



Original research article

Tackling transformational change in climate policy appraisal: experiences and perceptions of United Kingdom policy analysts

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ABSTRACT

Progress in implementing climate policy in the United Kingdom consistent with the country's target to achieve net zero emissions by 2050 has been modest. This is despite the well-established physical risks of climate change, the UK's broadly accepted intention to act decisively, and the international recognition of the need for transformational climate action. Previous research suggests that the practical and theoretical limitations of existing decision-making frameworks and the accompanying economic tools may hinder transforming objectives into action. We explore how practitioners perceive the current assessment of transformational climate policies in the UK, drawing on interviews with government analysts from multiple departments. We identify various challenges including a status-quo bias and inadequate treatment of innovation and uncertainty that the recommended decision-making framework creates when applied to transformational climate policy proposals. Practitioners believed that new decision-making frameworks are needed to improve the assessment of transformational policies. These frameworks should support evidence-based decision-making in areas of deep uncertainty to enable government to avoid pessimism and status-quo biases. Frameworks should also find the balance between a detailed representation of transformational change and communicability to decision-makers to be effective. More economic modelling tools that view the economy as a dynamic system are also needed to provide decision-makers with more robust evidence on transformational change.

1. Introduction

Marginal¹ transformation of the UK's economy will be inadequate to achieve the goal of net zero emissions by 2050, as mandated by the amended Climate Change Act [1,2]. Such is the dependence on fossil fuels that entire parts of the economy need to change [3]. For some sectors, this means deep decarbonisation and retrofits while others could cease to exist entirely [4]. At the same time, new sectors will appear, and others will see rapid growth [5]. In short, effective mitigation of climate change will require wide-scale structural change in the economy [6].

A level of recognition of the need for action on climate change exists globally, with an increasing number of countries, provinces, and cities

developing climate action plans and adopting net zero emissions targets [7]. Yet globally, climate action lags far behind the pace of change implied by these targets [8,9]. Since 1990, the UK has reduced greenhouse gas emissions by almost 53 % [10], placing it among the fastest decarbonising major economies. However, it is not on track to meet its 2030 nationally determined contribution, with only one-third of emissions reductions required covered by current credible plans [1].

It is increasingly recognised that policy to support 'transformational change' is necessary to meet climate goals [11–13]. The use of the 'transformational' framing in the academic literature on climate change mitigation is increasingly common [14,15] and is widespread in IPCC reports [2] as well as in the Sustainable Development Goals [16]. The

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¹ We interpret 'marginal change' as change that is *slow* and *incremental* as opposed to *significant* and *revolutionary*.

term is defined in different ways and can be interpreted to mean profound shifts in economic relationships [12,17], culture [18–20], governance structures [21], and markets [22]. Transformational change could also result from a combination of policies that, individually, might appear to have only marginal effects [12]. In this paper, we interpret transformational change in a broad sense as a fundamental and sustained shift in how a system operates, altering its core structures and dynamics.

Proposed reasons for a lack of transformational climate action are wide-ranging and include the influence of fossil fuel lobbyists [23], poor access to climate finance for mitigation and adaptation projects (particularly in the Global South) [24,25], and the possible uneven impacts of climate policies [26]. A key but understudied potential cause could be that structural issues and biases in the policy analysis frameworks used by governments to weigh up different policy options hinder effective decision-making [12,27–29].

The question of how decision-makers use limited public funds to support decarbonisation objectives is crucial to climate change mitigation efforts. Ex-ante policy appraisal (the assessment of the potential outcomes of a policy *pre*-implementation) is a key component of the policy design process in many countries, as it provides and contrasts different types of evidence to inform decisions [30]. The degree to which policy appraisal influences decisions is debated but it can be a useful tool for decision-makers [31,32], enhancing accountability [33,34], making public investments more cost-efficient [35], and estimating the social and environmental consequences of policies, whether intended or otherwise [36].

Several countries, including the UK [17], the US [37], Brazil, and India [29], base their ex-ante policy appraisal systems on cost-benefit analysis (CBA). CBA is a well-established public policy decision-making framework based on welfare economics that quantifies the potential costs and benefits of a policy option in monetary terms. It is viewed by practitioners and academics alike as a robust framework [38] that promotes transparency and the efficient allocation of public resources [39].

As a form of marginal analysis, CBA is well-suited for the majority of government policy decisions that are likely to induce small or incremental change. However, academic literature has suggested that the framework is ill-equipped to appraise policies where the aim or expectation is transformational change [12,27,28,40]. Specifically, Grubb et al. [12] identify three main areas where transformational change contradicts the main principles of CBA: *deep uncertainty* – where numbers cannot be placed on key parameters or outcomes; *heterogeneity* – where a set of actors with diverse interests and concerns are subjected to radical changes; and *irreversible change* – a permanent change to a system, which can involve the activation of tipping points.

Another key challenge of CBA relates to an intrinsic status-quo bias. While policy-related costs tend to be straightforward to establish with good degrees of certainty, the benefits, which pertain to assets or outcomes that are proposed and do not yet exist, tend to be more uncertain and more difficult to quantify. In cases of transformational change, a system may become qualitatively different, making comparisons against the counterfactual case ambiguous. When benefits are unquantifiable or ambiguous, they risk being excluded from CBA, creating a bias towards marginal interventions with quantifiable (but potentially lower) benefits [28,41,42]. Given the well-established need for large economic transformation to tackle climate change, it may be necessary to update or augment CBA with a framework able to handle or embrace the uncertainties generated by transformational change [12].

Alternative decision-making frameworks for transformational change are scarce [43]. Cost-effectiveness analysis (CEA) and multi-criteria decision analysis (MCDA) are two frameworks often used by governments, either alongside or instead of CBA [43,44], but neither is specifically designed to tackle the challenges of transformational change. Mercure et al. [28] propose ‘Risk-opportunity analysis’ (ROA), a novel complexity-science-based framework to support decision-making

for transformational change in the low carbon transition. ROA is a ‘generalisation’ of CBA in the sense that it attempts to capture a similar understanding of policy impact, but in a way which allows for policies to have uncertain, ambiguous, and potentially even extreme-valued risks in their impacts. It advocates for assessing not only how policy transforms a system, but also understanding the resilience of those outcomes, and how they create potential for opportunities [28] (see Sharpe et al. [42] for a detailed description of the key differences between CBA and ROA). The development of ROA is still in its infancy and, for the most part, the framework has only been applied to historical (e.g., offshore wind in the UK) or hypothetical future cases (e.g., accelerating the diffusion of electric vehicles) [12,28].

Despite the rich literature on the theoretical challenges of applying CBA to climate and energy policy, there is a lack of studies investigating how these challenges are perceived and encountered by practitioners and whether new decision-making frameworks are needed to enable more effective decision-making on climate action. We aim to address this research gap, using interviews with government analysts to understand how they perceive the appraisal of transformational climate policy in the UK. The UK government is considered to have well-established and world-leading guidance on policy appraisal and has heavily influenced appraisal processes in other countries [29,45] making it an instructive case study. We reflect on the relevance of our findings for a global audience.

The aims of this study are fourfold: 1) to understand how transformative policies are currently assessed in the UK; 2) to investigate how government analysts perceive the use of current frameworks applied to climate policies; 3) to establish whether analysts believe alternative decision-making frameworks can help provide decision-makers with better evidence on transformational change; and 4) to identify potential barriers to the adoption of new frameworks. The rest of this paper is structured as follows: Section 2 provides a brief description of the policy appraisal landscape in the UK as described by the Green Book guidance. Section 3 outlines our methodological approach. Section 4 identifies key findings from the interviews with government analysts. Finally, Section 5 analyses these findings with respect to how scientific evidence can provide better support to decision-makers in light of transformative change.

2. Policy appraisal in the UK

This section provides an overview of policy development in the UK and the role that appraisal plays in this process. We outline how policy appraisal in the UK should be carried out according to official guidance and we explore how actual practice varies in Section 4.

2.1. The role of appraisal in policy development

In the UK, appraisal forms an important part of the broader policy development process, providing an evidence base for decision-making and to ensure effective and efficient use of public resources. Fig. 1 shows the ROAMEF (rationale, objectives, appraisal, monitoring, evaluation, and feedback) cycle used to conceptualise policy development across UK government. In the real world, policy development is more complex and iterative than the ROAMEF cycle suggests, but it can be a useful thinking tool to clarify the key stages of the process. Establishing the rationale for action involves identifying the problem the government is trying to solve. This part of the cycle is inherently political as ministerial priorities shape which issues receive attention. Next, the strategic objectives are determined. Objectives must be specific, measurable, achievable, realistic, and time-limited (SMART).

In the UK, ex-ante policy appraisal is the responsibility of government analysts who are tasked with providing government ministers with objective evidence to support decisions. UK government analysts are non-partisan and their positions are not tied to administrations in power. As such, policy appraisal in the UK is primarily a technocratic exercise,

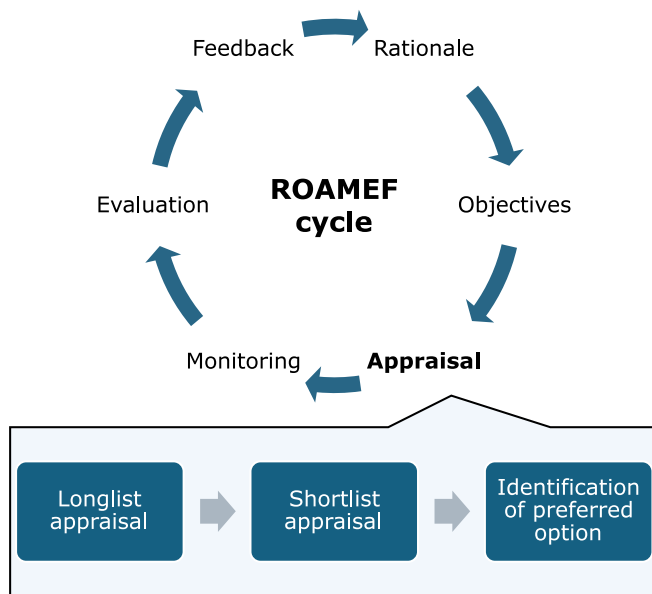


Fig. 1. The ROAMEF policy development cycle with a description of the key steps at the appraisal stage. Adapted from the Green Book [17]. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

although the choice of method, evidence, and other assumptions involve value judgements. Notably, the political context can shape the policy development through specific strategies or objectives (e.g., pursuit of net-zero targets, the ‘levelling-up’ program). While it is not the responsibility of government analysts to directly engage with pressure groups or industry incumbents, these actors can shape the broader policy landscape by influencing government priorities and objectives, which analysts must work within.

Following the appraisal process and implementation of spending proposals or legislation, outcomes are monitored against the pre-defined objectives. This serves to assess whether the intervention is working as intended. The evaluation process is covered by its own guidance – the Magenta Book [46] – which defines two main purposes for evaluation: learning and accountability. This aims to inform the design of interventions in the future.

2.2. The Green Book guidance for options appraisal

Standardised guidance on how the appraisal of policy options should be performed across government is provided by the ‘Green Book’ [17]. This covers both the spending control process (for spending proposals) and the regulatory control process (for legislation and regulation) through business cases and regulatory impact assessments respectively. The Treasury’s five case model is important to both, described as a “universal thinking framework” to consider the use of public resources from a strategic, economic, commercial, financial, and management perspective [17]. Some departments also have their own guidance that interprets the Green Book for use in specific contexts (e.g., Transport Appraisal Guidance (TAG) in the Department for Transport).

At the appraisal stage, analysts first longlist potential options according to the objectives. This involves an initial estimation of the potential costs and benefits of a wide number of options. Options that best meet the objectives are shortlisted and a more thorough analysis to quantify the lifetime costs and benefits is undertaken. At this stage, the Green Book explicitly requires the use of either CBA or CEA. The latter is a derivative method of CBA and involves comparing the relative cost of different options to produce the same outcome [17]. For example, where a policy aims to reduce emissions, options could be assessed and compared according to the cost per tonne of emissions avoided. The

Green Book specifies that it should be chosen for policy options where the costs and benefits will remain broadly unchanged or when the output is difficult to quantify [17]. MCDA must not be used as a substitute for CBA at the shortlist stage but can be used at the longlist stage.

Throughout the policy development process, several forms of analysis are used aside from CBA including a range of modelling approaches [47] and several systems thinking tools including systems mapping and theory of change maps [48]. The Green Book also provides several techniques for considering non-market values including revealed preference, willingness to pay, and subjective well-being techniques. It also features a set of standardised valuations of environmental values that include the damage cost of pollutants, land value uplift, and the cost of greenhouse gas emissions. Where it is not possible to assign a monetary value to certain impacts, their assessment can be communicated qualitatively alongside the quantitative outputs of the CBA or CEA. The Green Book provides specific instructions for how to adjust for optimism bias. This reflects the tendency for analysts to be too optimistic when calculating the costs and benefits of options. Distributional impacts should also be considered where relevant.

The two key quantitative outputs of the appraisal are the net present value (NPV); the total time-discounted benefits minus costs over the option lifetime, and the benefit-cost ratio (BCR); the NPV divided by the implementation costs. Discounting is used to enable comparisons between the costs and benefits of proposals, even when they are not incurred simultaneously. Based on these factors and the unmonetisable impacts, analysts determine the best option for the delivery of public value. This is referred to as the ‘preferred option’ which acts as a recommendation to the decision-maker. A sensitivity analysis must be undertaken on at least the preferred option. In its most basic form, this information is communicated to the decision-maker in an appraisal summary table along with an executive summary.

2.2.1. The 2020 Green Book review

The Green Book last received a major update in 2020 with a minor ‘maintenance’ update in March 2022. The impetus behind the 2020 update was an internal review and consultation that aimed to address concerns that the guidance was biased against less wealthy parts of the country [49] and inhibited the current government’s strategy to “level up” such areas [41]. It also aimed to revise guidance around the estimation of environmental impacts. The review found that, under previous versions of the Green Book, appraisals were often not considered within their wider strategic context, meaning the preferred option was sometimes selected based on the BCR alone and was therefore not always aligned with the strategic objectives of decision-makers [41]. According to the review, an overreliance on the BCR risked ignoring difficult-to-monetise costs and benefits even where strong evidence was available, inadequate consideration of distributional issues, and misrepresenting the uncertainty of costs and benefits [41].

As a result of the review, an annex was added to the Green Book which acknowledges a distinction between transformational and non-transformational proposals. This annex defines transformational change as “a radical permanent qualitative change in the subject being transformed, so that the subject when transformed has very different properties and behaves or operates in a different way” [17]. Together with other updates, the annex aims to emphasise that appraising the value for money of proposals requires more than just the BCR. In the case of policies to support the government’s net zero target, this means first assessing how they contribute to the target and not only how they provide value for money [41]. This annex now suggests that where proposals have likely transformational outcomes, alternative methodologies for appraisal may be justified although no specific methods are recommended.

3. Method

We used semi-structured interviews with government analysts from

the UK government to explore: i) how analysts believe climate and energy policies are currently assessed, ii) how analysts perceive such methods and broader current practice, iii) whether new frameworks could improve insights on transformation policy, and iv) analysts' views on the potential barriers to adoption of new decision-making frameworks.

The study formed part of the Economics of Energy Innovation and System Transition project (EEIST)² in collaboration with the UK's Department for Energy Security and Net Zero (DESNZ). This project aimed to improve the tools available to decision-makers to support public policy on climate change. This included decision-making frameworks as well as computational models. Interviewees were identified by contacts in DESNZ made through the EEIST project. They provided contact details of government analysts from different departments who worked directly on appraisal. While this allowed us to easily reach some senior analysts and led to a very high interview acceptance rate (93 %), this approach was non-random and potentially created a selection bias.

A total of 15 government analysts from DESNZ³ (10), the Department for Transport (DfT) (3), and the Treasury (2) were invited to interview, of whom 14 accepted. This included several analysts who were members of the Senior Civil Service. At the time of the interviews, BEIS was the government department responsible for energy and climate policy. DESNZ has since assumed these responsibilities. The DfT has a more specific remit to decarbonise the transport sector in England while the Treasury's role of maintaining the Green Book and overseeing public spending also makes them an important stakeholder in the development of the UK's climate policy. The number of analysts interviewed was small compared with the size of government departments. The interviews provide insights into a sample of experiences and perceptions, rather than the views of entire departments, and should be interpreted accordingly.

13 interviews⁴ were conducted online through Microsoft Teams between November 2021 and February 2022 by a single researcher. Interviews were recorded and transcribed with respondents' agreement on the condition of anonymity. Since the interviews, the Green Book received a minor maintenance update in March 2022. The changes relevant to this study include minor changes to the guidance on environmental valuation and NPV and BCR construction. These changes do not represent a significant shift away from the guidance at the time of the interviews. The interview duration was between 45 and 60 min and was structured in four parts: 1) the use of the Green Book; 2) CBA and climate policy; 3) other methods; and 4) new tools for transformational change. While broader forms of analysis are used at different points in the appraisal process (e.g., MCDA and systems thinking tools), the use of CBA was the core interest of the interviews. The primary subject of the interviews was the appraisal of climate and energy policy specifically but many of the themes covered were also relevant to policy appraisal more broadly (e.g., the use of the Green Book guidance, the 'levelling up' agenda, transformational investment).

In advance of the interview, respondents were sent a participant information form detailing the aims of the study and a link to an EEIST project report [12] outlining the risk opportunity analysis framework for decision-making. In the interview, respondents were asked about the viability of such a framework for use in the UK government. Interview data were analysed through qualitative data coding using the NVivo 14 data analysis software. We provide the codes used in the analysis in Supplementary Material Fig. S1.

² See <https://eeist.co.uk/about/>

³ DESNZ was formed in February 2023, assuming responsibility for climate and energy policy after the Department for Business, Energy and Industrial Strategy (BEIS) was dissolved.

⁴ One interview was a double interview with two analysts interviewed simultaneously. 14 analysts were interviewed in total.

4. Findings

We begin this section by identifying how climate and energy policies are appraised in practice according to the experiences of respondents (Section 4.1). We describe how the Green Book is applied, and which decision-making frameworks are the most prevalent in practice to assess transformational policy. Then, we outline how respondents view this current practice (Section 4.2) before exploring their views on new frameworks to support transformational change (Section 4.3).

4.1. Climate policy appraisal in the UK – current practice

4.1.1. The role of the Green Book

Because the Green Book provides appraisal guidance for the whole government, it is viewed by respondents as a high-level framework without specific rules for individual situations. This allows analysts a certain degree of flexibility to interpret the guidance as they see fit, providing the general principles are adhered to. One respondent referred to the Green Book as '*an anchor*', with '*quite a bit of room for interpretation within the rules*' (I7). On the whole, respondents regarded the flexibility offered by the Green Book as useful, enabling them to adapt their analytical approach where needed, often in response to the availability of data. Respondents believed that the government was very good at complying with the general principles and spirit of the Green Book.

4.1.2. Using CBA

In line with the Green Book guidance and consistent with many other countries [29], respondents identified cost-benefit analysis as the most prevalent framework for both general policy appraisal and the appraisal of climate and energy policies. In practice, how CBA is applied can vary, depending on the focus of the appraisal, the availability of data, and the department conducting the appraisal.

Respondents described that, even where the potential costs and benefits of a policy are uncertain and/or difficult to estimate quantitatively, analysts will usually try to find a numerical value. One respondent remarked that '*for most non-market things that you would want to factor into an appraisal, we usually find a way to put some kind of value on it quantitatively, even if it's quite uncertain*' (I7). This approach means that decision-makers, at least in theory, can still directly compare policy options through the BCR or NPV. This, however, does not reflect the fact that particular elements of the CBA output could be more or less certain than others.

Respondents reported that more uncertain and difficult-to-quantify factors are usually included in a qualitative addendum to the monetised output of the CBA. The qualitative description of unmonetisable factors is specified as a step in the shortlist appraisal process in the Green Book, but this was considered relatively unstructured. One respondent remarked that '*where the CBA doesn't capture it [certain factors], it all suddenly goes incredibly informal*' (I7). While this approach might avoid placing highly uncertain values on certain factors, it can make directly comparing policy options difficult.

Multiple BCRs can be used for policy options with important impacts that are difficult to monetise or highly uncertain. This approach is recommended by the Green Book in such circumstances. This also includes 'switching values', a form of sensitivity analysis, to explore how different assumptions for uncertain factors can affect the overall BCR. As one respondent explains, '*We'll often look at a BCR calculation in a kind of plain way, but also then one that's got those extra and slightly more uncertain modelling elements included in it. So, you can see both and see what difference that makes*' (I11). This approach appeared to be fairly prevalent and was used by analysts in both DESNZ and the DfT. The same respondent explained that this practice was more for the analysts to explore different assumptions rather than for decision-makers, stating that '*we [analysts] look at scenarios, but we still typically present one BCR [to decision-makers]*' (I11).

Finally, it was highlighted that the BCR or NPV, while important,

does not always determine the preferred option, and other considerations can be given more weight. One respondent used the example of legally binding targets that might require the government to choose a policy option with a negative NPV, *“technically something can be negative NPV, but if you’ve signed up to a particular target or a particular kind of legal requirement... that might still be better than the other options for doing it, given that you’ve agreed to sign up for that target”* (I14). This action was described as *‘a little bit dangerous’* by one analyst who went on to say that *“It opens up the door to, ‘well, we can just ignore what the appraisal says’”* (I7).

4.1.3. The value for money category approach

Using multiple BCRs can be used to determine the Value for Money (VfM) category of a policy option. The Department for Transport employs this VfM category approach, where analysts assess which of the six categories, ranging from very high to very poor value for money, an option falls into [50]. The BCR is central to this, but the category can be shifted up or down according to subjective judgement based on unmonetisable factors, uncertainty, and potential biases [51]. One respondent explains this further, saying that *“the value for money approach isn’t just based on a narrow-monetized benefit-cost ratio. It does bring in wider considerations of risk and uncertainty and impacts which cannot be or are hard to monetise, such as impact on the natural environment or on biodiversity or on community severance [barriers created by transport infrastructure], just to give a few examples”* (I9).

4.1.4. Using CEA

While CBA was recognised as the basis for most policy appraisals, some respondents suggested that cost-effectiveness analysis (CEA) was increasingly used. As highlighted in Section 2, CEA is a decision-making framework prescribed by the Green Book which measures the cost per unit of outcome. One respondent commented: *“We are slightly veering into cost-effectiveness analysis, particularly more so now we’ve got this focus on strategic objectives with the revisions to the Green Book really emphasized. But we still base most of our things on cost-benefit analysis”* (I5). CEA could already be the dominant decision-making framework in some policy areas, with one respondent highlighting that *“quite a lot of the biggest resource decisions that are made in the department around power are done basically using cost-effectiveness analysis rather than CBA”* (I7).

4.2. Perception of current appraisal practice

4.2.1. Perception of the Green Book update

The 2020 update to the Green Book was generally well-received by respondents. The definition of ‘transformational’ was perceived as helpful, placing greater focus on more strategic factors and taking emphasis away from a solely quantitative approach. One respondent explained *“It’s really good to see the Green Book review that’s putting that strategic context front and centre... I think is going to help people not over-focus perhaps on the economic case and instead look strategically at it, which inevitably hopefully will help policy appraisal”* (I4).

Other respondents thought that the update has had a more limited influence on appraisal and has instead acted to codify practices that were already taking place informally: *“I think even before this Green Book change, this is kind of what we were doing anyway. It just didn’t formally make part of the framework”* (I7). Some respondents also believed that the guidance on transformational change was still at an early stage and needed to be developed far more to provide more helpful support to the analysis of such policies: *“I think it [the treatment of transformational change] is still in its infancy across government. We’re still scrambling around with it in terms of how best to properly capture the impacts of a transformational change and therefore to reflect it appropriately in informing policy decisions”* (I5).

4.2.2. General suitability of CBA to climate policy

Since the vast majority of policies concern marginal change,

respondents believed CBA and the current Green Book guidance are suitable to conduct thorough appraisals and provide robust evidence to decision-makers most of the time. However, respondents also believed that using CBA to assess transformational change presented several practical and theoretical challenges.

The prevailing perception among respondents was that using CBA to assess proposals related to climate change was particularly challenging. One respondent went as far as to say that climate change and climate policy are perhaps *“one of the most difficult places to do a cost-benefit analysis”* (I12). Another respondent also held this view, saying *“fundamentally, the Green Book is about marginal analysis and ranking between options, which for a huge chunk of government policy is all you need. However, the moment you get to anything which is big, like climate change... it’s really hard to use CBA to do that properly”* (I2). No respondent offered divergent opinions on the suitability of CBA to climate change related questions but the degree to which they expressed similar strong negative sentiments varied.

A respondent from the DfT believed that the issues presented by CBA and other dominant methods lead to important factors sometimes being excluded from appraisals: *“In terms of actually capturing, trying to quantify transformational impact, the traditional appraisal tools basically can’t and actually, for a long time, [these transformational impacts] were purposefully excluded. One of the key aspects of transformational change in the transport sector is the well-known issue of land use change and the ability of transport investments to stimulate changes in land use. Current modelling and appraisal tools don’t reflect that”* (I9).

4.2.3. Unquantifiable impacts and CBA

More specifically and in line with much of the academic literature on CBA [29,42,52], respondents noted difficulties assessing policies with significant unquantifiable impacts when using CBA. One respondent highlighted that even though there is space to discuss any unquantifiable impacts qualitatively in the appraisal, *“anything that isn’t monetized is just much harder to take into account”* (I13). Respondents also believed that it is often the benefits of a policy that are particularly difficult to quantify, sometimes leading to these being excluded from the analysis altogether: *“copious times I’ve had BCRs which we’ve been able to monetize, and then we’ve said, however, there’s these additional benefits... it’s usually benefits to be honest, that we can’t quantify that you will also want to consider alongside. Copious times that has been dropped, and the BCR reported and anything else that isn’t monetised is dropped”* (I5). This is evidence of the status-quo bias CBA faces, where the costs of transformational interventions are generally more well-known than the benefits since transformational economic processes are intrinsically highly uncertain.

This respondent adds that *“we [analysts] rarely think about opportunities, we think about risks [of policies] but rarely the upside. I think as government analysts we’re trained to be thinking, this is the worst case that could happen. We’re always cautious with our assumptions”* (I5). While this could be due to loss aversion (the behavioural tendency to prefer to avoid losses than acquire equivalent gains), it is likely that the requirement for analysts to consider optimism bias (the tendency to be overly optimistic when valuing costs and benefits) when conducting an appraisal contributes to this caution too. This is an important risk to mitigate but the same level of consideration is not given to pessimism bias; the tendency for analysts to be overcautious and underestimate key benefits. This is similar to but separate from the status-quo bias which is intrinsic to the CBA methodology. Instead, pessimism bias is a product of risk appetite. This bias has been noted in historical examples of policies where governments have underestimated or even excluded the potential for technology costs to decline [12]. This significantly undermines support for policies aimed at advancing transformative climate action.

Important unquantifiable impacts of climate policy often relate to innovation, where respondents also noted frequent challenges. One respondent spoke about this challenge when assessing policy to support electric vehicles:

“For the electric vehicles side of things, for example, that static cost-benefit analysis, I think that looked awful...because battery prices were so high. But when you looked at it dynamically...with greater deployment and technological development, battery prices would decrease over time quite strongly, only once you’ve started the deployment. And recognizing that it was needed to reach our 2050 targets and that you therefore needed to start now, even though it didn’t look great from a cost-benefit perspective... the policy was agreed, and it went ahead” (I5).

CBA is based on a static model of the world meaning dynamic effects including technological innovation, are not usually incorporated. Such omissions can complicate the appraisal of low-carbon innovation policies, especially when the costs of new technologies are initially higher than those of established alternatives but can decrease with increased deployment. In addition to battery electric vehicles [53], such empirical trends have been noted in offshore wind [12], and solar photovoltaics [12,54].

Even when more dynamic approaches to consider innovation are incorporated in the appraisal, respondents noted it is extremely difficult to accurately estimate technology cost reductions and their wider potential economic benefits. One respondent gives an example of the difficulties faced when estimating the future price of offshore wind:

“We got the future price of offshore wind wrong by a factor of two, four years into the future. If we can’t be that accurate, within 50 per cent four years into the future, what real hope have we got for predicting 2050? And I think we con ourselves a lot of the time that we actually have good numbers because they came out of a big, complicated spreadsheet. And that’s not the reality in most cases. So, in a lot of cases, when we start basing our decision-making purely on the cost-benefit analysis, we’re kidding ourselves” (I12).

This challenge has more to do with the limitations of the modelling tools that provide important inputs. While forecasting technological change is notoriously challenging [55], most leading energy-economy models have underestimated cost declines of rapidly evolving renewable energy technologies [54] as these models traditionally represented slowly changing technologies [56]. Furthermore, the major models used by DESNZ (and most government departments worldwide) assume economic equilibrium [57] and are not designed to capture the likely non-marginal impacts on employment, trade, and the structure of economies caused by low carbon innovation [6]. One respondent explained this modelling challenge: *“The moment you start doing a major transition, most of the assumptions that underpin most models break down because you suddenly started doing large changes of input conditions and things that were assumed to be linear are now no longer linear” (I12).*

Difficult-to-quantify impacts can also include the systemic effects of a policy. Meeting emissions targets requires different sectors to decarbonise simultaneously. A radical change in one sector can impact many others through a web of complex feedbacks, so capturing such knock-on effects is crucial to understanding the consequences of policies. Some respondents identified this as an area where CBA falls short. One respondent gives an example of the systemic effects of decarbonising residential heat:

“I think definitely some of the systemic things [are a challenge of CBA]. Let’s say I’m doing policies to electrify heat or deploy heat pumps. Those obviously have knock-on effects like increasing electricity demand, increasing peak electricity demand, requiring more generation... if everyone is trying to use electricity at the same time, you’ve got to try and charge your EV at the same time as running a heat pump, that’s when your peak demands can get very, very large. So, I think it’s when you have those interactions and complexity whereby you can’t just look at one bit of the system in isolation” (I14).

4.2.4. Risk and uncertainty in CBA

Respondents also identified challenges to how risk and uncertainty

are considered within the CBA framework. These should be two important factors of climate policy appraisals given the substantial uncertainty regarding the physical risks of climate change as well as the existence of heavy-tailed risk; outcomes that have extremely high impact and not sufficiently low probability to make them insignificant [58,59]. A large number of respondents commented that generating quantitative estimates of impact uncertainty is fraught with difficulties, with one respondent adding *“I don’t think we really understand the sort of shape and distributions of a lot of the uncertainties” (I7)*. This respondent goes on to say that *“even if we were equipped to do more Monte Carlo style analysis, I don’t think we have the evidence to do it a lot of the time”* and that instead, uncertainty is mostly *“talked about qualitatively” (I7)*.

Another respondent supported this view, believing that when more advanced uncertainty analyses are conducted, this is *“just layering on yet another set of assumptions into the analysis” (I10)*. This was perceived to be potentially dangerous, with the respondent adding that, *“[the analysis output] can look like it’s spuriously scientific because you can quote confidence intervals and that kind of thing, but actually they’re kind of user constructed rather than informed by reality” (I10)*. Additionally, another respondent thought that the difficulty in estimating uncertainties for some options could lead to the exclusion of some impacts from the analysis: *“in particular sort of black swan events and things that are very high impact and very low likelihood... we tend to significantly underestimate the likelihood and then probably eliminate them rather than saying there is actually a chance of this happening” (I12).*

Some respondents also believed that even when efforts are made to estimate and communicate uncertainty in the initial analysis, this can be left out or diluted in the appraisal results presented to decision-makers for the sake of brevity. One respondent explained:

“We try and avoid single values where we can present ranges.... but often when policy teams are writing submissions to ministers, they will try and keep it short and succinct and so they will chop out the caveats and the ‘around’ or that ‘up to’ or the ‘roughly’ and they’ll cross that out and it will end up being, ‘it will cost £12 per person’. It will become more definite than it should be” (I5).

Another respondent supported this view, saying that often, by the time the analysis is presented to decision-makers, any *“error margins have almost invariably disappeared, and we simply look at the midpoint estimate” (I12)*. This could imply that the risks related to proposals might not be effectively communicated to decision-makers.

4.2.5. Perception of other methods

Respondents’ perception of multi-criteria decision analysis was mixed. Some perceived MCDA as not particularly robust and open to bias due to the subjective setting of weights. One respondent described this weighting as *“distort[ing] the neutral nature of analysis” (I4)*. Another respondent thought that MCDA could be *“just used for obfuscation” (I10)*. Other respondents noted its flexibility and its ability to consider unquantifiable factors in the appraisal more easily than with CBA, with one respondent believing that *“it is a useful tool and I think it helps you combine your quantitative work with some of the factors that are important but qualitative in a structured manner” (I7)*.

Meanwhile, some believed that cost-effectiveness analysis offered an advantage over CBA where there is a specific wider strategic goal such as decarbonisation. This is largely because the method does not specifically require the benefits of decarbonisation to be quantified. Despite this, it was also noted that, as a derivative method of CBA, CEA also faces many of the same challenges when assessing transformational policies; it, like CBA, is a framework for the assessment of marginal change. One respondent gives the example of using CEA to assess different options for decarbonising residential heating, highlighting that the most cost-effective policy option might not be adequate to achieve strategic goals.

“Insulating a home looks amazing for carbon cost-effectiveness because it saves you money and has a very long lifetime. Whereas putting a heat

pump into a home does not look as good because obviously, electricity is quite expensive at the moment... But if you go and put insulation in every single home in this country, you might reduce gas demand by 20%. But we need to reduce it by effectively 100% for net zero. So, it would only get you so far... I think [CEA] sometimes might mask the fact that, if we want to achieve some of our targets, we realistically have to do quite a lot of things that have slightly higher carbon cost-effectiveness because it's the only way you'll realistically meet your target" (I14).

A couple of respondents had positive views of the value for money approach for appraisal. While still based on a CBA or CEA approach, the VfM approach (detailed in Section 4.1.3) allows the analyst to combine the quantifiable factors and the unquantifiable factors in a single framework that was perceived as simple and easy to communicate. In particular, one respondent comments that they liked the VfM guidance in the DfT's Transport Appraisal Guidance, adding that *"It's got some really good advice about how to take into account the unmonetisable impacts when you're coming up with your value for money category, which is then what people should be focusing on at the endpoint, not just focusing on the BCR which only reflects really what you can monetize with some confidence" (I15).*

4.3. The role of new decision-making frameworks for transformational change

Almost all respondents believed that to at least some degree, new decision-making frameworks could help to provide decision-makers with better evidence when assessing transformational policies. One respondent explained, *"...there is a definite need for something a bit more structured and clear that we can use around transformational change" (I5)* while another respondent commented, *"I, think it's absolutely essential for us to develop new methods because some of the existing methods we have do fall short" (I1).* Only one respondent was less convinced of the need for new frameworks, acknowledging that while the government could be better at recognizing opportunities for transformational change, they were *"inherently a bit sceptical of something that tries to introduce a new framework to do that in addition to the ones that we already have" (I18).*

Factors motivating this desire for new frameworks included many of the shortcomings of CBA described in Section 4.2. In particular, the current 'misrepresentation' (I4) of unmonetisable factors, the reliance on an NPV value which *'itself might not actually mean that much'* (I14), and improving how risk and uncertainty are communicated to decision-makers were highlighted as motivating factors. On the latter point, one respondent expressed, *"If there is a way of being able to set out a rational basis in a way that is clearly communicable, why you're taking action in ways which are highly uncertain, potentially transformative, but risky, I think would be enormously beneficial" (I16).*

Regarding risk-opportunity analysis more specifically, respondents generally expressed positive interest while some believed they did not know enough about the framework to offer detailed reflections. A couple of respondents believed that ROA was not too dissimilar from current practices to appraise transformational policies, with one respondent commenting, *"I think it's probably just putting more of a formal structure around what we're kind of broadly doing already. We're certainly not doing it across the board, I don't want to pretend that. I think there's definite opportunity for that [ROA] to take hold and be impactful" (I17).*

4.3.1. Barriers to the adoption of new frameworks

Respondents highlighted several barriers that any new framework must overcome to be a useful tool in UK policy appraisal. First, it was acknowledged that CBA is a very well-established method that has informed appraisals for decades and is now entrenched in the UK government. This has resulted in a certain degree of institutional inertia that is also reflected in the important role the Green Book plays in appraisal. As such, replacing or supplementing CBA represents, as one respondent described it, *"a huge learning step for everyone, which will take several years*

to come into play" (I12).

Moreover, CBA was viewed by many respondents as a relatively straightforward framework that decision-makers understand well and often appreciate. This was seen as a major advantage; decision-makers who are typically non-experts in a particular policy area can easily and quickly compare the expected impacts of different policy options. This was described by one respondent, *"with conventional CBA, it has many flaws, but you have a quite good yardstick for saying: is project A better than project B? That's one advantage of being able to monetize stuff, you can actually compare them" (I19).*

If new frameworks are to move away from an approach that seeks to quantify all impacts, the appraisal output risks becoming more complex and, as one respondent put it, *"overwrought" (I18).* Other respondents supported this view, one saying that *"they [decision-makers] want a number. They want to be able to compare policy 1 with policy 2... If it [the appraisal output] was too broad and wordy, it may be less influential" (I15).*

One respondent also believed that by placing less emphasis on the quantification of impacts, decision-makers could find it more challenging to use evidence to make decisions, instead relying more on their judgement than they would when presented with BCRs. Another respondent believed that, without a diverse range of inputs, such new frameworks could introduce bias to the analysis quite easily, and analysts or decision-makers could *"hide behind the qualitative element of it [the framework]" (I13).*

Finally, respondents highlighted capacity constraints as a potential barrier to new frameworks. In addition to the additional time needed to train analysts, new frameworks that better capture system dynamics and improve the representation of uncertainty will likely be a greater time burden to analysts. Yet respondents already believed that *"getting enough person time on it [the appraisal] is a challenge" (I17).* Another respondent from HM Treasury added, *"In successive spending reviews over the last three years...we've heard departments saying that we were asking them for too much information and it's just not feasible for them to produce it to a high quality and in time" (I18).* All this put together means that new frameworks could stretch the capacity of analysts to the point where there is a risk that the quality of the appraisal and therefore the evidence presented to decision-makers is diminished.

5. Discussion and conclusions

5.1. Unsuitability of CBA for transformational change

The experiences and perceptions of UK government analysts shown here support the view in the wider literature that cost-benefit analysis is an unsuitable decision-making framework for the appraisal of transformational policy. This has notable implications for the analysis of the potential impacts of climate and energy policies to support the UK's net zero emissions target. By using CBA to appraise such policies, important unquantifiable impacts could be misrepresented, systemic effects missed, and significant benefits and extreme outcomes omitted from the analysis altogether. Specifically, government analysts suggested evidence of a status quo bias, a frequently noted shortcoming of CBA [28,29], where consistent overlooking of potential benefits because they are more uncertain than the costs leads to outcomes that favour more marginal decisions.

This leads to decision-makers receiving a picture of the potential outcomes of transformational policy that is either incomplete or, worse still, misleading. While cost-effectiveness analysis is increasingly used for the appraisal of climate and energy policies, this framework faces many of the same limitations of CBA and is still traditionally based on a static view of the world. As such, neither method can adequately consider the important consequences of radical innovation including structural economic change [6] and cascading effects from positive tipping points [60].

5.2. Risk opportunity analysis as a way forward

Given these shortcomings and the perceived need for new decision-making frameworks, there is scope for risk opportunity analysis to improve the appraisal of transformational policy. ROA aims to address many of the challenges raised in both these interviews and the academic literature, integrating a thorough risk assessment and opportunity enumeration into the appraisal process. Notably, this can also help to overcome the systemic status quo bias inherent in CBA which can hinder transformational decision-making.

ROA is still a form of CBA [42] and as such should be viewed as an evolution of current practice rather than starting from scratch. Indeed, some respondents believed that ROA is a formalised version of some of the UK government's current approaches to dealing with transformational policy. Nevertheless, it is likely that given ROA's increased number of steps, it will place greater demands on analysts, something that was identified as a potential challenge by respondents. It would therefore be important that a proportional approach is taken when determining the appropriate decision-making framework for the appraisal of specific policies. CBA is fundamentally a framework for the appraisal of marginal policy decisions, and as respondents highlighted, is likely appropriate and proportionate for the vast majority of government policies which are not transformational. A pluralistic approach to decision-making frameworks should therefore be adopted while also acknowledging that identifying the transformational potential of policies is another challenge. Although a single policy proposal analysed in isolation might be considered to have only marginal impacts, when considered alongside many other policies, this could represent a step in the direction of transformational change [12]. Identifying the potential for transformational change could therefore be almost as important as ensuring the decision-making framework is appropriate for the job.

Additionally, while introducing more complexity into the analysis may be necessary to improve the representation of transformational change, the design of ROA should guard against the risk that the analysis output becomes overly convoluted. Specifically, the presentation of multiple metrics could cause information overload [61] and make the direct comparison of policies more challenging for decision-makers. This runs the risk of ROA having a limited effect on decision-making. ROA must be flexible enough to cater to the needs of decision-makers and the requirements of particular proposals, producing specific numbers where needed but also able to provide in-depth risk assessments and opportunity enumeration as appropriate.

How the UK government responds to the challenges posed by transformational policies is very likely to have global significance. As highlighted in Section 1, many countries look to the UK and the Green Book guidance specifically as a global standards setter for policy appraisal. For instance, the Green Book has directly shaped the creation of the Brazilian cost-benefit guide [29,62]. The UK has also led the way for the integration of subjective well-being approaches for valuing non-market goods into appraisal systems [63], guidance that is now commonplace in many countries [64]. This global influence means that the UK is well-placed to facilitate methodological improvements to the appraisal guidelines in many other countries.

5.3. Development of dynamic modelling tools

Many of the computational models used in DESNZ and the DfT are cost-optimising models based on assumptions of economic equilibrium that are unsuitable for assessing transformational change. If key inputs to ROA are from the same static, aggregated models that currently feed into CBA, many of the old issues, particularly around innovation, will not be mitigated. Using these kinds of models can also lead to status-quo biases [65], where opportunities for cost-declines of key nascent technologies are underestimated or omitted altogether. Poor sectoral detail coupled with a static view of the economy also means structural change impacts including induced or indirect employment, regional trade

effects, and output shifts are absent.

ROA will therefore require the support of dynamic modelling tools with detailed representations of technological change and high levels of sectoral detail [40] to not just improve forecasts of technology cost declines but also to provide an enhanced picture of the consequences of transformation across the whole economy. This can also help to shape policy that enables a just transition, by better anticipating where and in which sectors output and employment losses are likely to occur as a result of decarbonisation and innovation [6]. This will not be an easy undertaking, as time is running out to develop tools and train users to meet climate targets.

5.4. Study limitations, reflections, and future work

The findings presented here should be considered alongside the following limitations. First, while Green Book guidance is not notably different since the time of the interviews, we cannot exclude the possibility that current practice has shifted somewhat during this time. Second, relative to the number of analysts who work on the options appraisal of climate policies, this study included a small number of interviewees. It should be noted therefore that the views presented here are not necessarily representative of entire government departments; nor did the study aim to capture this. However, as interviewees were predominantly senior analysts, they provided rich insights on the appraisal landscape based on broad experience analysing climate and energy policies. We believed this was a more suitable approach than aiming for wider representation with a larger number of more junior analysts which could have resulted in less depth of insight. Additionally, some respondents believed they did not have enough information about ROA to comment on its potential usefulness or challenges it could pose. Alternative approaches such as focus groups or interactive workshops could have enabled more in-depth discussion, enabling respondents to engage with the method collaboratively.

It should be also noted that not all climate and energy policies are necessarily transformational; many could have more marginal effects. Respondents were not asked directly to distinguish between transformational and marginal policies. Their responses, however, suggested that current methods were often seen as inadequate for climate policies because their objectives required transformational change.

It is important to note too that the technical limitations of CBA alone do not explain the shortcomings to date of progress on transformational climate policies. Other factors should be considered, including but not limited to the complex role of incumbency in transitions [66], institutional inertia which can reinforce incrementalism, and the level of pessimism bias within the broader policymaking landscape. Therefore, methodological developments such as ROA should not be considered a panacea for the challenges presented by transformation but could nevertheless assist in the presentation of more useful and appropriate evidence for decision-making.

At present, the principles of ROA are well established, but its practical steps are not clearly defined. To ensure that it is both practical from an analyst's point of view and insightful from the perspective of decision-makers, the framework and associated guidance to standardise procedures should be co-developed with these stakeholders. This should help ensure that the framework is more concrete and fits the needs of analysts and decision-makers. In the short-term, the appraisal of transformational interventions could be better supported with the continued application of systems thinking tools. While these tools form part of current practice, respondents believed their use was not widespread and at an early stage. Such tools can help to understand the broader potential consequences of spending proposals and legislation beyond those that are more obvious and straightforward to quantify.

While this study has shown that practitioners perceive challenges with CBA and transformational change and believe ROA could be a useful remedy, further work is needed to obtain the perspective of decision-makers as the end users of these frameworks. This should also

aim to improve understanding of the extent to which the appraisal process informs decisions, particularly around transformational change, which is currently unclear. Moreover, future work could also investigate the political and institutional dynamics that shape appraisal, including how government analysts interact with and respond to these influences [34,67]. Furthermore, we call for the continued development of modelling tools that consider endogenous technological change and recognise the economy as an evolving system.

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CRedit authorship contribution statement

Cormac Lynch: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Pete Barbrook-Johnson:** Writing – review & editing, Methodology, Conceptualization. **Pablo Salas Bravo:** Writing – review & editing, Methodology, Conceptualization. **Jean-Francois Mercure:** Writing – review & editing, Conceptualization. **Femke Nijse:** Writing – review & editing, Conceptualization. **Jin Qin:** Writing – review & editing, Conceptualization. **Roberto Pasqualino:** Writing – review & editing, Conceptualization.

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Data availability

The data that has been used is confidential.

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