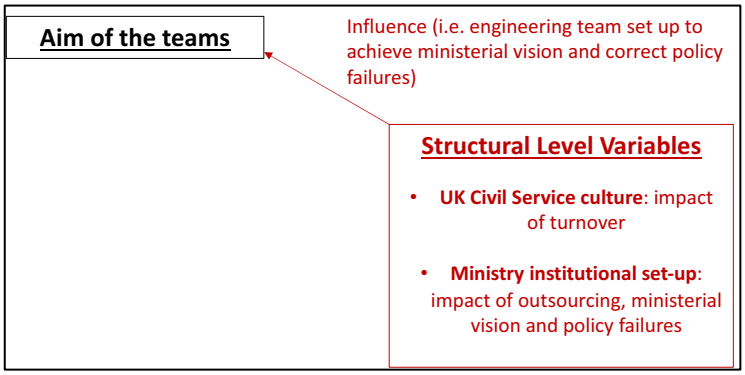

Figure 1. Structural level variables for TE in policy practice

2.2. Actor Level Variables

The second set of factors that impact engineer-policy adviser collaboration can be found at actor level, meaning TE in policy practice is shaped by what knowledge is needed and which actor is called upon. As we established, political vision and policy priorities tend

to define the aim of the different teams within the ministry. The aim of the team in turns define what knowledge is needed within that team (for it to achieve its aim) which then defines what type of professional profiles should make up that team.

In the case of the engineering advice team, the aim is to 'supply technical information on energy-related issues to policy teams within the ministry'. It therefore makes sense that the team is mostly made up of what I call 'generalist engineers', engineers that can provide advice on the multiple policy areas covered by the ministry.

> *"**We are quite adaptable**. Because it is small team, we need to be able to **move into other areas more quickly**. So, if we need to work on floating offshore wind or something I might have to put four people on it and create a sub-team quickly to answer immediate questions. **The barriers are actually quite fluid**." – Eng*

> *"I tend to recruit if I can PhD students when they finish university, that sort of **background where you're taught to learn quite quickly**." Eng*

Policy teams in the ministry are quite different, their aim is to create policy, to seek information from several sources to create policy proposals. The policy teams are composed of policy advisers with generalist backgrounds, namely humanities, political and social sciences with professional policy experience. Given the ministry deals with energy policy questions which are socio-technical in nature, it is seen as a plus if a policy adviser has an engineering or scientific background. This is particularly helpful when interacting with technical actors in and out of the ministry.

> *"**[Policy advisers]** expect to be briefed on what's required, to **seek advice from several sources and to make a decision.** So, it's **rather like a judge in a trial**. They don't expect to become experts in whatever the subject of the trial cases." - Sen*

> *"The **role is generalist** in that you're looking at planning law, tax law, then you're looking at business development type work. I think **if you had an engineering background it would definitely be an asset though.** It would be valued and **add to your credibility**." – Pol*

As with most TE problems, the expertise needed to create energy policy is extremely distributed and both engineers and policy advisers have to coordinate and balance a network of experts including industry, academia, regulators and arms-length bodies to name a few. Due to space constraints, we will not expand on this here as more quotes and examples have been given in a 2022 article by Lioté [1]. However, in addition to points already made, it must be noted that due to civil service budget constraints the engineering advice team remains small, therefore a lot of engineering work is outsourced. This adds actors (external consultants) to the engineering advice process.

> *"Anything which has to do with **things we cover internally they get from us**. **We're only a team of 10 engineers so we don't have the capacity to do everything**, a six-month study on something is going to be 5% my capability so I don't do that. But **we also run a number of what we call frameworks which enables external consultancies to bid for work."** – Eng*

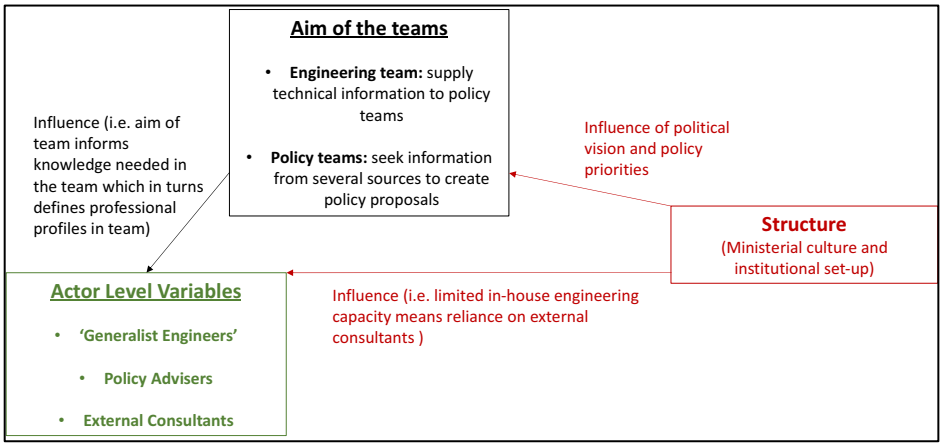

Figure 2. Actor level variables for TE in policy practice

2.3. Process Level Variables

The final set of variables that impact TE in policy can be found at process level, meaning the difference in policy process influence how engineering advice is given and how it is combined with other types of expertise. Focusing on the engineering advice and policy teams, we can identify a difference in policy process, dependent on in-house engineering capacity, that modulates advice activities. As we discussed earlier, the policy teams are driving the policies so both processes start with a policy question, asked by the policy teams to the engineers.

If there is enough engineering capacity within the engineering advice team, the advice stays 'in-house'. This process type is described in depth in Lioté's article [1] and consists of three steps: an initial conversation where the information required to answer the policy question is clarified, a research phase where the engineer and the policy adviser gather information and communicate internally, and a communication phase where a narrative is generated to summarise the final results. Again, due to space constraints we will refer the reader to the original article for a discussion on the challenges and opportunities this presents for TE in policy practice.

If there is not enough in-house engineering capacity however, which is quite frequent as we mentioned above, some of the engineering work is outsourced. In this configuration the engineers' role change slightly and instead of providing direct advice to the policy teams they work with them and the external consultant to prepare the bid, oversee the research and translate the results back for the policy teams. Once the outsourced research is done, the engineers and policy teams still collaborate to create a coherent narrative to communicate the final results to the ministers. As long as the outsourcing process works, it creates a positive feedback loop for the ministry that see this process as a successful way to provide engineering advice.

> *"**When research is commissioned**, you [**engineer**] **will** be helping with the **design of the requirements**, then you'll **review the bids**. And then finishing the work itself which would involve kind of **agreeing exactly what they [consultants] are going to do and then checking up on their progress** and that's where **the intelligent customer** idea comes in.*

*You're going to be **interpreting the results they're generating for the policy units and asking the right questions** and so on." – Eng*

*"**Outsourcing has been internalized by the organisation completely**, and if it looks like it's working there **is limited incentive to change it up**" – Sen*

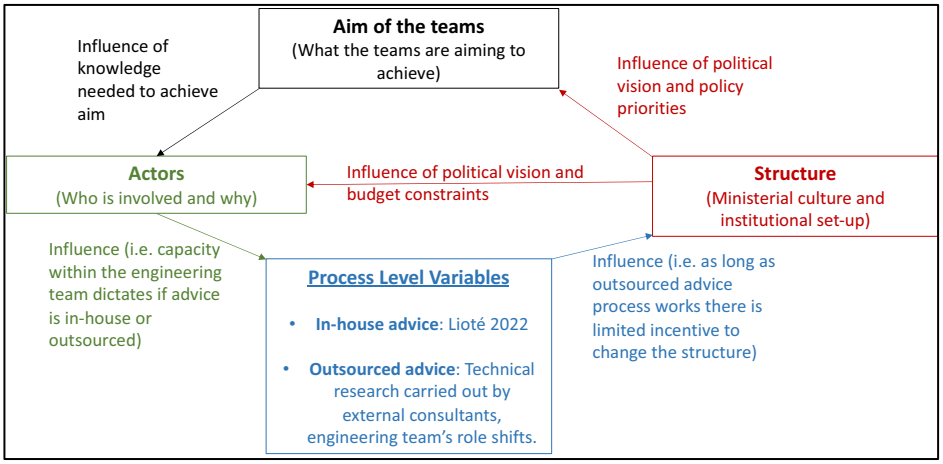

Figure 3. Process level variables for TE in policy practice

3. Discussion

Our results section clearly highlights three main components of TE in policy practice (structure, actors and process) and the link between them all, with team aim acting as a joint between structure and actors. Our framework for understanding TE in policy can be summarised as such:

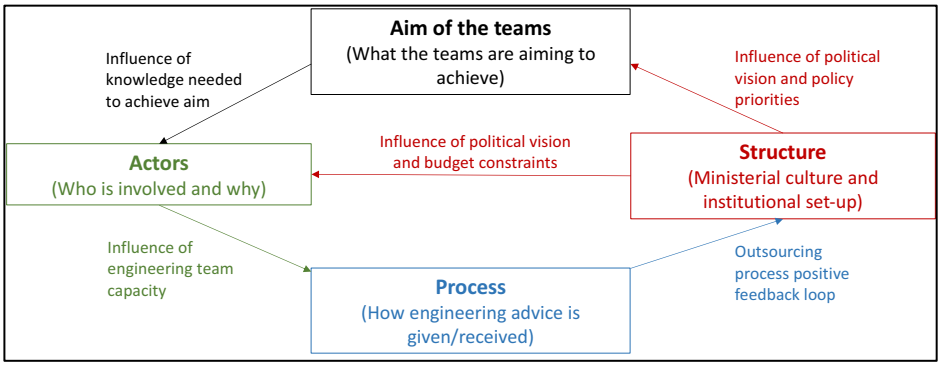

Figure 4. Framework for understanding TE in policy practice

In the following discussion, we link each component of the framework back to Engineering Studies, Science and Technology Studies (STS) and Expertise in Policy academic literature to reflect on what a TE enabling governance structure, team composition and process look like in policy practice.

3.1. TE Enabling Governance Structure

Our results suggest that turnover in policy teams is an issue for TE in policy. The churn is linked to a loss of corporate memory and tacit knowledge and impacts the balance power between engineers and policy advisers. This point has been made by scholars looking at UK policy making who note that policy advisers are incentivized to remain generalists if they want to progress their career, creating knowledge retention issue across the Civil Service [7,8]. This become even more of an issue in engineering-informed policy areas where engineers who stay in their role for longer become de facto knowledge holder in that area, limiting the ability of the policy adviser to negotiate with the engineer, a key component of the policy process [8,9].

A governance structure that enables a balanced combination of engineering and socio-political insights in policy should therefore include well aligned incentives and strong knowledge retention mechanisms. This includes encouraging slower turnover of policy teams where possible, keeping a decision paper-trail and reports into a dedicated and easily accessible database and having big enough teams to retain tacit knowledge during staff transitions (if a few people are replaced within the policy team, the rest of the team can bring them up to speed).

Our results also show that the engineering team is set-up to support policy teams once the policy direction has been set but are not as involved in setting those directions. Many STS scholars and the author of this paper however have pointed out that, by limiting the involvement of technical experts in policy direction setting, public administrations often limited the policy options available to them down the line [10–13]. A governance structure that best enables TE should therefore aim to have engineers present when the policy course of action is debated and selected.

3.2. TE Enabling Team Composition

In the UK's energy ministry, the aim of the engineering advice team is to supply technical information to policy teams within the ministry. We pointed out that it therefore makes sense to hire 'generalist engineers', engineers that are adaptable and quick-learners to provide advice on the multiple policy areas covered by the ministry. This has also been pointed out in the academic literature by prominent STS scholars who have argue that "over-specialization is a disadvantage for the [technical expert in policy], who must be able to interact with [advisers] in fields that are quite peripheral to their own" [14: p.94, echoed in 15 and 16].

Policy teams are set-up differently, they aim to balance several sources of information to draft policy proposals. As mentioned, the policy teams are composed of advisers with generalist backgrounds who see their role as a balancing act between a technical solution and the politics of the situation, for example the political viability of a technical option [2,16,17]. With that said, given energy is a socio-technical policy area, a policy adviser with a technical background is seen as an asset. This enables the adviser to more easily speak the 'language of the engineers', facilitating the interface between the engineering and the policy team [18].

The team compositions that seem to best enable TE in policy practice are therefore an engineering advice teams with generalist engineers working with policy teams partly made up of technical policy advisers. McCarthy also points out that a 'systems architect' role should be added at a more structural level to "see where communication could break down, and where and why divergent expectations emerge" between engineers and policy

advisers [18: p.147]. These team compositions have two broader implications for education and policy governance. Generalist engineers can be hard to find as engineering training is often quite specialized [19] however new engineering education programmes are being developed to create more of these profile-types. Additionally, public administrations might push-back against hiring more engineers (as engineers or as policy advisers) as this might be quite expensive, especially if they have to compete with private sector salaries where most engineers work [20].

3.3. TE Enabling Policy Processes

We have identified a difference in policy process for engineering advice, if there is enough internal capacity the advice stays 'in-house', if not some of the research is outsourced. Best practices for 'in-house' engineering advice and their implications for TE in policy practice have been discussed at length in Lioté's article [1] and, for brevity, we won't discuss them here again.

Instead, we turn our attention to the second process type for engineering advice: outsourcing. Since the 1970s, the UK Civil Service has progressively reduced its in-house engineering capacity (for reasons beyond the scope of this paper), frequently relying instead on commissioned engineering research instead [8,21]. However, even if the engineering research is outsourced to external consultants, in-house engineers have an important role to play in the advice process. When the research is outsourced, the engineering team act as a 'broker' between the private engineering consultant and the policy teams. Meaning they help prepare the bid, oversee the research and translate the results back for the policy teams, or in Gluckman's words: "translate the different languages of the two communities and align information needs with outputs" [22: p.2].

Just like with in-house advice, when the research is outsourced the engineering team is involved in translating engineering outputs into policy language [1,9]. In doing that, the engineers are recombining explicit knowledge – a technical report – with tacit knowledge – what is of interest to the policy advisers in this situation [23]. This blending of explicit and tacit knowledge means that the engineers become more that just 'mobilisers of expertise' but experts in their own right [1,24].

An outsourced engineering advice process that enables TE in policy practice therefore still needs in-house engineering capacity. Instead of mobilising a network of experts and carry the research internally the engineering team will act as 'intelligent customers', bridging the interface between consultants and policy teams. This point bring us back to our conversations about structure and actors, for the outsourced process to function administrations still need to invest in their in-house engineering capacity and favour generalist engineers – adaptable engineers with good communication skills.

4. Conclusion

Drawing on ethnographic evidence from the UK's energy ministry, this paper identifies three main components of TE in policy and the relationships between them. This enables us to start drafting a framework for understanding TE in policy practice that takes into account institutional structure, policy actor and process. By linking each of the three components with relevant academic literature we have been able to explore what a TE enabling governance structure, team composition and process looks like in policy. This paper highlights the importance of well-aligned incentive structures and knowledge

retention mechanisms to support the combination of engineering and socio-political insights in policy making. Public administrations should aim to hire generalist engineers and policy advisers with technical backgrounds to facilitate the exchange of socio-technical information necessary to create energy policies. Finally, even if some engineering research is 'outsourced', governments should invest in their in their in-house engineering capacity to remain 'intelligent customers' in engineering advisory markets. We hope that the framework we have drafted can help understand TE in policy better and can be expanded and refined as data beyond the UK's energy ministry is collected.

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