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Cartography of pathways: A new model for environmental policy assessments

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ABSTRACT

How can assessments of environmental policy issues be policy-relevant without being policy-prescriptive? The predominant technocratic and decisionist responses to this question misleadingly assume that value-neutral scientific recommendations for public policy means, or even objectives, are possible. On the other end of the spectrum, the literature on democratic and pragmatic models of expertise in policy often does not satisfactorily explain what researchers can contribute to public discourses surrounding disputed, value-laden policy objectives and means. Building on John Dewey's philosophy, this article develops the "pragmatic-enlightened model" (PEM) of assessment making, which refines the existing pragmatic models. It is used to some extent by Working Group III of the Intergovernmental Panel on Climate Change. According to the PEM's policy assessment methodology, policy objectives and their means can only be evaluated in light of the practical consequences of the means. Learning about the secondary effects, side effects and synergies of the best means may require a revaluation of the policy objectives, for instance, regarding the use of bioenergy for climate mitigation. Following the PEM, assessments would—based on a thorough problem analysis—explore alternative policy pathways, including their diverse practical consequences, overlaps and trade-offs, in cooperation with stakeholders. Such an arduous interdisciplinary cartography of multiple objectives, multi-functional policy means and the broad range of their quantitative and qualitative practical consequences may face considerable practical challenges and uncertainty. Yet, it could make assessments more policy-relevant and less prescriptive, and could effectively support a learning process about the political solution space.

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1. Introduction: environmental assessments require a refined orientation

For the guidance of global, large-scale scientific assessments of complex environmental issues, such as, for instance, the assessments by the Intergovernmental Panel on Climate Change (IPCC) and the Global Environment Outlook (GEO) series by the United Nations Environment Programme, the criteria of policy-relevance, legitimacy and credibility seem widely accepted. However, these criteria are hard to achieve in practice, at least simultaneously; this is due to the many significant trade-offs and challenges that hamper successful assessment making (Cash et al., 2003; see supplementary material A.1 for more detail). For example, controversial yet socially highly relevant aspects of the issues at stake are sometimes watered down or avoided in assessments (Siebenhüner, 2003). This can considerably reduce the policy-relevance of the assessments. On the other hand, policy-relevant studies or reports are sometimes criticized for being strongly biased from a social and political perspective.

In the end, proposals for the very specific institutional arrangements of assessment bodies are required to reduce or even overcome these trade-offs. However, there is a lack of adequate guidance for the large-scale environmental assessments even on a fundamental and strategic level. This is particularly valid for assessments that also focus on—often highly disputed and strongly value-laden—policy solutions, i.e., specific response options, rather than on natural scientific problem analyses only. The main reason for the lack of appropriate guidance for these assessments is that the general and predominant models of the roles and responsibilities of scientific expertise in policy are flawed, as confirmed by many observers (including, for instance, Pielke, 2007; Brown, 2009; Hulme, 2009; Kitcher, 2011; Sarewitz, 2011). The weaknesses of these models are mainly due to the underestimated philosophical challenges regarding implied value judgments and the objectivity issue in assessments, as this article will argue (see also Putnam, 2004; Douglas, 2009). The supplementary material (A.2) explains the three models that are still predominant in our view: the technocratic, decisionist and pragmatic models.

Critics, apologists and practitioners of assessment institutions usually work with such general models in mind.[2] These general, normative models inter alia guide the institutional arrangements and procedures of environmental assessments, as well as the concrete practices within those arrangements. In this action-guiding function, the models contribute considerably to the quality and effectiveness of assessments (Hulme, 2009; Pielke, 2007).

The main critique in the literature points out that, in practice, the most predominant model, i.e., the technocratic model with its clear-cut policy recommendations, is often turned into a symbolic legitimation model (Jasanoff, 1990; Sarewitz, 2004). This means that certain political standpoints in scientific studies (i.e., the proposed objectives and means) are allegedly justified by referring to a consensus; however, these are in fact strongly biased towards certain disputed political or social standpoints in a non-transparent manner (e.g., by concealing their value judgments or uncertainties). If one-sided value assumptions in assessments are not sufficiently made transparent, researchers can become, deliberately or unintentionally, "stealth issue advocates" through their reports (Pielke, 2007). There is also some demand by policymakers for this kind of report in order to create legitimacy for their policy narratives by making use of scientific authority (e.g., Pielke, 2007).

Yet, also assessments that follow the so called decisionist model that avoids any recommendations on policy *objectives* can become value-laden and policy-prescriptive because their assumption that researchers can provide sound science without implying disputed value judgments in their scientific justifications is misleading (Putnam, 2004; Hands, 2001; Douglas, 2009). Facts and values are always entangled in scientific research (Dewey, 1986). All scientific statements at least imply cognitive values (such as consistency, coherence or objectivity, see Douglas, 2009) that have, however, the same fundamental characteristics as ethical value judgments (Putnam, 2004). Furthermore, some predominant cognitive values in scientific research are built on ethical values (Douglas, 2009). Additionally, value-laden "thick ethical concepts" (i.e., descriptive concepts with strong normative-ethical connotations) are often used in assessments, including those for framing the problems (Putnam, 2004). Examples include "efficiency," "vulnerability," "risk" and "development." The widespread, mistaken belief in value-free science opens the door wide for the deliberate misuse or unintentionally misguided use of expertise in policy—notably for policy-prescriptive assessments through implied ethical judgments already at the level of problem framing (Skodvin, 2000; Hulme, 2009). Moreover, assessments that follow the decisionist model are often significantly less policy-relevant in a substantial sense, as there is no role for research regarding the critical discussion of policy objectives, such as the 2 °C goal.

A large number of more promising approaches, here summarized as the "pragmatic model," have been developed in recent years; and some of these ideas have already been applied in assessments. This pragmatic model envisages cooperative knowledge production and a role for mutual learning between experts and decision makers in environmental policy. It more or less accepts the value-ladenness of scientific knowledge production, yet allows for a scientific contribution to the discussion of disputed, value-laden environmental policy issues. The major challenge of the pragmatic model is to specify this potential contribution and to show how value-laden research can still be sound and reliable. Yet, many existing variants of the pragmatic model that generally highlights the procedural and institutional aspects fail to respond to this philosophical challenge in a satisfactory manner. Often, like the technocratic and decisionist models, these model variants fail to take the key interdependency of policy objectives and means fully into account.

Consequently, this article aims to provide a refined model, i.e., a framework and strategic orientation, specifically aimed at large-scale assessments of long-term environmental problems and specific policy response options in light of the complexity, uncertainty and multiple policy objectives

[2] Often, these science-policy models are neither made explicit, nor are they necessarily comprehensive and consistent.

associated with them. This model may help these assessments to better deal with disputed, value-laden environmental policy issues in a scientifically sound and policy-relevant, but not in a policy-prescriptive manner. Yet, this model also acknowledges the strengths of some existing approaches in the literature and practices of assessment making and, therefore, refines them; It builds on previous works in public policy analysis and other research fields (e.g., Hulme, 2009; Robert and Zeckhauser, 2011; van der Sluijs et al., 2010; Dunn, 2012). This article mainly goes beyond the literature by discussing more clearly—and in a philosophically systematic and consistent manner—the decisive role of the practical consequences for the assessment of the objectives and means of environmental policy, resulting in a proposal for how to constructively deal with the inevitable fact/value entanglement in assessments. This work may inter alia contribute to the current discussions about the design of upcoming assessments (e.g., IPCC AR6, GEO-6, and those by the Intergovernmental Platform on Biodiversity and Ecosystem Services, IPBES).

2. Theory: the interdependency of objectives and means

Understanding the interdependency of policy objectives, means and consequences (supplementary material A.2 explains these three terms in more detail) is key for the development of a refined pragmatic model as more appropriate guidance for assessments. It helps develop a compelling methodological idea for how environmental policy objectives and means—given the inevitably implied ethical values—can actually be assessed by researchers in a scientifically sound and reliable manner. The analysis of the interdependency in this section builds on the theory of philosophical pragmatism in the tradition of John Dewey and Hilary Putnam. It is a philosophy of science and furthermore a meta-ethical theory. The Deweyan–Putnamian variant of pragmatism is explained in Dewey (1986, 1988) and Putnam (1999, 2004). Although Putnam does not call himself a pragmatist, he has contributed significantly to pragmatist theory.

The core idea of pragmatism is to trace and evaluate the practical consequences of hypotheses, be they scientific, ethical or just verbalized gut feelings in ordinary life. Hypotheses are possible means to solve any kind of practical problems; the ''rightness'' of hypotheses (of any kind) depends on their potential to solve problematic situations, as experienced by us. Though this may sound disturbing for some natural scientists, the pragmatist method builds on the successful principle of experimentation that is fundamental to natural science. Basically, Dewey's abstract idea of inquiry consists of five main steps (Dewey, 1986, pp. 105–122):

(1) Noticing a problematic situation.
(2) A precise and thorough analysis of the problem and its causes, constituents and contexts. This includes identifying objectives as desired consequences and as specific, comprehensive problem-solving conditions.
(3) Developing tentative hypotheses for (a set of) means to attain the objectives.
(4) Evaluation of these proposals for means, and possibly a revaluation of the initial objectives, by critically considering the potential, practical consequences of the means. These practical consequences refer to (a) the sum of direct effects of the objectives in step two; and (b) the unwanted side effects as negative and synergies as positive co-effects on additional objectives. Direct effects also comprise potential secondary, later effects in causality chains that diminish or increase the direct effects in total.
(5) Evaluation after the actual implementation: do the hypotheses for means and objectives need to be revised in light of the real practical consequences of the implemented means?

These five steps form a pattern of inquiry that can, as a *meta*-theory, guide the use of the diverse *specific* research methods employed in academia. For Dewey, a successful scientific inquiry transforms an indeterminate problematic situation into a determined one with the help of adequate hypotheses (means); this usually requires a ''transaction'' of the people involved, which includes learning processes about valuable objectives and their means (Kuruvilla and Dorstewitz, 2010). A crucial precondition for a successful Deweyan inquiry into complex social issues is some kind of dialogue between researchers and the public. This essential cooperative aspect of knowledge production is mainly because researchers alone can hardly be aware of all socially and politically relevant objectives and means-consequences, or of all possible means.

The crucial implication of the Deweyan pattern of inquiry for a framework of environmental public policy analysis is that researchers should not simply explore possible policy means to given policy objectives because objectives cannot justify their means. Rather, both the means and the objectives should be critically reflected on in light of the diverse practical consequences of the means, according to step four in Dewey's inquiry. Pragmatism suggests that a critical inquiry into the means-consequences could possibly change previous evaluations of the policy means, and even policy objectives, dramatically. And ''changing one's values is [...] frequently the only way of solving a problem'' (Putnam, 2004, p. 98). Consequently, the policy objectives and the means are highly interdependent and cannot be evaluated separately. Moreover, there is a continuum of objectives and means: objectives in one specific context can become the means of another case, and vice versa (Dewey, 1986).

Analyzing and evaluating practical means-consequences can have several learning effects: first, the low-hanging fruit can simply be that the *meaning* of the frequently ambiguous policy objectives is clarified and possibly corrected, for example, in terms of more precise evaluative criteria (i.e., specific indicators, metrics, etc.), as these evaluative criteria are always directly related to the policy objectives at stake. Second, the initial appraisal of the *means* can change in light of their actual or potential consequences—possibly requiring a search for better or additional means; because of the complex biophysical and socio-economic system dynamics, the practical consequences of the climate policy means may include economic costs, risks, externalities and consequences related to the many objectives from completely different policy fields.

Third, a given set of *policy objectives* possibly has to be completed with additional objectives after the exploration of the means-consequences when it turns out that the identified side effects and synergies of the means correspond to the objectives that were missed by the initial list of objectives at stake. In addition, as these objectives are interrelated through side effects and synergies, the weights of given policy objectives may have to be revised and relativized, or the objectives may have to be completely abandoned, for instance, if even the best available means have severe side effects. Fourth, *competing sets of objectives* can be compared in a similar manner, i.e., via their practical means-consequences. Even in the rare case that there is no initial disagreement over a specific set of objectives regarding a policy problem, the actual practical consequences of the best means to realize these objectives can surprisingly lead to a world that is, in fact, not desirable and necessitates a completion and revision of the initial objectives. Yet, the sheer existence of co-effects due to multi-functional policy instruments does not yet tell us what to do; the weighing of different public policy objectives in order to find an acceptable compromise between them is an exercise that requires a social welfare function and fair democratic procedures. Fig. 1 summarizes these thoughts on the role of practical consequences in the (r)evaluation of policy objectives and means.

Let us illustrate this pragmatist policy analysis methodology with a hypothetical example of climate change mitigation goals by assuming the dual initial policy objective to stay below 2 °C global warming in order to avoid severe climate impacts, but in an economically efficient manner (see supplementary material A.2 for background information). Further assume that carbon taxes and subsidies for renewables are the major policy means; these means will likely result in specific measures in the energy and transport sector. Given the complexity of socio-economic and biophysical systems, the direct effects could be the least-cost attainment of the 2 °C goal at first, inter alia due to a high share of bioenergy in the global energy mix. The secondary direct effects of large-scale bioenergy production could however cause increasing greenhouse gas emissions due to direct and indirect land-use changes of the large-scale biomass production. Moreover, the suggested means may have synergies, for instance, with the additional objectives of energy security or health improvement due to reduced air pollution from fossil fuel combustion. However, there could also be severe side effects in terms of risks, for instance, regarding food production prices and land-use changes (IPCC, 2014, Chap. 11). Then, food security would also have to be added to the context-specific list of relevant policy objectives (and to the related list of evaluative criteria), and the policy objectives may have to be weighed differently against each other in light of the newly discovered co-effects, possibly leading to a revision of the 2 °C goal as such in this hypothetical case.

Section 1 already argued that not even scientific findings on policy means and their causal effects can be value-free. The close entanglement of policy objectives and means makes this point even more obvious. More generally, since a scientific inquiry is always and essentially related to human action and value-laden objectives, a fact/value conflation is constitutive for pragmatist thinking. There are thus no facts without values (Dewey, 1986), though one can still conceptually distinguish between the positive and normative purposes of statements. But, how can highly value-laden public policy analyses, if they follow the pragmatist pattern, still generate objective, reliable results to ensure sound science in solution-oriented environmental assessments? Actually, we can never have direct access to things in the real world that are free of any particular value-laden perspective or concepts (Putnam, 1999). Moreover, for pragmatists, there is no possibility to come to infallible, everlasting, absolutely certain knowledge. However, this does not necessarily have to lead to epistemological relativism that can at best refer to an actual consensus among scholars or coherence among theories. The point is that the problematic situations and their resolutions through scientific inquiry

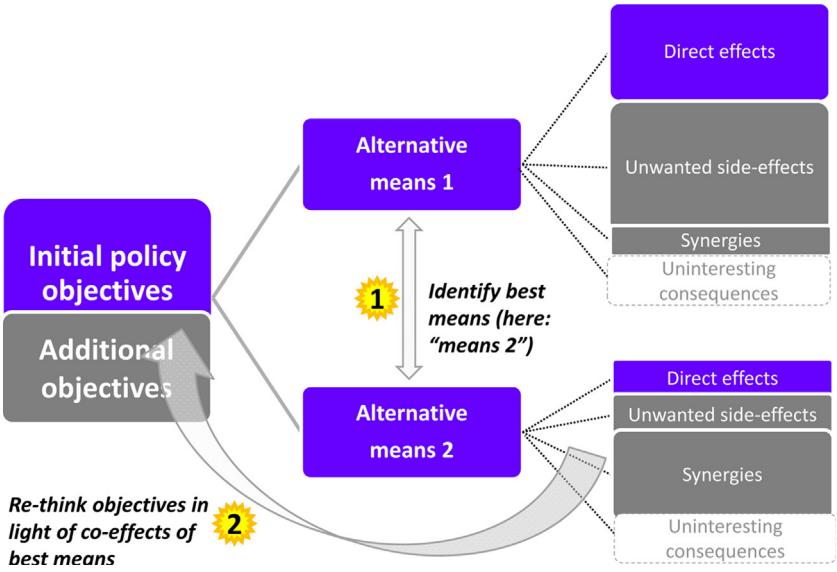

Fig. 1 – The interdependency of objectives and means via their practical consequences. The means (step 1) and the objectives (step 2) are to be evaluated and possibly revised in light of the direct effects and co-effects of the means.

sometimes resemble other situations regarding key characteristics. In this case, the successful results of a pragmatist inquiry could perhaps be applied to these other, similar situations, and perhaps be acceptable for many people. In this sense, hypotheses that have repeatedly turned out to be sound and reliable in terms of their practical consequences for the solution of the problematic situation at stake can serve as the premises for further inquiries, such as, for instance, certain laws of nature, or certain cognitive values and principles in scientific research. It is the reality out there in the world, and the assumed causalities, that make our best natural and social scientific theories—despite always being value-laden—so extraordinarily successful in terms of their problem-solving abilities in similar situations (Putnam, 1999, 2004). Consequently, by exploring and evaluating the practical consequences of the means to achieve policy objectives, scientific research can reasonably contribute also to highly value-laden policy debates.

3. Result: the pragmatic-enlightened model of assessment making

Building on this pragmatist theory of how policy objectives and means can be scientifically evaluated, let us now refine the promising pragmatic model of scientific expertise in policy. This will result in the pragmatic-enlightened model (PEM). In the following, we sketch the structure of a PEM-guided assessment that comprises several stages and that is an echo of standard policy process models (e.g., Dunn, 2012).

The first stage is the comprehensive analysis and definition of the policy problem at stake, which corresponds with step two of the Deweyan pattern of inquiry. The participation of stakeholders and civil society representatives affected by a given problem is useful to adequately identify and address the problem and related objectives in assessments. The importance of an adequate and thorough problem framing can hardly be overestimated. According to an old proverb, a problem well put is half-solved. However, in spite of several decades of discussions on this topic, framing the problem of climate change is still disputed (Hulme, 2009). In these cases, assessments should explore alternative, disputed problem-framings and related policy objectives, and discuss their pros and cons, respectively.

The second stage builds on the interdependency of objectives and means. It comprises (1) the identification of possible means and (2) the critical exploration of the possible practical consequences of these means, using multiple criteria in quantitative and qualitative terms. This is the core stage of a solution-oriented environmental assessment process. As in the first stage, researchers may play a strong role because their elaborated methods come to bear fully here. But, without learning from the people affected by the policy problem and potential solutions, and without taking into account their interests, preferences and fears, researchers are at risk of overlooking relevant objectives and, consequently, specific means-consequences. Moreover, Dewey rightly states that "to participate in the making of knowledge is the highest prerogative of man and the only warrant of his freedom" (Dewey, quoted in Brown, 2009, p. 135). Yet, stakeholder engagement formats and limitations in assessments cannot be discussed here due to the restrictions of space.

A decisive feature of the PEM is that several *alternative* policy pathways (i.e., objectives and means) as well as their practical consequences are explored in a large-scale environmental assessment process and presented to the target audiences at the end. For the PEM, scientific consensus can at best relate to the consistency and scientific quality of the statements on a particular policy alternative. A proponent of the technocratic model could possibly object that there is no need to present alternatives because it is theoretically possible to come to objective scientific statements, even when considering highly value-laden policy evaluations, which was argued when pragmatism was explained above. There are, nonetheless, several reasons to present alternatives. First, the pragmatist methodology presupposes the thorough exploration of alternative pathways before the best pathways can be identified in terms of their practical consequences. There is no a priori method that can help decide what the best policy pathway is, because such an approach would always mistakenly presuppose fixed objectives and criteria instead of interdependency with the practical consequences. Second, due to the many uncertainties and complexities regarding large-scale environmental policy issues, the objective identification of the best policy pathways is virtually impossible, and presenting alternatives and their uncertainties may at least allow for a constructive public discourse; although, for pragmatism, insights can already be useful and valuable if they are mere estimates or opinions instead of fully objective and certain knowledge. Third, independent from methodological thoughts, presenting alternative policy pathways and their consequences may help avoid the misguided use of expertise in policy, as policymakers can no longer legitimate policy pathways by referring to an alleged "inherent necessity" of a certain policy pathway based on a (pseudo) scientific consensus, nor can they refer to scientific uncertainties and disagreements.

Yet, the scope of possible future pathway analyses has to be narrowed down because of the vast range of environmental policy pathways and related consequences and the limited resources available for assessment processes. However, there is a danger of being biased in this selection of pathways because the "definition of the alternatives is the supreme instrument of power" (Schattschneider, 1960, p. 66). To avoid severe bias in assessments, policymakers and other stakeholders should be involved in the selection process also because the chosen pathways have to be relevant to them. In addition, these scenarios ought to reflect several politically important and disputed objectives, ethical values and prevalent policy narratives, respectively.

Once the assessment results are published, there should be an extensive public discourse, e.g., on the national level, about the selected, thoroughly explored, alternative policy pathways throughout society at large. This public discourse is no longer part of the scientific assessment process itself, but is informed by the assessment results and presupposes transparency of important assumptions, value judgments and uncertainty in the assessment report. Following the public discourse, a decision has to be made by policymakers, and the chosen policy pathway (though rarely fully identical to any of the

pathways analyzed in the assessment) has to be implemented as law, for instance.

After the policy is implemented, there is a third and final stage of an assessment. Analogous to step five in Dewey's pattern of inquiry, the *actual* means-consequences need to be explored ex-post. The goal is learning for future policy problems and the next assessment cycle (for example, the periodic IPCC assessments). This third stage can lead to a refinement of earlier problem analyses, objectives and means-hypotheses, as well as a revision of the "meta-narrative," i.e., the selection of competing policy narratives to be explored in-depth. Fig. 2 summarizes the basic structure of a PEM-guided assessment.

The PEM builds on the pragmatist idea that objectives and means are interdependent via their practical consequences, leading to three core characteristics of the PEM: (1) the thorough exploration of diverse practical means-consequences, including co-effects; (2) stakeholder engagement and public discourse; and (3) the mapping of alternative viable policy pathways, with transparency of important assumptions, value judgments and uncertainties. As a refinement of the pragmatic model, the PEM is "enlightened" in that it considers the interdependency of objectives and means and the conditions under which a certain policy pathway can be attractive. In the predominant models of expertise in policy (see supplementary material A.2), no one feels responsible for the practical consequences of a public policy decision.

4. Towards application

Superficially, the PEM claims may seem to be widely shared, just combining the strengths of the prevalent approaches: (1) evaluating both policy objectives and policy means in scientific assessments, and analyzing their costs and benefits (technocratic model); (2) avoiding policy-prescription (decisionist model); (3) and including stakeholders (pragmatic model). This implies that at least some PEM elements seem robust and are not confined to the proponents of pragmatist philosophy. However, the major difference from most existing approaches (exceptions include, for instance, Lasswell, 1951; Habermas, 1971; Dunn, 2012; Douglas, 2009) is the systematic idea of a feedback loop between the objectives and means in policy discourses, which has far-reaching implications for any science-policy model and practice. Through exploring the full range of practical means-consequences and through emphasizing the pragmatist feedback loop with the related learning processes, the PEM goes beyond making value conflicts transparent, as suggested by Robert and Zeckhauser (2011) with their useful taxonomy of disagreements, beyond regulatory impact assessment in the tradition of cost-benefit analysis (Kirkpatrick and Parker, 2007) as well as beyond Pielke's (2007) honest broker of policy alternatives, for instance—though the PEM argues in a similar direction than these approaches do.

Compared to the predominant technocratic and decisionist models, the PEM promises to more successfully avoid policy-prescription in value-laden policy analyses carried out by researchers. This is mainly achieved through (1) the presentation of policy alternatives based on opposing political standpoints and policy narratives, and (2) transparency of disputed assumptions. On the other hand, the scientific exploration of specific policy pathways can be a valuable input for the public discourse and provide highly policy-relevant information on policy objectives, means and particularly their practical consequences. In contrast, negotiating a political consensus should not be the task of researchers, but of policymakers only (see also van der Sluijs et al., 2010). Moreover, the serious engagement of researchers with stakeholders and the public could significantly improve the quality of assessment outreach and public discourses. The pragmatist methodology could also promote more reliable and scientifically sound expertise, since researchers are free to acknowledge the limitations and value-ladenness of their knowledge production.

Among the reasons why large-scale assessments often do not explore policy alternatives (as observed by Hulme, 2009; Siebenhüner, 2003; Pielke, 2007), let alone a broad range of practical means-consequences, seems to be a misguided conception of values. Either values are regarded as subjective and irrational and to be avoided in assessments whenever possible, or researchers, to some extent depending on their discipline, have very strong opinions about them (e.g., in terms of policy narratives) and regard them as fixed criteria, i.e., as

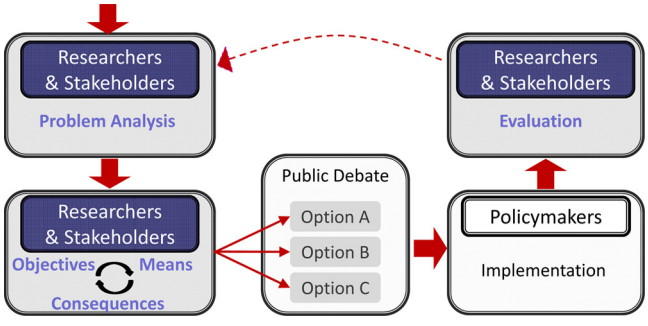

Fig. 2 – The PEM model. The PEM as a model for solution-oriented assessments suggests that after researchers and stakeholders have jointly framed the problem, they explore the objectives, means and consequences. The two white boxes indicate steps in the policy process that are outside the assessment-process per se, such as public debate on alternative policy pathways, as well as policy decisions and implementation by policymakers. Next, there is a scientific ex-post evaluation of the actual means-consequences, which is also the starting point for a new assessment cycle.

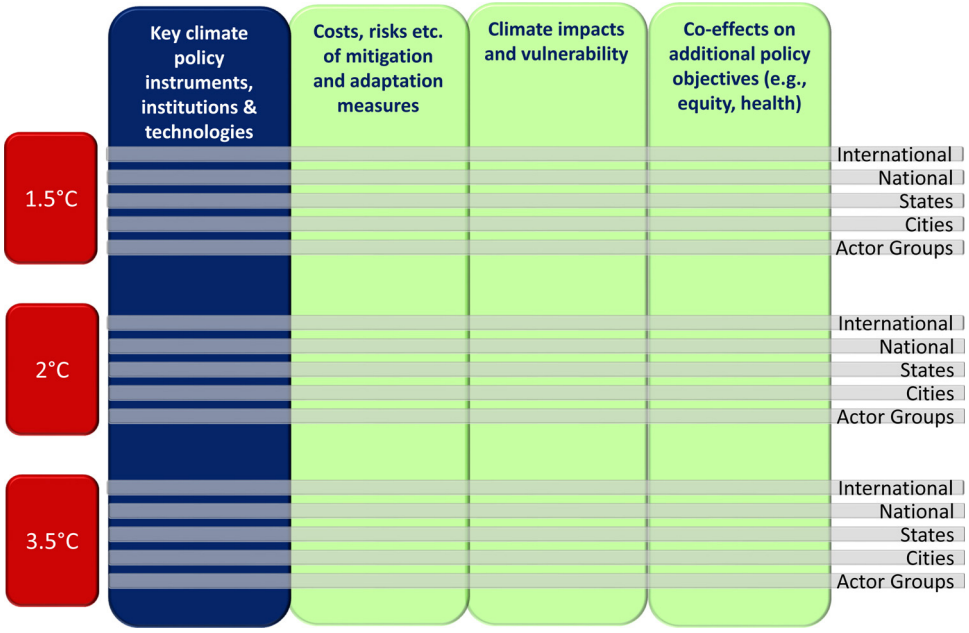

Fig. 3 – Potential key dimensions of future IPCC WG III assessments. Simplified overview of assessment dimensions regarding climate policy pathways. Given the major climate policy objectives of mitigation, adaptation and economic development, future IPCC assessments could perhaps explore the differential costs, risks, climate impacts as well as co-effects related to additional policy objectives in the event of a 1.5 °C, 2 °C or 3.5 °C global temperature rise, for instance.

ends in themselves (Dewey, 1986). Certain conceptions of utility or costs and a single discount rate in economic analyses of environmental policy pathways could fall into the latter category. With Dewey, the PEM offers a methodology that allows for a more constructive discussion and learning process about values and objectives, which may change or be completed when the means-consequences are thoroughly explored in an assessment.

As a framework for environmental assessment making, the PEM can make a significant difference in terms of the specific practices of assessments, including goals and methods for policy analysis and the type of key messages in assessments. The PEM is already being applied in practice, and further testing will be required to critically evaluate its practical consequences. As a prominent example, the PEM already guides the IPCC WG III to some extent (Edenhofer, 2012; IPCC, 2014, Preface). In a Special Report (IPCC, 2011, p. 59, Fig. TS.2.9), the IPCC provided an overview of alternative and highly disputed narratives regarding future bioenergy use and explored some of the practical consequences of each pathway. Moreover, instead of recommending a specific climate mitigation goal or avoiding these disputed political issues, the recent IPCC WG III report (IPCC, 2014) explored the implications of alternative ambition levels for climate mitigation, adopting a multi-metric perspective. Sophisticated multi-scenario analyses were conducted for this purpose that explore the implications of alternative policies, timings, delays and metrics, as well as technological and other assumptions for climate policy in general and specific sectors.[3] Some of the potential co-benefits of ambitious climate policy were analyzed in more detail than before (IPCC, 2014, Chap. 6) to better understand the political solution space. Moreover, the IPCC included a chapter (IPCC, 2014, Chap. 3) on ethical issues to make this crucial and controversial dimension of the climate policy debate more transparent and explicit. The treatment and transparency of uncertainties have also been improved (Mastrandrea et al., 2011), and the IPCC WG III conducted an interesting multi-stakeholder meeting.[4]

Yet, many gaps in knowledge still have to be filled by future IPCC assessments if they are to be guided by the PEM idea. For instance, the policy pathways to be explored by the IPCC should be more directly linked to the existing, disputed policy narratives and social value beliefs, and IPCC assessments could explore even more systematically and comprehensively how the world would look in the event of a 1.5 °C, 2 °C or 3.5 °C global temperature rise. This is because researchers cannot settle the issue of disputed mitigation goals, as this is not a technical or "scientific" question, but is rather, a highly political question. By exploring the practical consequences of each goal, they can however contribute a great deal to this debate.

This, however, would inter alia require more literature on ex-post analyses of climate policies. The various practical consequences of policy instruments that are already implemented are poorly understood, also because there are complex interdependencies between different governance levels and scales. Moreover, to achieve a more comprehensive understanding of the pros and cons of certain policy options, research

[3] See, e.g., http://www.feem-project.net/limits/ and http://ampere-project.eu.

[4] See http://www.ipcc-wg3.de/meetings (Expert Review Meeting in Washington, DC, in August, 2012).

on the socio-economic impacts of climate change, adaptation measures and the socio-economic and technological aspects of climate policies must be combined. This would require merging the current WG III with WG II of the IPCC. A picture as complete as possible of the solution space for climate policy must be achieved, in order to reveal differential impacts and mitigation costs in the event of various climate scenarios. Furthermore, to explore the political leeway, it may also be useful to explore extreme scenarios, including worst-case scenarios, due to the ambiguity that often makes probability-density functions impossible (Kunreuther et al., 2013).

Fig. 3 summarizes some of the PEM-guided thoughts on possible key dimensions of future IPCC assessments in a stylized way.

The PEM-guided cartography of the political solution space is clearly an immense and time-consuming effort. Pre-studies and pre-assessments are required to provide the knowledge needed to fill at least some of the fields about means-consequences in Fig. 3. It is hardly surprising that not all researchers prefer such a laborious, highly interdisciplinary (natural and social sciences as well as humanities) exercise of mapping the frequently uncertain means-consequences. Rather, standard research is often method-driven instead of problem-driven and organized around scientific "tribes." Incentives like academic credits may be useful to make the cartography exercise and the production of pre-assessments more attractive for academics. Moreover, an effective research organization is required to ensure the provision of policy-relevant research to help fill the knowledge gaps indicated in Fig. 3. Assessment bodies may play a key role as coordinators.

Other reservations about PEM-style assessments can be due to the observations (1) that some policymakers as well as researchers might have very clear opinions about the "right" policy option, which they do not want challenged during a PEM assessment (Sarewitz, 2004), and (2) that many governments presumably do not want their policies to be critically evaluated (Siebenhüner, 2003). Therefore, ex-post analyses in assessments sometimes face severe opposition by certain governments (Edenhofer and Minx, 2014). The reason why we regard such arduous assessments as nonetheless worthwhile is our assumption that policymakers and the public are not yet well informed about the specific options and practical consequences of environmental policy, and at least some researchers and stakeholders are willing to learn in this regard. Moreover, without such large-scale assessments and their consistent metrics and definitions, the alternative proposals for policy pathways in different studies cannot be compared and evaluated adequately.

5. Conclusion

This article developed the PEM as a model for solution-oriented, large-scale environmental assessments. The basic claims of the PEM may possibly also be interesting for other formats of scientific expertise in policy. According to the PEM, researchers, along with stakeholders, act as the "cartographers" of different, viable policy pathways and their practical consequences by acting as the "mapmakers" of the political solution space. They provide a guidebook with alternative options for policymakers (i.e., the "navigators") and the public. Such maps cannot replace travelling (i.e., decision-making), nor can they resolve all environmental policy conflicts, yet they can provide an important orientation in otherwise uncharted territory.

The PEM provides a framework for the application of the valuable plurality of research methods and approaches. Mapping possible future means-consequences implies innovatively exploring terra incognita, as the original strength of researchers. For detecting non-trivial, quantitative and qualitative practical consequences, it is useful to apply a broad range of methods and to go beyond standard approaches in a creative and highly interdisciplinary manner. Already rough estimates and mere plausible assumptions can help to understand policy pathways better—as we can learn from Africa's cartography (Krugman, 1995)—though many gaps in knowledge and uncertainty will still block our view into the future. Sometimes, researchers can also substantially contribute to the environmental policy debate by creatively developing new ideas for future scenarios and specific policy options (or detours). Even new policy narratives may stem from scientific discourses (Hulme, 2009).

Mapping policy pathways in assessments is an iterative exercise that frequently requires adjustment if new forks in the road, alternative destinations, pitfalls and uncharted territories turn up. Due to the high uncertainties, long-term issues, such as global environmental change, require trial-and-error policy-making. Assessments can strongly support this through ex-post policy analyses. In the light of newly discovered practical consequences, objectives might be revised and means can be adjusted. Mistakes in policy-making can occur, and from them, society as a whole can learn for the future.

The cartography of policy alternatives and their consequences possibly allows for the identification of potential overlaps between different, disputed policy narratives at the level of specific courses of action in a given context, even if more fundamental value conflicts remain unresolved. This, but also the clarification of the trade-offs, could help to overcome the environmental political stalemate. Juxtaposing general, vague policy narratives and values with the diverse practical consequences of specific policy options could contribute, at least on a long-term basis, to the resolution of social, ideological value conflicts and the often-deadlocked political debates. However, in many cases, conflicts and disagreements over policy options remain. The cartography of policy pathways helps to clarify what the controversies and trade-offs are really about in more specific terms, and to allow for a more direct and constructive discussion. This may also reveal the mere strategic rhetoric of some policymakers. Environmental assessments should, therefore, increasingly analyze issues of political economy and conflicting interests in a differentiated manner, as well as identify the winners and losers of policy options; this would be truly policy-relevant.

PEM-guided assessments envisage, as a long-term impact, learning processes and a reflective equilibrium for alternative policy options and may, in that sense, contribute to the development of a deliberative democracy and to the re-establishment of trust in scientific assessments. However, this presupposes a new culture in academia that provides the kind

of studies needed for this cartography exercise, and that accepts the arduous cartography of, and the sometimes painful learning about, the political solution space as a fully respectable and serious scientific task on its own.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.envsci.2015.03.017.

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