Improving decision making for carbon management initiatives

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Abstract: This paper reviews five challenges faced during decision making about carbon management initiatives. The first of these challenges deals with behavioural and perceptual obstacles, which often leads to the introduction of systematic biases during decision making. The remaining four obstacles deal with the complexity associated with the carbon management problems themselves. These include neglecting the objectives and related measurement criteria, which will guide decisions among competing risk management options; the tendency to look for singular solutions to complex problems, rather than considering a broad array of options; a lack of explicit attention devoted to the full range of tradeoffs that should be considered when choosing among alternatives; and a failure to recognise that preferences, and the decisions that result from them, are fundamentally constructive in nature. We conclude by outlining a decision-aiding approach that has been shown to improve the quality of decisions about carbon management.

Keywords: decision making; carbon management; climate change; CCS; policy.

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1 Introduction

As awareness and concern about the negative social, ethical, environmental, and economic consequences of climate change increase, so does the frequency with which researchers and policy makers must explore strategies to mitigate its effects. These range from reducing sources of carbon (such as the decarbonisation of energy systems and supply- and demand-side efficiency measures) to geoengineering Earth's climate (e.g., using stratospheric sulfate aerosols).

Another increasingly popular class of mitigation strategies focuses on increasing sinks of carbon from the atmosphere by enhancing land-based and oceanic carbon uptake. A number of natural strategies have received serious attention from researchers and policy-makers including changing agricultural practices to increase carbon retention – such as no-till agriculture (Lal et al., 2004) – as well as discouraging deforestation, and incentivising reforestation, via economic or policy levers (Kenney et al., 2015a).

At the same time, interest is growing in artificial means of increasing the number and capacity of carbon sinks. Garnering significant attention in many industrialised countries is the strategy of separating carbon from fossil fuel emissions and capturing it in the oceans or underground in geological reservoirs (e.g., in depleted oil fields, coal seams, or saline aquifers). Several such carbon capture and storage (CCS) (sequestration) projects are operating or proposed, with many more underground carbon injection initiatives operational for enhanced oil recovery purposes (GCCSI, 2019).

As with many technological solutions to anthropogenic problems, public concern about – and opposition to – CCS has been reported. Perhaps the most well-known example is the opposition to the deployment of CCS in Barendrecht in the Netherlands (Terwel et al., 2012). But the Dutch are far from alone in their sentiments toward the technology; negative perceptions of CCS have also emerged in the USA (Krause et al., 2014), Canada (L'Orange Seigo et al., 2014), France (Ha-Duong et al., 2009), Spain (Oltra et al., 2010), Switzerland (Wallquist et al., 2009), the United Kingdom (Shackley et al., 2004), and elsewhere across Europe (Upham and Roberts, 2011).

In order to overcome opposition to CCS, a commonly held assumption among policy makers is to increase the public's knowledge of the technology, through risk communication and environmental education, with a focus on CCS's risks and benefits (Ashworth et al., 2012; Hansson and Bryngelsson, 2009; Itaoka et al., 2009; van Alphen et al., 2007). It is difficult to argue against this viewpoint. When it comes to complex and uncertain technologies like CCS, our view is also that the quality of decision making (and stakeholder engagement) will be improved if decision makers know more about the problems and opportunities they are being asked to consider. However, at the same time, research in the decision sciences suggests that more knowledge and better information will not necessarily lead to better decisions about specific CCS initiatives, or endorsing CCS in general (Arvai, 2014b).

Decision researchers have long demonstrated that in loosely structured situations, people struggle with a predictable set of difficulties when making complex decisions about technologies like CCS. One set of difficulties are behavioural or perceptual in nature; that is, they are related to how information is presented and framed, and how intuitive or routinised judgmental processes interact with, and often preempt, more in-depth analysis (Arvai, 2014a). One of the fundamental conclusions from this research is that decision makers often end up making choices that only partially address the full range of their concerns.

A second set of difficulties is associated with the decision problems themselves. Decisions about carbon management are both complex and involve significant uncertainties. Making these decisions thoughtfully and comprehensively involves analysing and evaluating various elements of these decisions, rather than ignoring elements or simplifying the decision in general. The former requires pulling the decision problems apart into more cognitively manageable components, yet without simplifying them to the point that the resulting choices ignore their multi-attribute nature (Bessette et al., 2014; Gregory et al., 2012).

With these two difficulties as a backdrop, this paper reviews five obstacles to improved decision making about carbon management initiatives. These obstacles stand out because we encounter them – individually or in combination – in all manner of decisions, involving all kinds of decision makers. The first of these obstacles is linked to human behaviour and perceptions: in particular, decision makers' overreliance on judgmental shortcuts leading to systematic biases in decision making. The remaining four obstacles deal with the complexity of the problems themselves. These include neglecting the objectives and related measurement criteria, which will both guide decisions among competing risk management options; the tendency to look for singular solutions to complex problems, rather than considering a broad array of options; a lack of explicit attention devoted to the full range of tradeoffs that should be considered when choosing among alternatives; and a failure to recognise that preferences, and the decisions that result from them, are fundamentally constructive in nature. We conclude by outlining a decision-aiding approach that has been shown to improve the quality of decisions about carbon management.

2 Decision-making obstacles

2.1 Judgmental shortcuts and systematic biases

A commonly held view in the behavioural sciences is that humans are fundamentally rational decision makers who will make choices in order to maximise utility or welfare. To illustrate this point, in decisions that involve risk and uncertainty, rational decision makers should choose the alternative with the highest net benefit considering all of the attributes that define all of the alternatives under consideration. Accordingly, evaluating alternatives so as to assess overall utility would involve a series of rather complex and time consuming calculations that proponents of rational choice assume decision makers can make quickly and well (Stanovich, 2010).

An alternative viewpoint is that decision makers – because of task complexity coupled with limited processing ability – are unable to be fully rational. Instead, decision makers' capabilities are 'bounded' (Simon, 1972; Simon, 1955) such that they make the best of their decisions by evaluating a much tighter set of considerations (Gigerenzer and Selten, 2002). To make these decisions even more efficiently, decision makers have been observed relying heavily upon a series of intuitive heuristic principles that reduce complex judgments into much simpler operations (Gilovich et al., 2002; Kahneman et al., 2011). The advantage of judgmental shortcuts is that they reduce the amount of time, as well as the level of effort, required to make decisions without compromising well-being, especially for many routine decisions that demand low levels of effort and accuracy (Johnson and Payne, 1985; Payne et al., 1993). However, a reliance on judgmental shortcuts also poses a serious challenge to high quality decision making: As the context of the choice becomes more complex or unfamiliar, a heavy reliance upon these heuristics frequently leads to introduction of systematic biases that lead decision makers away from choices that are closely aligned with their stated priorities.

A commonly applied judgmental heuristic[1] in judgments and decisions about unfamiliar technologies (such as CCS) is known as availability. Here, decision makers make judgments about the likelihood of certain events and outcomes based on the ease with which they can be brought to mind, and not based on the actual probability distribution of the outcomes in question. The bias is introduced when the reasons underlying the salience of outcomes – e.g., prominent coverage of certain events by the media – is not well calibrated with their real-world probability distribution (Tversky and Kahneman, 1973). And because probabilities and outcomes are the key factors in computations of risk, the availability heuristic often leads decision makers to mischaracterise that risk.

Research suggests that the cancellation of the CCS project proposed by Royal Dutch Shell for Barendrecht was, in part, a result of strongly negative public reactions to the project. These reactions, in turn, were heavily influenced by a high-profile public relations campaign (against the CCS project and its proponents) and negative portrayals in the local media (Ashworth et al., 2012; Terwel et al., 2012).

A similar situation unfolded in Canada during 2011 following claims of CO_2 leakage from an enhanced oil recovery operation and CCS monitoring site near the town of Weyburn, Saskatchewan (Boyd et al., 2013). While the facility near Weyburn continued to operate, other Canadian demonstration projects that had been planned (e.g., a university-sponsored project near Calgary, Alberta) were casualties of the controversy. In both the Barendrecht and Weyburn cases, thoroughly reviewed scientific estimates about the probabilities and risks associated with CO_2 leakage could do little to counteract public risk perceptions based on negative portrayals of CCS.

Another judgmental heuristic likely to be consequential for decisions about carbon management is based on what psychologists refer to as affect. Affect is defined as an instinctive emotional state that is invoked when people are confronted with a stimulus. These include, for example, feelings of joy, dread, and fear. Affect is also a characteristic that people may instinctively attach to a stimulus, for example qualities such as goodness or badness (Slovic et al., 2005). The related affect heuristic leads to judgments about objects, activities, and other stimuli that are shaped by the varying degrees of positive or negative feelings that they invoke or that people attach to them (Finucane et al., 2000). The affect heuristic is powerful in that it can readily prevent decision makers from analysing problems or opportunities in depth. For example, when making choices about environmental issues, alternatives can prove themselves to be so emotionally charged that they preempt decision makers from fully evaluating the alternative options based on whether they are decision makers' best, long-term interests (Campbell-Arvai et al., 2014; Wilson and Arvai, 2006).

It should not come as a surprise that the affect heuristic often spills over from personal decisions into policy decisions (Wilson and Arvai, 2006; 2010). For example, many decision makers support or reject certain technologies because of the positive or negative emotions they invoke, and not because of their risks or benefits. A case in point is atmospheric geoengineering (i.e., solar radiation management via stratospheric sulfate aerosols), which is rejected by many decision makers on emotional grounds well before they undertake a more thorough analysis of its feasibility, risks, and benefits (Keith, 2014). As public fears about certain examples of carbon management (e.g., CCS) mount, it is highly likely that the affect heuristic will play an important role in modulating judgments and preferences about them.

2.2 Objectives and performance measures

Our research on judgmental heuristics, and the affect heuristic in particular, supports the dual processing theory of decision making (Epstein, 1994; Zajonc, 1980). The affective system, often referred to as 'System 1', is preconscious and automatic, and attaches meaning to incoming information based on feelings and emotional connections. The analytic, rational system – or System 2 – requires decision makers to undertake a much more conscious appraisal of incoming information. From a neurological perspective (Montague and Berns, 2002), these systems act in parallel, not in series. As a result, high quality decision making processes must achieve an appropriate balance between the two systems, such that neither preempts the other (Arvai and Campbell-Arvai, 2013).

In addition to achieving a balance across these two judgmental systems, decision making processes must also strive to achieve a balance across the range of objectives that guide decisions. Objectives are the raw materials of decision making, and they reflect what matters to – and the values of – decision makers (Keeney and Raiffa, 1993). Too often, however, decision makers rush through the process of identifying the full range of objectives that guide their choices. The result is that the resulting set of objectives is incomplete (e.g., decisions about resource development that only consider the objectives of environmental protection and job creation). The implication of an incomplete set of objectives is that the overall performance or utility of different courses of action cannot be accurately determined because other important objectives are omitted from the analysis (e.g., enhancing community well-being, protecting cultural traditions).

In our own work, we have found strong support from decision makers for taking the time at the start of a decision making process to identify a comprehensive set of objectives, which characterise the key values and concerns of decision makers and stakeholders (Kenney et al., 2015b). These objectives can be visually summarised using tools such as means-ends networks, objectives hierarchies, value trees and influence diagrams (Keeney, 1992).

In addition to being comprehensive, objectives should also be understandable; e.g., concise and free from ambiguity. It is almost always the case, for example, that decision makers and stakeholders can benefit from greater resolution around concepts such as 'sustainability', which, given the range of knowledge sources in developing community settings, could have a number of different meanings (Gregory et al., 2012). The objectives used to guide decisions should also be independent, meaning that each objective contributes independently to the overall performance of the alternatives under consideration. Finally, objectives should also be articulated with agreed-upon definitions and directionality. For example, decision makers often want lower costs, more jobs, and a higher degree of environmental protection (Keeney and Raiffa, 1993). In thinking about directionality, decision making processes must also seek clarity on the definition of actions; e.g., precision in terms of what it means to 'protect' or 'maintain' certain targets of concern (Gregory et al., 2012).

Once a set of objectives has been identified, the next consideration is to determine how each objective will be achieved. In other words, decision makers must identify indicators that will take the objectives from more abstract statements, to concrete ways of measuring (or forecasting) the anticipated performance of the alternatives under consideration. Like objectives, these performance measures should be complete and concise, and should address the range of consequences associated with a given alternative without obscuring the outcomes with extraneous data. Likewise, performance measures should be unambiguous and understandable, with all stakeholders in agreement about the measures' meaning, magnitude and direction (Gregory et al., 2001).

Finally, decision making processes must be explicit about the kinds of performance measures that are required. Performance measures come in three forms: natural, constructed, and proxy (Keeney and Gregory, 2005). Natural measures tend to be measured in universally recognised units like costs (e.g., in dollars), and directly measure the objective in question. Constructed measures must be created if there are no obvious or universally agreed upon single measures available. Issues such as the quality of life, perhaps in areas where carbon management is to be deployed, would fall into this category. Here, multiple measures are often combined to produce a single index, and numbers are used to reflect different levels of a qualitative or descriptive scale. Finally, proxy attributes are indirect measures of objectives, and are used when neither natural nor constructed measures are available. An improvement in public health is an oft-cited objective and the rates of certain illnesses are commonly used as a proxy measure.

2.3 Multiple options

Too often carbon management initiatives are framed as ‘take-it-or-leave-it’ alternatives. For example, should the geologic storage of CO_2 be adopted in a certain area, yes or no? This approach poses a significant obstacle to high-quality decision making in that ‘decisions’ about contentious issues with single alternatives are akin to ultimatums that do little to help decision makers grapple with the multi-attribute and multi-solution nature of complex problems (i.e., how to manage the sharp increase in greenhouse gas emissions). Rather than focusing on single alternatives, decision making processes about carbon management should offer a set of complete and comparable (proposed) solutions to a problem or opportunity (Kenney et al., 2015b).

A second challenge is that too often the development of options focuses too narrowly on what stakeholders or decision makers perceive to be idealised courses of action. In our view, the development of alternatives should focus on identifying courses of action that are substantially different from one another, thereby giving decision makers the opportunity to learn about how different objectives will be influenced by diverse alternatives. The bottom line here is that the identification of alternatives should be viewed as an opportunity to explore a wide range of creative solutions; even those that may at first seem implausible (Keeney, 1992).

A third challenge manifests itself when carbon management initiatives, which are required because of the consequences of certain actions, are isolated from the causes of the emissions. Because carbon management alternatives are always implemented in conjunction with other activities (e.g., resource development in the case of enhanced oil recovery, or carbon capture during energy development), our research suggests that decision makers must begin to look for portfolios of options rather than individual actions (Bessette et al., 2014).

This means undertaking an objectives-based evaluation of technologies like CCS in conjunction with – and, importantly, without – the activities that lead to the greenhouse gas (GHG) emissions in the first place. To this end, he US National Academy of Sciences (NRC, 2009), amongst others (Socolow et al., 2004), have suggested that decision making tools with the added capability of developing and analysing combinations of alternatives – e.g., different energy generation technologies combined with different kinds and levels of carbon management technologies – be developed so that decision makers may take a systems approach to achieving GHG emissions reductions. For this reason, the inclusion of portfolio analysis alongside other decision support tools is increasingly being viewed as a critical addition to the suite of approaches used for developing and evaluating carbon management options (Bessette et al., 2014; Choptiany, 2017; Fleishman et al., 2010; Palmgren et al., 2004).

2.4 Tradeoffs

Decisions with multiple objectives require that decision makers confront tradeoffs, which is an explicit exploration of how much of something decision makers are willing to give up in exchange for getting something else. In the realm of carbon management initiatives such as CCS, these tradeoffs may be considered across objectives. Or they might be based on different tolerances for uncertainty and risk; that is, how much loss, uncertainty, or risk are decision makers willing to accept in terms of one dimension of a decision in order to achieve gains in another dimension?

Confronting tradeoffs is difficult from both a psychological and practical perspective. Psychologically, tradeoffs that make decision makers feel as though they must subvert some morally significant values in favour of others, which invokes a sense of constitutive incommensurability (Tetlock et al., 2000). Many decision makers react to this conflict by avoiding tradeoff analysis to the extent that they can. It is common, for example, for decision makers to consider only a small handful of objectives – sometimes just a single objective – when making choices; see the discussion of bounded rationality above. It is important to note that the objectives left out of consideration are not necessarily judged to be unimportant on their own. Rather, these objectives often are important but have been discounted because they are difficult or uncomfortable to balance against other attributes (Arvai et al., 2012).

From a practical perspective, confronting tradeoffs poses challenges because it is hard to know where and how to begin. When tradeoffs are confronted, it is instinctive to think of them in general terms; e.g., a willingness to compromise some measure of economic growth in exchange for some measure of environmental protection. But in decisions about carbon management, the measures associated with these objectives are much more specific. For example, does a specific price on stored carbon – e.g., \$60 tCO_2 stored – justify going forward with a CCS project as a means of curbing the deleterious effects of climate change? If not, what about \$120 tCO_2 stored? Moreover, how does the tradeoff calculus change over time as additional CCS projects are brought online?

An additional complication for carbon management initiatives is that there are many more than two objectives in play at any given time. In addition to environmental and economic objectives, decision makers are asked to consider issues related to human health, environmental justice, flexibility, and social well-being. These too must be accounted for using performance measures that quantify achievement under different alternatives (see above), and must be traded-off when making choices about carbon management initiatives (Bessette and Arvai, 2018). And, as the number of objectives in play increases so too does the level of complexity involved in confronting tradeoffs (Clemen, 2004).

In light of these challenges, decision researchers – ourselves included – have been experimenting with different kinds of decision-support tools that help decision makers to explore tradeoffs in a manner that is direct and comprehensive (in that all of the objectives are considered). For example, we have been combining energy systems models and interactive computer interfaces to help decision makers develop and forecast the performance of portfolios. We have also gone beyond visual displays in developing decision-support tools that help decision makers to more thoughtfully confront on an objective-by-objective basis, e.g., see Bessette et al. (2014).

2.5 Constructed preferences

Taken together, the previous four sections challenge the common assumption held by many behavioural scientists (and project proponents) that decision makers have a series of pre-existing preferences about carbon management initiatives that simply need to be activated through the provision of information about a project's risks and benefits. This is an incorrect assumption. Rather than simply reviewing information about a decision problem and the available options, identifying the appropriate pre-existing preference, and then making a choice, research shows that decision makers construct their judgments across a wide range of decision contexts – often from scratch – during elicitation processes (Lichtenstein and Slovic, 2006; Payne et al., 1992).

Generally, these decision contexts share one or more of three characteristics. First, the decision context may be novel, with the implication that pre-existing preferences cannot possibly exist. Second, decision makers are almost always faced with a situation in which the evaluation of competing alternatives causes conflict between two or more pre-existing preferences or objectives. In these cases, tradeoffs become necessary, which requires the construction of new preferences that balance conflicting priorities. Third, decision makers may be required to translate qualitative expressions of preference into quantitative ones (or vice versa). Moving from a general judgment that CCS is a desirable strategy to determining one's willingness to pay for it (e.g., as an additional levy on utility bills) requires a constructive process.

Decisions about carbon management initiatives include all three of these elements. In this context, the vast majority of decision makers are unable to evaluate decision problems and alternatives by simply drawing on pre-existing preferences. Instead, they must construct their preferences in response to cues that are available during the decision making process itself (Arvai et al., 2012; Lachapelle et al., 2014). Some of these cues will be internal, reflecting deeply held worldviews or ideologies. And some will be external, in the sense that they are associated with the information that accompanies a decision problem. For example, these may become apparent in light of local, regional or even national or international events (e.g., media coverage as in the case of the Barendrecht and Weyburn examples).

The constructive nature of preferences means that decision support processes must be designed to help improve the quality of resulting choices. The explicit recognition that decision makers rely heavily on contextual cues that are available to them as they construct judgments makes it possible for analysts and facilitators to provide a more defensible and helpful context – in other words, a structure – for decision making. Indeed, it is our opinion that proponents of carbon management initiatives – e.g., in industry and government – are obligated to employ decision-aiding processes that help decision makers to construct the highest-quality judgments possible in light of the various constraints they face.

3 Structuring carbon management decisions

Structured decision making (SDM) is a decision support approach that focuses on the judgmental challenges discussed above – both those that are behavioural and perceptual in nature, and those that are a product of problem and task complexity. SDM helps to decompose complex decisions, thereby addressing judgmental challenges common to individual and group deliberation, which are outlined above. In doing so, SDM highlights the objectives, alternatives, and required tradeoffs in order to provide maximum insight about the choices that decision makers face (Arvai et al., 2012; Bessette et al., 2014; Bessette and Arvai, 2018; Kenney et al., 2015b).

SDM relies on the normative benchmarks for high quality decision making that come from multiattribute utility theory (Keeney and Raiffa, 1993) and decision analysis (Clemen, 2004) to frame the stakeholder engagement process. In addition, a SDM approach draws on insights from behavioural decision research to identify common biases in decision making that must be addressed in order to maximise decision quality (Kahneman et al., 1982; National Research Council, 2005). SDM also draws on the guidance of and good practice in risk communication (Arvai and Campbell-Arvai, 2013; Arvai and Rivers, 2013; Leiss and Larkin, 2018) and deliberation (National Research Council, 1996) so as to elicit information from stakeholders and technical experts in credible and defensible ways.

SDM comprises five[2] key elements (Gregory et al., 2001; Hammond et al., 1999):

1 defining the decision problem that is to be the focus of analysis

2 identifying stakeholders' and decision makers' objectives that will guide the decision making process, including the performance measures that will be used to gauge success or failure

3 creating a broad array of creative alternatives that directly address objectives

4 forecasting the consequences associated with alternative courses of action, including key sources of uncertainty

5 helping decision makers to confront value tradeoffs that arise when selecting among alternatives.

A range of analytic tools is available for use during an SDM process. These include decision trees and influence diagrams for characterising decision points and alternatives, objectives hierarchies for displaying the values and concerns of stakeholders, portfolio builders for creating alternatives, consequence matrixes for depicting the objective-by-objective performance of alternatives, and software tools for tradeoff analysis. When SDM processes are led by analysts and facilitators, they often rely upon interviews, workshops, surveys, and experiments (e.g., choice and factorial experiments) to collect necessary information about objectives and preferences (Arvai et al., 2014) However, SDM can also be practiced by individuals and groups working on their own (Hammond et al., 1999).

We have studied and applied SDM for carbon management decisions in North America, as well as abroad. In a pair of applied studies, we worked with colleagues to develop and test an interactive decision-aiding framework designed to help decision makers construct internally consistent preferences, while also providing stakeholders (and decision makers) an opportunity to thoughtfully construct and compare carbon management portfolios (Bessette et al., 2014; Bessette et al., 2016). To make these studies as realistic as possible, we worked in a real-world decision context; the focus of both studies was to inform decisions about energy transitions in communities looking to replace aging coal-fired generation infrastructure. In order to make decisions about carbon management relevant, different approaches for reducing GHG emissions (e.g., CCS, demand-side management) could be treated separately, or coupled with different energy generation options (i.e., fossil-fuel based power plants, as well as non GHG emitting generation options, like small modular nuclear reactors).

Both studies involved the development of a software interface, which

1 provided necessary background information to users regarding the development of coupled carbon management-energy development strategies

2 accounted for users' values and objectives

3 allowed for the construction of bespoke portfolios bounded by real-world technological, supply, and demand constraints

4 provided a more rigorous basis for addressing tradeoffs.

This latter element was especially important as it facilitated choices that were in line with decision makers' stated priorities. Three analytic approaches were used to evaluate the framework: participants' self-reports of satisfaction, the amount and type of knowledge participants gained, and the overall decision quality as a function of the internal consistency of participants' decisions (Bessette et al., 2014; Bessette et al., 2016).

Overall, participants in these studies reported[3] very high levels of satisfaction and comfort with their decisions. An analysis of the data from one of the studies (Bessette et al., 2014) suggested that these high satisfaction ratings were linked to the fact that the objectives, and performance measures, used to guide the decision making process were elicited from the community where the study took place. The data from both studies also suggested that the ability to both create and evaluate a wide range of energy and carbon management portfolios was both helpful from the standpoint of ensuring a transparent process and helping decision makers to untangle what was a rather complex problem. Specifically, participants who built portfolios and compared them with many others felt they had been provided with significantly more and yet also just the right amount of information about energy development and carbon management to make their decisions. By contrast, participants who did not have an opportunity to build portfolios reported wanting more information (Bessette et al., 2014; Bessette et al., 2016).

Both studies also showed that the SDM process, with its emphasis on tradeoff analysis, was also instrumental in leading to internally consistent decisions; according to many decision researchers, internal consistency (more than self-reported satisfaction) is the most accurate metric for measuring decision quality (Clemen, 2004; Keeney and Raiffa, 1993). Recall from Section 2.1 that one of the challenges associated with the use of judgmental heuristics is that they often lead to choices that do not always reflect decision makers' objectives. For this reason, explicit attention to tradeoffs across alternatives and objectives serves as an important de-biasing tool (Bessette et al., 2014; Bessette et al., 2016).

A second, related project borrowed insights from the work of Bessette et al. (2014, 2016) in an effort to utilise SDM in guiding the development of a coupled energy-carbon management strategy in Canada's Northwest Territories (Kenney et al., 2015b). The initial focus of this work suggested ways that decision makers in the Northwest Territories (NWT) might better structure decisions that will require portfolios of solutions that address decision makers' and stakeholders' (e.g., First Nations, public, government, and industry) objectives across a broad geographic scale.

As with the previous example, this work emphasised educating decision makers about judgmental biases, the elicitation of objectives and performance measures, creating portfolios of alternatives, and tradeoff analysis. But, unlike the previous example, this SDM effort is not treating carbon management as a single discreet decision. In most places, not just the NWT, it will be through interlinked regional and national carbon management strategies that real progress on curbing GHG emissions can be made.

In terms of results[4], the application of the SDM process in the NWT helped government decision makers to move beyond a simplified characterisation of carbon management as something that can be applied in a standardised fashion across the territory. This, in turn, led to the recognition that not only would portfolios of technologies be needed at each geographic location; different portfolios of options would need to be developed for different geographic regions in the territory. The application of the SDM process also helped decision makers to clarify the range of objectives that guide energy and carbon management decisions across the territory, as well as the performance measures that could be used to evaluate portfolios of alternatives. Finally, decision makers in the territory were provided with tools that would help them to confront tradeoffs, which we believe will lead to more internally consistent choices moving forward.

A third study applied SDM in a developing country setting, to a forest-based carbon management program in Vietnam (Kenney et al., 2015a). Our work utilised a series of SDM workshops with both national and village level stakeholders in an effort to identify objectives, along with associated performance measures, and to begin designing alternatives for the carbon management program. While stakeholders at both levels generally agreed on the core objectives, they differed in terms of the ways to achieve these objectives; this highlights the need for locally-specific decision making processes that effectively capture the range of relevant objectives.

As the SDM process in Vietnam progressed, we received positive feedback from village level participants who expressed a sense of ownership over the program design process. Participants at the national level also provided positive feedback about SDM as a useful participatory method for designing, managing and implementing this program in Vietnam.

In the end, our research suggests that SDM serves as an effective approach for involving multiple stakeholders in complex and often contentious issues facing developing communities. Likewise, SDM brings much-needed methodological precision to decision contexts that increasingly demand science-based rigour. All of this must unfold against the backdrop of the manifold challenges that typify developing communities: poverty, limited infrastructure, low literacy levels, a diversity of cultural norms and local traditions, poor coordination among decision makers, and – all too frequently – a lack of democratic and transparent decision making processes. SDM, therefore, is a way to help decision making processes surrounding carbon management – in both developing and developed country contexts – recognise and respond to these challenges.

4 Conclusions

We have focused in this paper on challenges to, and the structure for, decision making about carbon management. We are not the first to take an interest in these issues. Others who have studied decision making processes set against the backdrop of human-environment interactions have identified similar challenges (e.g., dealing with priority setting, and calibrating decisions to these priorities). These, in turn, have led to critiques of decisions for their perceived failure to meet linked environmental, social and economic goals (Arvai, 2014a; National Research Council, 2005, 2008).

In spite of these critiques, very little research has focused on developing science-based guidance regarding how best to address these challenges. Instead, too many policy makers view decision making as a black box or as art over science. As a result, we often see very general statements about the ingredients necessary for high quality decision making: e.g., involving all of the interested parties in decision making processes, providing timely access to information, ensuring transparency, and the like.

In our view, it will continue to be difficult for policy makers to address complex, multi-objective decisions – like those about carbon management – without treating decision making processes in terms that go well beyond general recommendations. Overgeneralising the decision making process only results in a failure to focus explicitly on several issues central to higher quality decision making: addressing judgmental biases, clarifying objectives and associated performance measures, thinking creatively about alternatives, confronting tradeoffs, and recognising and adapting to the constructive nature of judgments.

For this reason, one of the most important contributions of a structured decision making approach is its ability to convey the key elements of a complex problem in terms that capture its primary impacts – and potential solutions – in ways that can more easily be understood and addressed. As a result, it becomes easier for decision makers to understand the expected physical, economic, or social impacts of an action, and importantly, how they are related. SDM also makes it easier for decision makers to understand and confront the tradeoffs that must be made when selecting amongst competing options (Arvai et al., 2001; Bessette et al., 2014; Bessette et al., 2016). This, in turn, leads to choices about carbon management – as well as other problems at the human-environment nexus – that do a better job of addressing matters that are of concern to decision makers (and stakeholders). In our view, this is what higher quality decisions about carbon management ought to be all about.

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Notes

1 A treatment of the wide range of judgmental heuristics, and their implications for decision making, is well beyond the scope of this article; for a more thorough review, we direct readers to other sources, see Gigerenzer et al. (2011), Gilovich et al. (2002) and Kahneman et al. (1982).

2 A sixth step in SDM, which is described in some publications involves the implementation of selected alternatives, see Arvai et al. (2012) and then the adaptive management of them as part of a detailed monitoring process, see Arvai et al. (2006) and Gregory et al. (2006).

3 For a detailed accounting of all results from this study, see Bessette et al. (2014).

4 Unlike the work of Bessette et al. (2014), this work was of a purely applied nature; hence, empirical measures of decision-makers' satisfaction internal consistency were not available; see Kenney et al. (2015b).