



Common Frame of Reference to support the understanding of adaptation decision-making under high-end scenarios

Deliverable D1.1

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Preface

This document results from a working draft ('living document') about the development of a Common Frame of Reference (CFR) that intends to support the analysis and understanding of adaptation decision-making processes under uncertainty, particularly the extreme uncertainty associated with high-end scenarios (HES).

The development of Deliverable 1.1 (Task 1.1 in WP1) was modified in line with the overall WP1 timeline to allow a quicker development of the empirical work under Task 1.2, i.e. the decision-makers and stakeholder interviews. Initial development work around the CFR took place in 2014 to serve as a basis for the development of the background and template for the interviews. However, it was decided to provide only a draft version of the deliverable by January 2015 so that the experience and findings from the interviews could be used to further refine the CFR. Hence, this final version of the CFR was further developed and refined as the interviews in the IMPRESSIONS case studies were conducted and their findings reported.

According to the project's Description of Work, partners FFCUL, SEI and PLUS were the primary responsible for this work. Contributions from other partners representing WP5, which is developing a framework for the overall synthesis of project outcomes, have been sought and included in this document. Besides input from all the IMPRESSIONS case studies the work presented here intends to provide a solid basis that allows for potential links with IMPRESSIONS' WP3 conceptual framework for the modelling of climate change impacts, adaptation and vulnerability (CCIAV), WP4/5 conceptual framework for developing pathways and strategies, and WP5 conceptual framework for integrated climate governance.

The main goals of this document are:

- a) To present some initial considerations about the contexts in which decision-makers (and those supporting them), involved in climate adaptation-related processes, account for the long-term, acute uncertainties implied by high-end scenarios (HES); and**
- b) To conceptually detail a Common Frame of Reference (CFR) that supports the analysis (through the multiple IMPRESSIONS case studies) of how those uncertainties are dealt with (or not) in the context of existing decision conflicts and other (non-climate) long-term trends and risks.**

The CFR is expected to support the review and identification of key uncertainties and sensitivities as well as potential needs, barriers and drivers for considering high-end scenarios in adaptation-related processes. Furthermore, it aims to frame those decision-making processes through a set of well-defined and soundly conceptualised typologies of adaptation-related decisions that can further (empirically) tested across the IMPRESSIONS case studies. Finally, the CFR seeks to contribute to a clearer understanding of the multiple dimensions involved in adaptation-related decision-making processes, while still allowing for context and culture specificities (e.g. the interfacing nature and relationships between scientific data, uncertainty, decision-support and decision-making).

In line with the overall goals of IMPRESSIONS and the specific objectives of WP1, the outcomes of this work are expected to provide new insights into how planned adaptation occurs in practice and how adaptation-related decision-making processes can be expected to change under HES. Furthermore, these results will potentially lead to a better representation of adaptation (and related concepts) in the suit of models, pathways and other techniques being developed and applied in other WPs in the IMPRESSIONS project.

1. Background and scientific underpinnings

1.1. Climate change uncertainty as an adaptation decision-making challenge

Climate change creates an additional layer of uncertainty for decision-makers, who already face multiple short-term and strategic economic, social and political (i.e. non-climate) challenges. Despite improvements in the climate change science-policy interface (Rayner & Jordan 2010), most decision-makers do not routinely consider future scenarios when making decisions, nor do they find it easy to make use of available knowledge on climate change and impacts (Dessai et al. 2005; Hulme & Dessai 2008; Porter et al. 2012). A common problem is the mismatch between the scale of what is known about the world and the scale at which decisions are made and action taken (Kates et al. 2001).

Science-supported decision-making has been the focus of research in multiple scientific and societal challenges (Willows & Connell 2003; Ranger et al. 2010; Adger et al. 2012). Many environmental, economic and societal decision-making processes as well as their underlying knowledge base, tend to be framed from a particular disciplinary perspective (e.g. natural sciences vs. social sciences; basic vs. applied science; technological or economic vs. environmental focus). Climate adaptation decision-making processes are not a novelty in this regard. Experience has shown that implementing and communicating climate change impacts and vulnerability assessments in support of practical decision-making is a significant challenge (Adger et al. 2005; Tompkins et al. 2010).

Whilst a target to limit climate change to 2°C above pre-industrial levels has been agreed by the EU and subsequently by the UNFCCC, high-end scenarios (HES) are becoming increasingly plausible. HES can be described as those going beyond this target or as representing the upper end of the range of possible futures. Such scenarios include climate and the underlying socio-economic storylines both as the drivers of emissions and as narratives capturing a range of societal challenges. From a natural science perspective HES may imply increasing climate variability and extremes (IPCC 2012) as well as the possibility of triggering tipping points (Lenton et al. 2008), lending further difficulties for assessments. From a societal point of view HES can imply difficulties in processing and using information about highly extreme and uncertain futures, hindering the capacity to respond. As there are potential psychological and social barriers to adapting to a world much warmer than today HES may push ecosystems and societies beyond their limits of adaptation (Dow et al. 2013; Klein et al. 2014) thus raising additional problems for decision-making. Difficulties in mainstreaming climate change concerns into sectoral policies and different governmental levels may be expected, with actors having very different objectives, approaches and sensitivities towards the climate change challenge.

Recent literature on adaptation decision-making under uncertainty (Hallegatte 2009; Stafford Smith et al. 2011; Wise et al. 2014) has highlighted two key gaps: (i) the emerging need for innovative strategies in uncertainty-management methods; and (ii) the notion that such methods need to be framed within a broader sorting of decision types and systematised into adaptation support frameworks. Several frameworks have been developed to assist decision-makers in developing their policies and plans, while simultaneously addressing uncertainties. However, these do not necessarily equip them with the knowledge required to consider HES. Existing modelling frameworks for assessing impacts and vulnerabilities have significant limitations under such scenarios. For example, most impact and adaptation assessments do not account for tipping points and still take a sectoral, short-term and single-scale approach. This may lead to some degree of scepticism (e.g. towards scenarios and other forms of data) on the part of decision-makers that are well aware of these limitations and caveats.

Thus, novel decision-making frameworks are required to deal with HES. This is particularly important because incorporating uncertain scientific evidence about climate change into real-world adaptation processes is bounded by a significant suite of other societal challenges. Therefore, any decision-making framework for HES needs to account for context sensitive conditions within current decision-making processes, paying explicit attention to the importance of existing barriers, decision conflicts and potential trade-offs between incremental and transformative adaptation under HES.

One of the better known examples is the IPCC that has, since its inception in 1998, struggled to express and communicate uncertainties in ways that are meaningful for decision-making. To this end it has published a range of 'guidance notes on uncertainty' to assist authors. In its latest version, used in the 5th Assessment Report (AR5), the process for evaluating the appropriate level of precision with regards to uncertainty starts with evaluating the validity of a finding (Mastrandrea et al. 2010). The validity is measured by a parameter referred to as 'confidence' built up from two dimensions. The first dimension characterises the type, amount and quality of evidence, e.g. model results, theoretical understanding and observation data while acknowledging that such evidence can also vary in its consistency, e.g. projections can be divergent or convergent. The second dimension relates to the degree of agreement and consensus across relevant scientific disciplines. It expresses the authors' synthesis judgement about the validity of a finding as a qualitative term. If the authors agree that the level of confidence allows probabilistic quantification, such information can be provided for communicating the uncertainty of a finding (see Figure 1; Mastrandrea et al. 2010).

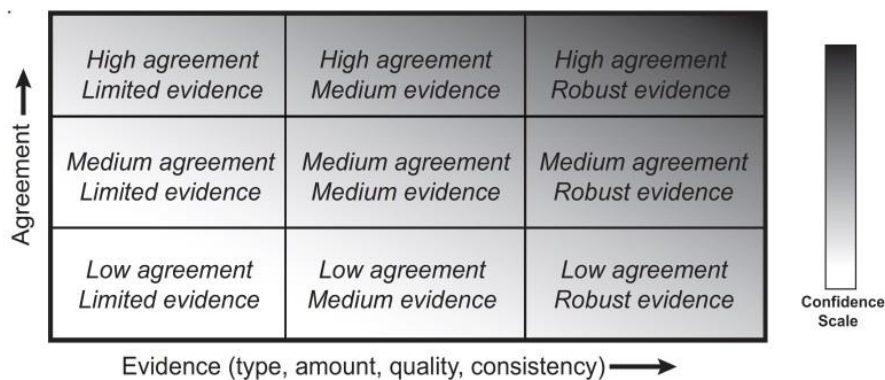


Figure 1: A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent, independent lines of high-quality evidence. Source: Mastrandrea et al. (2010).

1.2. Integrated Assessment in support of climate adaptation related decision-making

IMPRESSIONS is expected to develop a multi-scale and innovative Integrated Assessment (IA) approach to better understand the climate change impacts, adaptation and vulnerability (CCIAV) issues associated with HES. The growing awareness of the intrinsic complexity and close interconnection between the multiple causes and effects of social-ecological problems occurring at multiple scales of time and space have also led to the mounting recognition of the limitations of conventional approaches to support the evaluation and decision-making of the attendant risks, impacts and vulnerabilities, often unable to deal with more than one scale or domain at a time. In addition, the inadequacy in the processes used in the communication of the available knowledge, and in particular in the field of climate change so that it can become useful to policy makers, led to the development of alternative approaches aimed at overcoming the traditional disciplinary fragmentation of scientific knowledge.

Practitioners working in the interface between science and policy first advocated to move from 'disciplinary' research to 'multi-disciplinary', and 'interdisciplinary' research while the more recent 'transdisciplinary' movement that is, working beyond the strict remits of science so as to embrace end-users and actual agents of change (see figure 2) is also receiving mounting attention.

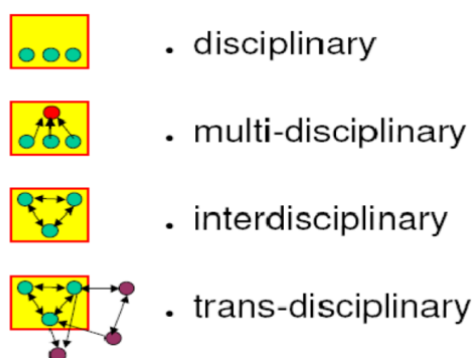


Figure 2: From disciplinary to transdisciplinary approaches in integrated assessment (Source: Pim Martens 'Solution-oriented/transdisciplinary research for sustainable development', presented at the International Conference on Sustainability Science, Rome, June 23-25, 2010)

For nearly three decades, the field of IA has pursued the development of methods to collect, structure, synthesize and communicate multiple sources of knowledge of complex issues to support robust decision making (Toth and Hizsniyik, 1998, Jäger 1998). The criteria of 'robustness' is of paramount importance when considering the quality of the knowledge gathered to support policy making. Being able to decide how to decide is at least as important as the actual decisions.

The successful implementation of climate change strategies depends on the level of legitimacy and acceptance of the processes used to produce the knowledge used in decision-making. In this respect, 'trusted knowledge' needs to be able to withstand the potential conflicts and constant questioning on the validity of procedures used in its production as well as being fit for purpose in the context of application. This calls for a selection and application of explicit assessment criteria and procedures which ensure representativeness of diversity, agreed openness, independence, transparency and ownership, among other more common criteria such as efficiency, equity and to the extent such knowledge serve to broader societal goals such as sustainable development.

In fact the IPCC can be seen as the largest and more comprehensive attempt to develop an IA process to support decision-making with regard to climate change. However, the success on to which extent of such endeavour, based mostly on conventional methods and a particular mode of

interaction, to influence decision-makers in a decisive or transformative way (see IMPRESSIONS WP5 M19 document) is still a question of debate¹.

Trust and the legitimacy of knowledge, while being basic preconditions for the use of knowledge in policy making, by itself cannot guarantee or be sufficient conditions for the use of such knowledge in policy making. Given the IPCC mandate to be policy relevant but not policy prescriptive, present research is indicating that the IPCC reports tend to operate more as 'reference books' rather than as 'manual for action' to support policy-making at European level. Such a mismatch between the production and use of scientific knowledge is conditioned by a number of functional, structural and social factors that prevent adequate joint problem identification and framing of knowledge between producers and potential users.

Hence, conceptual models interpreting the relationships between science and policy and the wider publics either as linear or one-directional processes - also known as the 'deficit models' in the public understanding of science - are being replaced by more iterative ones which understand the structuring of the complexity of the science-policy interfaces as networks of social learning. Heterogeneous agents with multiple claims and concerns are seen to interact also in multiple ways using many different cognitive, expressive and political resources during the various stages of the science-policy development. That is, from the early definition of the problems at stake, to the selection of options and the monitoring of the implemented of decisions, and then back to the redefinition of policy objectives (see section 1.4).

However, and while such framework can be very helpful to underline the different kinds of decisions that relate to the various stages of the policy-making process, it is clear that such over-rationalistic planning approach also needs revision. In fact, the 'rules of interaction' in each stage cannot fully anticipated or predetermined beforehand but constitute emergent properties of 'tinkering complexity' between multiple constituencies of action, in which experimentation and negotiation around particular boundary objects is seen as central for improving the next rounds of science-policy interactions. Both to failures and successes are therefore seen as potential positive sources for reframing of the new modes of interacting, in a cyclical, learning mode².

Decisions aimed at supporting systems transformation pathways require procedures, tools and IA methods oriented to gather structure and communicate transformative kinds of knowledge. Hence, and with regard to sort of adaptation-related decision-making, a major distinction could be drawn between:

- a) Transformative adaptation decisions, which aim at transforming institutional arrangements, e.g. in the redistribution responsibilities about who should be part of the solution and how;
- b) Conventional (or incremental) adaptation decisions, which aim at keeping the overall system and current practices mostly intact.

In IMPRESSIONS WP5 M19 it is argued that confronting and finding innovative solutions to HES demands transformative kinds of knowledge as well as the conventional ones. That is, that both

¹ See Beck (2012) for the criticism on the 'linear model of expertise' of the IPCC based on the knowledge deficit mode of interaction and the strategies of the IPCC to restore 'trust'. In this regard, the literature has identified several strategies to deal with uncertainties: these to be 'reduced' or 'hidden' but in order to 'restore faith' in the scientific knowledge they need to be openly addressed in the most democratic way (see van der Sluijs et al. 2010).

² In this sense the EU project ADAM introduced the idea of a 'Policy Appraisal Framework' to unveil iterative mode of complex interaction, and support 'Integrated Climate Governance' using the overall more transformative and participatory approach, based on the ideas on the Integrated Sustainability Assessment (Weaver et al. 2006; Tàbara 2010; <http://www.tyndall.ac.uk/adamproject/about>)

kinds of knowledge need to be combined and in no case one can replace the other as they serve to different purposes and concerns.

In this respect, it is important to underline the existence in an asymmetry in the way ‘confidence’ is used to assess on the one hand, statements about the severity of climate risks and problems, and statements about possible solutions to deal with these risks on the other. As confidence is assessed, e.g., in IPCC AR5, mostly by the two dimensions level of expert agreement and level of evidence, it is obvious that, when it comes to proposing solutions, and in particular those which have a more transformative nature, many difficulties emerge: it is often much easier to achieve a high level of consensus on the problems than on the possible solutions and in many cases evidence on the effectiveness of solutions is lacking often because such research has not been carried out.

The ‘opportunity space’, defined by the IPCC (IPCC 2014), as to the decision points and pathways that lead to a range of possible futures with differing levels of resilience and risk depend very much of the kinds of knowledge gathered to assess them (figure 3). According to the IPCC, ‘decision points result in actions or failures-to-act throughout the opportunity space, and together constitute the process of managing or failing to manage risks related to climate change’.

It is precisely these kinds of decisions points which the IMPRESSIONS WP1 Common Framework of Reference could help to identify, both to support the development of multi-scale IA tools, methods and knowledge, as to identify the kinds of needs and ways of framing climate-societal problems which can to lead to high-resilience and low-risk futures³.

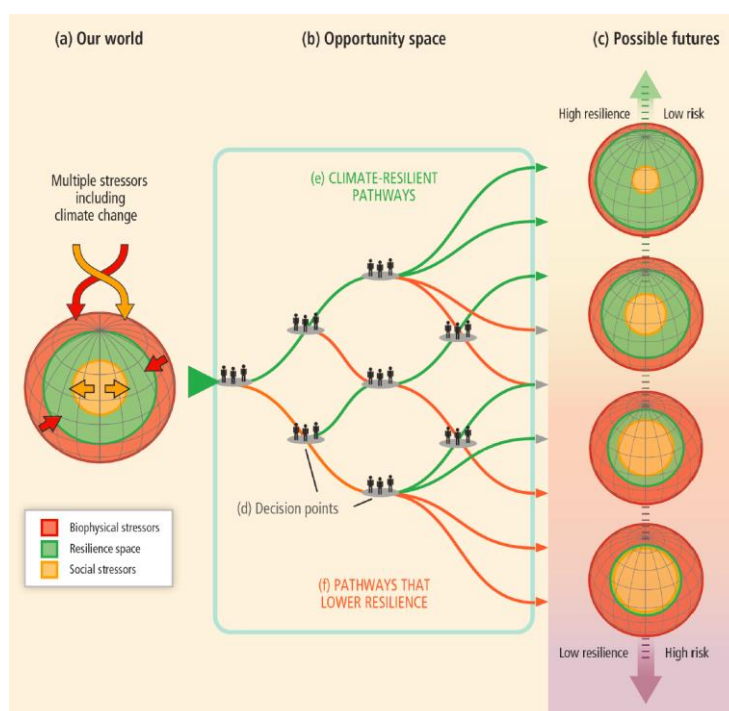


Figure 3: Decision points and the opportunity space. Source: IPCC 2014.

³ According to the IPCC, “Climate-resilient pathways (in green) within the opportunity space lead to a more resilient world through adaptive learning, increasing scientific knowledge, effective adaptation and mitigation measures, and other choices that reduce risks. Pathways that lower resilience (in red) can involve insufficient mitigation, maladaptation, failure to learn and use knowledge, and other actions that lower resilience; and they can be irreversible in terms of possible futures”.

1.3. Decision-making centred approaches to adaptation

While techniques for addressing uncertainties in future climate change have evolved (e.g. the development of Bayesian probabilistic climate projections), such scientific advances do not always translate into improved decisions or clearer treatment of uncertainty in practice (Mearns 2010) - and can even have the opposite effect (Hall 2007; Tang & Dessai 2012). This underscores, for example, the importance of co-producing knowledge and tools to deal with uncertainty directly with stakeholders (Hanger et al. 2012), particularly for HES.

Various frameworks and a multitude of national and international support platforms, such as the EU Climate-Adapt platform, have been developed to assist researchers (and 'boundary' personnel) as well as decision-makers in the development of adaptation policies and strategies, while simultaneously addressing uncertainties (e.g. Walker et al. 2003; Willows & Connell 2003; Dessai & van der Sluijs 2007; Ranger et al. 2010; Hanger et al. 2012; Patt et al. 2012). Usually aimed at capturing and describing the complexity of (science-supported) adaptation-related policy- and decision-making processes, these frameworks argue strongly for decision-centred approaches by conceptualising, developing and providing comprehensive and pragmatic guidance, techniques and tools for dealing with, among other issues, uncertainty, long time horizons and contested values (Wise et al. 2014). However, these decision support frameworks are not necessarily designed to equip decision-makers with the knowledge they require to consider adaptation under HES nor do they necessarily provide researchers (and boundary organisations) with the tools to support them in 'navigating' such high-end future worlds.

Such 'worlds' may be characterised by complexity of feedbacks and potential tipping points in the climate system at higher degrees of change. Adapting to a 4°C warming, for example, cannot be seen as a mere extrapolation of adaptation to 2°C (Stafford Smith et al. 2011). HES, therefore, require a more careful and nuanced approach to dealing with uncertainty that goes beyond the current state-of-the-art. HES represent stronger prospects of additional challenges for mitigation, adaptation and decision-making in general. This means that several key decision-making elements need to be better framed in order to re-conceptualise adaptation under HES including, among others, the:

- Decision lifetime (i.e. the sum of lead and consequence time) and the need to nest short-term action into longer-term frameworks;
- Uncertainty envelope in both climate change drivers and the type of adaptation responses;
- Necessary acknowledgement of cultural, political and economic contexts;
- 'Resilience' nature or scope of actions, e.g. incremental and/or transformative change and development of continuous 'adaptive' pathways;
- Multi-scale issues surrounding governance systems and institutions; and
- Need for innovative science-based methods, tools and indicators to support decision-making.

The lifetimes of a set of different types of adaptation-related decisions are shown in Figure 4 against the timescales of some of the main projected global changes and implications for adaptation. Further detail is provided in Table 1 on the implications of combining different types of responses and lifetimes of adaptation-related decisions with different types of uncertainty drivers, including consideration of current characteristics of decision-making about risk.

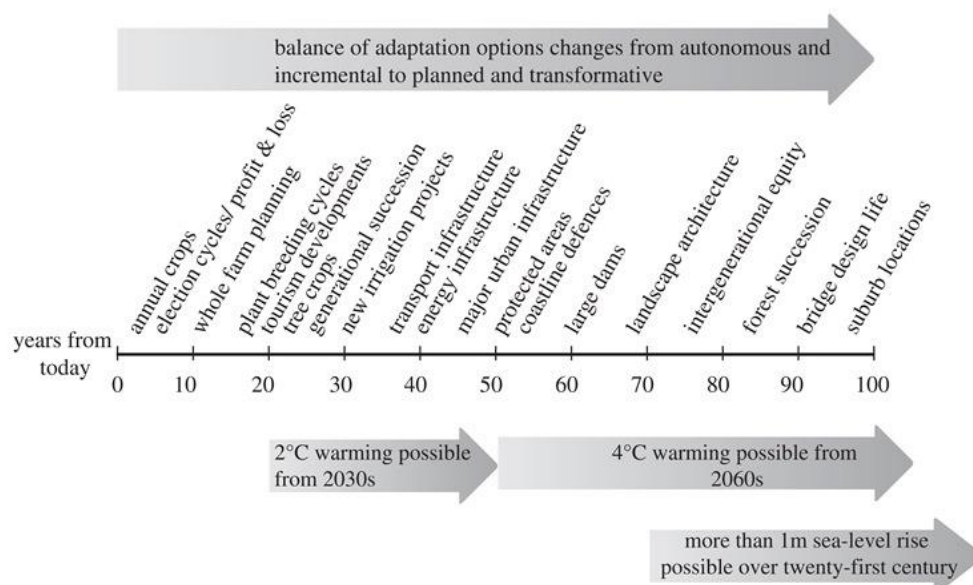


Figure 4: Timeline illustrating the lifetimes (sum of lead time and consequence time) of different types of decisions, compared with the time scales for some global environmental changes, and the changing implication for adaptation. Source: Stafford Smith et al. (2011).

It is important to acknowledge that adaptation-related decisions are neither made in isolation from other factors nor are they immune to changes in context specific situations such as culture, economy, politics, resources, institutions, and geography among others (O'Brien et al. 2004; Adger et al. 2008; Adger et al. 2012; Engle et al. 2014).

Therefore, these decision-making processes comprise a high level of uniqueness and solutions have often to be determined on a case-by-case basis. Each decision goes through a unique process of development and implementation (Walker et al. 2003). This raises, for example, the question of whether it is possible to extract comparable and valuable lessons from how other decision-makers across different cultural and socio-economic contexts dealt with uncertainty and ultimately how they came to decide on adaptation actions.

Table 1: Implication of different combinations of decision lifetimes, driver uncertainty type and adaptation response types for decision-making strategies and tactics under diverging climate futures. Source: Stafford Smith et al. (2011).

	decision lifetime, relative to rate of climate change	type of driver uncertainty	type of adaptation response options	characteristics of decision-making about risk	some options available to reduce decision risk ^a
1	short- or long-term	monotonic or indeterminate	same type and extent of response under all scenarios	'no regrets': normal business planning to implement response cost-effectively	monitor to ensure no regrets response still suffices
2	short-term (easily reassessed)	monotonic or indeterminate	little divergence between scenarios over short-term means considering only one set of responses	ongoing, incremental adaptation in line with pace (and direction) of change	monitor rate of change to provide advanced warning of thresholds and need for transformation
3	long-term (implications may last for 50-100 years)	monotonic	same type but different extent of response for different scenarios	precautionary risk management: use benefit-costs analysis to determine appropriate level of response now	reassess regularly to ensure rate of change still in risk envelope; real options, safety margins, shortened decisions
4			different type (and extent) of response for different scenarios	risk-hedging against alternative futures (with gradual transfer of resources as uncertainty diminishes); act now, given monotonicity	high likelihood of need for transformation at some stage; reversible options, soft adaptations; shortened decisions often impossible
5		indeterminate	same type but different extent of response for different scenarios	robust decision-making paradigm in the face of uncertainty about direction of change	monitor change to identify if conditions are moving outside 'robust space'; reversible options, safety margins, soft adaptations, shortened decisions all useful
6			different type (and extent) of response for different scenarios	risk-hedging against alternative futures (with gradual transfer of resources as uncertainty diminishes); delay acting if possible	hardest combination: real options most likely to pay off if possible; likely to need support from higher levels of governance

^aAbbreviated terms for some options from Hallegatte [8] and Dobes [49]: '*real options*'—conscious decision delay where benefits of improved information exceed risk of costs of delay; '*reversible options*'—favouring reversible and flexible options; '*safety margins*'—buying safety margins in new investments (e.g. bigger foundations pre-adapted to higher structures that are not yet built); '*soft adaptations*'—promoting changed behaviours and arrangements over physical infrastructure (e.g. reduced household water demand rather than a new dam); '*shortened decisions*'—reducing decision time horizons (e.g. housing with a short lifetime) within a long-term view.

Research into decision-oriented approaches has been evident in recent years as these seem to be regarded as more able to tackle the challenges of planning for future uncertain consequences of change and unpredictable values and preferences of future societies (Wise et al. 2014).

Recent efforts of further developing the concept of adaptation (and mitigation) pathways focused on processes rather than on the outcomes of decision-making, has led to the expansion of the current 'cycle of decision' framing into long-term contextual, iterative and time-dependent pathways of continuous responses framed within a non-linear space (figures 4 and 5). Methods for constructing 'response pathways' with stakeholders to the challenges presented under HES are being developed in IMPRESSIONS WP4. These will be tested by the CCI-AM models in WP3 and comprehensively analysed in WPs 4 and 5.

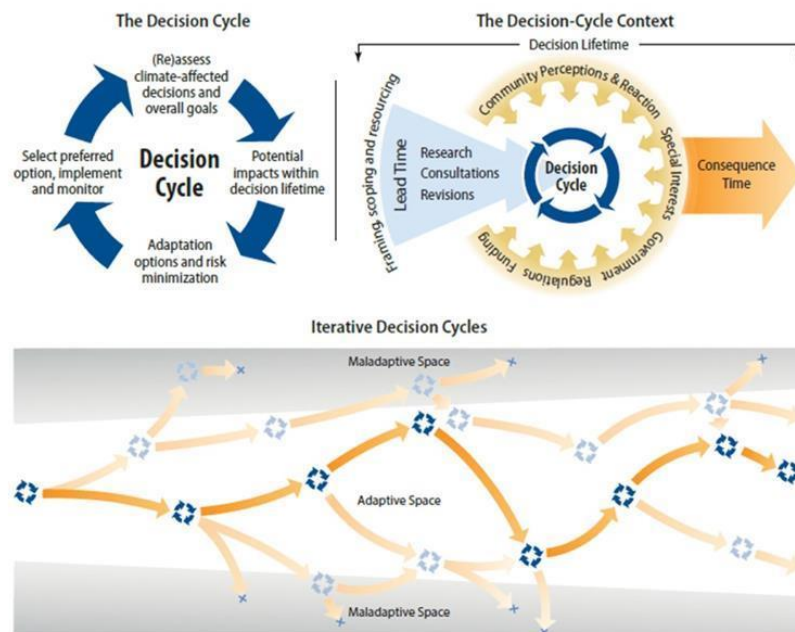


Figure 4: The current ‘classic’ conceptualisation of adaptation pathways – as a series of adaptive learning decision cycles over time (top left, cf. Willows & Connell 2003; Haasnoot et al. 2013) with their decision lifetimes (top right – the sum of lead and consequence times, cf. Stafford Smith et al. 2011), where some chains of decisions lead to maladaptive outcomes over time, but there may be other alternatives that are adaptive (bottom, cf. Reeder & Ranger 2011; Haasnoot et al. 2013). From the perspective of the current decision point at the left, a currently satisfactory pathway can be plotted through the future (strongest colour), but this must be re-visited at each decision point. Source: Wise et al. (2014).

Over the past years adaptation has been analytically framed in multiples ways (Table 2; Wise et al. 2014). Adaptation research (and to some extent also adaptation practice) has seen analytical developments, e.g. in terms of methods, tools and frameworks, ranging from completely positivistic/reductionist perspectives to more rationalist and even post-normal approaches.

It has been argued that practice-oriented research (*Science for adaptation*) as well as fundamental inquiry and disciplinary concept development (*Science of adaptation*) are required to move adaptation action forward (Swart et al. 2014). Decision-making under uncertain HES may provide the ultimate example of such a need as it will require significant efforts both from policy and practice as well as from an analytical perspective.

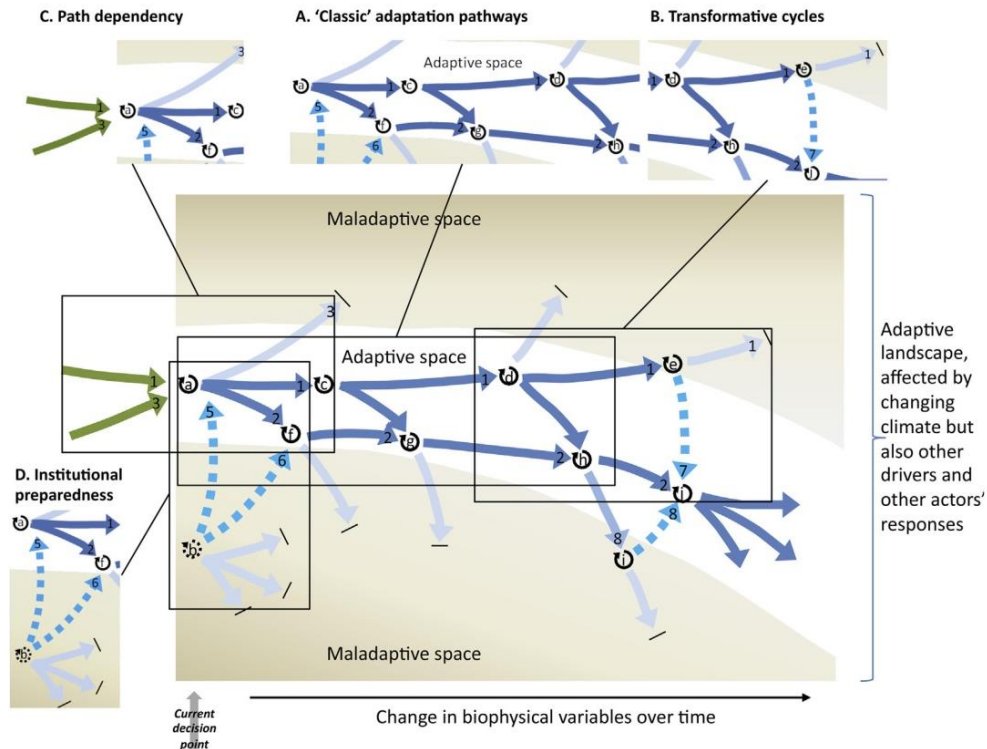


Figure 5: One decision-making actor’s adaptation pathways through an adaptive landscape, where the boundaries between adaptive and maladaptive responses are changing over time, due to biophysical changes, but also due to changes in social and institutional context, including the actions of other decision-makers who may perceive different adaptation pathways. Circle arrows represent decision points, dark blue arrows represent pathways that are contemporaneously adaptive, grey arrows lead to maladaptive dead-ends; dashed blue arrows represent more-or-less transformative pathway segments, and the green arrows show antecedent pathways prior to the current decision cycle. Source: Wise et al. (2014).

Table 2: Summary of seven analytical framings of adaptation. Source: Wise et al. (2014) based on UNEP (2012).

Framing	Focus and emphasis
Livelihoods-based	This approach emphasises the importance of existing social conditions, individual perceptions, local experiences and informal institutions as critical aspects for determining how communities cope with current climate conditions as a starting point for developing appropriate adaptation responses
Impact-analytical	This approach of the IPCC views adaptation as a single (or few) decision(s) that is (are) taken on the basis of projected future impacts, where it is assumed impacts and decisions can be singled out and formally quantified and evaluated using multi-criteria, cost-effectiveness or cost-benefit analyses
Institution-analytical	This framing emphasises the need for horizontal integration of policy to mainstream climate change adaptation considerations into existing policy processes
Decision making under uncertainty	In this framing, the analysis starts with a concrete decision (e.g., raise dikes) based upon all information on the range of possible impacts, rather than with climate scenarios and projections of impacts
Social & institutional process	This framing emphasises how in linked social-ecological systems the outcomes of actions can usually not be predicted as they depend on actions of many agents as well as the social, cultural and natural context. The focal points of analyses thus are institutions (formal and informal rules) that shape the interplay between the actors
Multi-level governance	This framing emphasises how the cross-scale and systemic nature of climate impacts requires understanding and creating multi-level institutions and organisations that promote vertical and horizontal integration
Social learning & adaptive management	In this framing, the complexity and non-determinism of many resource management situations is recognised and adaptive processes of improving management goals, policies and practices through learning are adopted to help bridge the science-policy gap

One example of methodological approaches that are closely related to decision-making in the context of climate change is the issue of valuating costs (of adaptation measures) and benefits under different future outcomes. The economic methods depend heavily on the ability to estimate future market and non-market values. These methods face many criticisms that are mostly exacerbated in the context of climate change, and more especially under complex, highly uncertain and long-term scenarios such as HES.

A comprehensive review of different methods for such valuations is underway in IMPRESSIONS WP5 Deliverable 5.1. This makes the fundamental distinction between probabilistic (e.g. cost-benefit and cost-efficiency analysis) and non-probabilistic (e.g. threshold-based and mini-max regret) methods. Such distinctions are also fundamental for decision-making in relation to high-end risks under deep uncertainty and will be further taken into account in the final version of the CFR.

1.4. Understanding decision-making under uncertain HES

In order to advance our understanding of how adaptation-related (and -relevant) decision-making processes occur in real world cases, there is the need for analytical frameworks that are of practical use when investigating decision-maker's choices, in particular if operating under the assumption of 'high-end' uncertainty. However, practical experience from national and international decision-makers both in Europe and in other parts of the world has shown how difficult it is to apply such theoretical frameworks to real-life adaptation decisions (Capela Lourenço et al. 2014). Uncertainties in the evidence and the application of the necessary knowledge base are obviously not the only reason for concern. Yet they rank highly when considering questions such as 'how to make an adaptation decision?' or 'how to implement adaptation in practice?'

If positioned in a broader adaptation-related context or, for example, as they naturally occur in a risk management cycle, decision-making processes usually encompass some initial framing of the adaptation problem followed by a set of decision-support activities such as research, consulting or policy analysis, and finally the making of an actual decision and the monitoring and evaluation of its outcomes (Walker et al. 2003; Willows & Connell 2003; Dessai & van der Sluijs 2007; Ranger et al. 2010; Kwakkel et al. 2011; Hanger et al. 2012; Patt et al. 2012; Wise et al. 2014).

These conceptual descriptions of an adaptation-related decision-making process have some common key features that evolve along time as more research into the topic becomes available, namely:

- Their iterative nature;
- The presence of multiple steps (or stages) and feedback mechanisms; and
- A growing representation of complexity, both in the number of involved agents and in the links across them (i.e. decision-makers and decision-support agents).

However, the entry point to these processes is not necessarily always the same and, in practice, the stages in decision-making will not always follow from one another consecutively. It is often necessary to return to previous steps, e.g. to take into account new options only identified after a first round of assessments or appraisal work (Willows & Connell 2003).

Different systems may also need to be assessed differently and pre-existing conditions may influence the way a decision-maker acts and goes through this cycle. Furthermore, each decision or policy undergoes its own unique process of development and implementation with the involvement of researchers or other analysts potentially taking many different forms (Walker et al. 2003).

1.5. Developing new ways to support decision-making under uncertain HES

IMPRESSIONS will take account of these issues in the development of a novel decision-making framework, the CFR, which accounts for highly context sensitive conditions and barriers (Moser & Ekstrom 2010). It will locate decisions about HES within existing decision-making processes, paying explicit attention to the importance of existing obstacles, decision conflicts and trade-offs.

The methodological framework will not pre-empt the views of decision-makers by imposing climate uncertainty as the key barrier to decision-making. Instead, it will seek to draw on an analysis of existing needs, drivers and barriers in real-world decision-making processes (e.g. including psychological factors and political and economic incentive structures).

From an on-going literature review and reflections within IMPRESSIONS, it is possible to start outlining how a successful support framework for adaptation-related decision-making under HES looks. Namely, such a framework needs to:

- Acknowledge diversity, by recognising that not all decision-making processes are equal nor are the uncertainties they face;
- Provide proper systematisation, by framing adaptation processes within a broad classification of decision-making types;
- Harness complexity, by allowing decisions involving simpler aspects of uncertainty not to be inhibited by elements of uncertainty that are particularly problematic or difficult to handle;
- Reduce the necessary level of cognitive processing, by allowing for more explicit and transparent means to deal with uncertainty;
- Provide uncertainty-explicit analytical pathways, by turning complex decision-making processes into manageable and actionable pathways;
- Reduce current decision-making risk in face of uncertainty, by allowing for flexibility and adjustment to current practices, tools and realities;
- Aim at improving current and future decisions, by helping both decision-makers and those supporting them to arrive at better adaptation solutions;
- Focus on decision-making oriented approaches as primarily analytical framing without compromising (and recognising) other potential framing approaches;
- Be able to deal with multiple 'typologies of context' and the complexities of problem-solving approaches;
- Allow both positivist/reductionist and rationalist approaches to be deployed;
- Consider multi-level complexities by allowing continual cycles between incremental and transformative actions;
- Be transparent, by including a clear understanding of definitions, variables, data sources and methods;
- Allow for transdisciplinarity and interactivity with stakeholders, when needed;
- Allow for the use of current specific vulnerability and adaptation indicators and proxies without compromising the development and use of more generic resilience ones;
- Consider feasibility as criteria and include means of verification and learning.

The ultimate goal of the CFR is to provide an initial understanding and framing to adaptation decision-making processes (including under HES), so that a set of conceptualised types of adaptation-related decisions are provided and support the empirical work carried out with decision-makers, throughout IMPRESSIONS case studies.

Interviews with decision-makers in each of the case studies will provide empirical evidence for identifying the critical needs, capacities, drivers and barriers of European decision-makers for considering HES and their associated uncertainties, in the development of adaptation policy and practice. Over the course of IMPRESSIONS this evidence will be used to further refine the CFR and improve the understanding of how adaptation-related decision-making processes occur in reality, including how decision-makers deal with the uncertainties associated with HES in the context of their existing decision conflicts and other (non-climate) long-term trends and risks.

In addition the assembled knowledge will be used to enhance the representation of adaptation processes (i.e. decisions and their outcomes framed by HES contexts) in the suite of models being developed and applied in WP3 of the IMPRESSIONS project.

2. Developing and applying a new Common Frame of Reference

In this section we present a first conceptual draft of the Common Frame of Reference (CFR). To provide a useful tool for the systematic analysis of a wide range of adaptation-related decisions the IMPRESSIONS CFR must ensure cross-contextual comparability (thus the ‘common’). For this reason the CFR should contain analytical elements that allow for the description and systematisation of, among others:

- Common typologies of decisions, non-decisions and associated uncertainties;
- Common definitions, understandings and disagreements;
- Common insights on practices of dealing with climate and non-climate adaptation information;
- Common outcomes (positive or negative) of decisions (if available).

Because of the context of IMPRESSIONS, the CFR must explicitly account for the use of HES. It is suggested that this is done by using the framework to evaluate the current - or planned - uptake of HES as a support to evidence-based adaptation decision-making, bearing in mind different scales and contexts. This may include, for example, looking at EU and national climate actions and policies. The case studies are expected to provide such a context.

In order to develop a methodological framework that supports the understanding of adaptation decision-making processes under HES, it is proposed to start by looking at frameworks that analyse how those processes have evolved so far, i.e. not specifically focusing on high-end ‘worlds’.

This does not mean that two separate CFRs will be developed (i.e. one without high-end followed by one with high-end), but rather that existing concepts and methods which have been used previously to analyse adaptation decision-making processes can serve as the starting point. In other words, one CFR will be developed that allows for comparability across scales and contexts and, thus, is suitable for using across the project’s case studies.

Existing work proposed in Capela Lourenço et al. (2014) has been used as the starting point for the IMPRESSIONS CFR. Here, the authors developed an initial Common Frame of Reference (see Figure 6) that was used in the analysis of twelve real-world examples of science-supported adaptation decision-making processes and as a guiding framework to explore the effect of uncertainties in these sorts of decisions. It was based on both the academic literature and on the practical experience of the authors in dealing with adaptation -related processes in real-life cases.

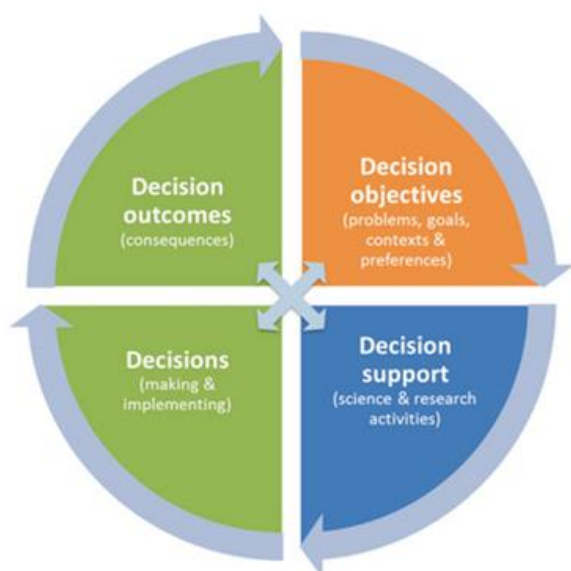


Figure 6: Four-dimensional Common Frame of Reference to support the analysis of science-supported climate adaptation decision-making processes (Capela Lourenço et al. 2014).

The framework consists of four interconnected and complementary dimensions: (i) decision objectives; (ii) decision support; (iii) decision-making; and (v) decision outcomes.

These dimensions are often depicted separately in the literature, under different denominations or as part of a decision cycle. Combined into this CFR they are not intended to represent any prescriptive or rigid structure, but rather a flexible representation of what can commonly be found in real-world adaptation-related decision-making processes.

Equally, this CFR does not intend to be exhaustive, but rather to provide a common approach in understanding how adaptation decision-making under uncertainty develops (and in IMPRESSIONS under HES). This is particularly useful when comparing across different decisions types, decision support methodologies, and variable geographical, socio-economic and cultural realities.

Each of the CFR's four dimensions consists of a set of key features (or typologies) that are designed to allow for a conceptual screening of any real-world adaptation-related decision (see Table 3). The CFR thus provides an analytical framework that maps those decisions against the same common background allowing for comparability and further research into how adaptation decisions are made.

In IMPRESSIONS this is particularly useful since there are five case studies, each with a different subset of decision-makers (to be interviewed in Task 1.2), and different scenario (WP2) and modelling frameworks for different sectors and scales (WP3).

Additionally, one of the objectives of WP1 is to ensure that insights gained from the empirical analysis are used to inform the project so that scenario and model development can be advanced in ways that deliver useful and relevant results for decision-making (e.g. advancing the representation of adaptation processes in models).

This means that the use of a CFR provides the ideal basis to screen, in a traceable and systematic fashion, all types of decision-making processes uncovered by the IMPRESSSIONS case studies, both in terms of empirical knowledge gained via interviews as well as through scenario/modelling exercises.

Table 3: Summary of some of the key features of the Common Frame of Reference four-dimensions (to be further developed in IMPRESSIONS).

Decision objectives	Decision support			Decision-making	Decision outcomes
	To model or not to model?	Top-down or bottom-up?	How certain am I?		
Normative/regulatory	Model-based	Predictive top-down (optimisation or 'science-first')	Statistical uncertainty	Decision made and implementation agreed	Monitoring and evaluating approaches
Strategic/process-oriented	Non-model based	Resilience bottom-up (robustness or 'decision-first')	Scenario uncertainty	Decision delayed	
Operative/action-oriented			Recognised ignorance	Decision not made or not related to adaptation	

2.1. Decision objectives

The entry point to an adaptation decision-making process is often connected with the definition of its objectives. This ‘decision objectives’ dimension of the CFR relates to the adaptation problem, as well as to the goals, objectives, values and preferences of the decision-maker and those of the relevant stakeholders and agents.

Choices and decisions will affect the structure and/or performance of the system to which they are applied, so context is very important and plays a determinant role in this dimension. Although sometimes developed in isolation by decision-makers and their support teams, a decision objective is very often discussed with, or constrained by, stakeholders of all sorts.

Within this dimension three types of objectives can be identified, each with its own specificities in terms of uncertainty management:

- **Normative or regulatory**, associated with governance actions that aim to establish a standard or norm;
- **Strategic or process-oriented**, associated with the identification of long-term or overall aims and the necessary setting up of actions and means to achieve them;
- **Operative or action-oriented**, related to the practical actions and steps required to do something, typically to achieve an aim.

Breaking down adaptation decision-making processes that encompass multiple problems into single adaptation decision types does not imply that these are taken in isolation nor that context should be forgotten. But in the real-world even if the same adaptation process encapsulates multiple decisions they do not all necessarily share the same information needs.

For example, if a municipality decides that a flood prone area needs to be adapted against future climate change impacts, it may need to change not only planning instruments (normative), but also physical infrastructures such as roads (operational).

Figure 2 may be used to provide a hypothetical example of how to apply this dimension. Each of the 19 adaptation options presented in the figure, along the time axis, can be characterised according to its specific decision objectives (see table 4).

Table 4: Illustrative distribution of each (types of) adaptation options per categories of decision objectives.

Type of decision (as per Figure 2; Stafford Smith et al. 2011)	Decision objectives (interpretation by the authors)
Annual crops	Operational
Election cycles/profit & loss	Strategic
Whole farm planning	Strategic
Plant breeding cycles	Operational
Tourism developments	Strategic
Tree crops	Strategic/operational
Generational succession	Strategic
New irrigation projects	Strategic
Transport infrastructure	Normative/Strategic
Energy infrastructure	Normative/Strategic
Major urban infrastructure	Normative/Strategic
Protected areas	Normative/Strategic/Operational
Coastline defences	Normative/Strategic/Operational
Large dams	Strategic/Operational
Landscape architecture	Normative/Strategic
Intergenerational equity	Normative/Strategic
Forest succession	Normative/Strategic/Operational
Bridge design life	Normative/Operational
Suburb locations	Normative

A similar logic will be applied to each of the IMPRESSIONS case studies, using the outcomes of the interviews with decision-makers to map out and analyse what specific types of adaptation-related decision objectives are at stake in each case. An analysis of existing needs, drivers and barriers (particularly those that are non-climate) of each particular decision type, as well as decision conflicts and trade-offs that may occur under HES, will be assessed via the interviews with decision-makers (and in accordance to the overall goals of each case study).

From the on-going literature review it is possible to describe and systematise an initial set of elements that provide a basis for characterisation of the CFR decision objectives dimension and its future application to the case studies.

Table 5 provides an example of emerging characteristics of adaptation decision objectives that can be further explored and clustered for analysis via the interviews.

Table 5: Initial characterisation of adaption decision objectives.

Decision objectives
Lifetime (lead + consequence time); definition of short- and long-term dependent on the type of decision
Resilience scope (incremental and/or transformative action)
Address prevailing governmental arrangements vs. institutional transformation

2.2. Decision support

The 'decision support' dimension refers to the science, research or other types of activities (such as consultancy or policy advice) which are designed and carried out to support the adaptation decision-makers and the problems being considered. Basically the whole of the IMPRESSIONS project is a potential adaptation decision support activity if used for that purpose (as stated in its work plan).

This dimension and the way uncertainties are dealt with within it can also be associated with the broader adaptation context as it can usually be seen in, for example, a risk management process cycle. Decision support activities are obviously not exclusive to the adaptation context and are carried out in a variety of policy and decision problems.

Three generic features - among others to be further developed in IMPRESSIONS - that are of relevance to this dimension can be distinguished:

- **To model or not to model?** A common approach to decision support is to create a numerical model of the system, defining its boundaries and structure. It is likely to represent the system's elements and the links, flows and relationships between them. Nevertheless, most decisions are made without the use of a model;
- **Top-down or bottom-up?** The direction of the approach that is applied to support the decision-making process. In other words, the direction used by the adaptation assessments or other support activities that are carried out, the way uncertainties are handled and ultimately the advice produced. The literature usually distinguishes between 'predictive top-down' (also termed optimisation or the 'science-first' approach) and 'resilience bottom-up' (also named robustness or the 'decision-first' approach);
- **How certain am I?** Uncertainties manifest themselves along a spectrum that progresses from a theoretical full deterministic knowledge of a system ('I'm completely certain of what I know') to an extreme of total ignorance ('I don't even know what I don't know'). The sort of activities that support decision-making usually fall in between these extremes and deal with three more 'realistic' levels: statistical uncertainty; scenario uncertainty; and recognised ignorance.

Under IMPRESSIONS there is a broad range of intended adaptation support activities (e.g. climate and socio-economic scenarios, visions and pathways, models). Hence, it would be beneficial to start by fitting a specific predefined set of scientific and philosophical underpinnings (or good practices) to the activities that actually emerge from the case study interviews. These can then be assessed under HES later in the project in order to understand if their basic assumptions hold.

From the on-going literature review it is possible to describe and systematise an initial set of elements that provide a basis for characterisation of the CFR decision support dimension and its future application to the case studies.

Table 6 provides an example of emerging characteristics of adaptation decision-making support that can be further explored and clustered for analysis via the interviews.

Table 6: Initial characterisation of adaptation decision-making support.

Decision support
Uncertainty scope (characterisation; tools and methods); robustness; scenario-based; risk-hedging
Uncertainty driver; for drivers of relevance to the decision; monotonic (uncertainty on timing) or indeterminate (uncertainty on timing + effect)
Nested decision-making; short-time embedded in long-term frameworks
Allow for flexibility on the timing of actions
Provide guidance and clarity
Allow continuous adaptation (including transformative actions)
Pathways approach (process-focus) emphasising the adaptive nature of decision-making processes in the face of uncertainty and complexity
Understand the 'resilience scope' (when, where and how to connect incremental action with transformative aspects)
Draw upon efforts in 'cognate' sectors (e.g. DRR, water resources) and sustainable development
Clear analytical framing critical for support at multiple levels, i.e. incremental + transformative
Vulnerability vs. resilience framing? Vulnerability framing works better for specific risks/actions while resilience works better in addressing a broader spectrum of impacts, their interrelationships and dynamics? Does a resilience framework actually improve decisions under uncertainty?
Quantitative approaches (indicators, models, proxies) require: common definitions, methodological standards (both for development and application), transparency, and stakeholder participation (for clarity on assumptions, variable selection, sources, aggregation and interpretation of results)
Qualitative approaches (case studies, expert elicitation) can aid in establishing rules for indicator development and aggregation, validate frameworks, and locate causal factors at local and regional scales
Assessing resilience requires balancing comparability and data needs with the local specific nature of resilience and with manageable data collection efforts
Hybrid approaches can help in nesting decision-making frameworks, by focusing on both short-term coping and long-term adaptation aspects of resilience
Past events should not be used as a one-off resilience indicator but rather treated as an opportunity to test and improve indicators

2.3. Decision-making and decision outcomes

Within this section we consider the final two dimensions together. These two dimensions deal with the actual ‘real’ adaptation decisions that are made and their consequences (including monitoring and evaluation needs). The former is rather straightforward to analyse since it can be directly traced to implementation, e.g. a decision that was made and implemented thus can be assessed against initial objectives. In contrast, the latter is difficult to evaluate since some time has to pass (shorter for climate variability and longer for climate change) until the consequences of the decision are visible and can be evaluated. This needs to be taken into consideration during the IMPRESSIONS case study interviews.

Nevertheless, from the on-going literature review some emerging elements can be derived for both dimensions. Table 7 provides examples of characteristics of adaptation decision-making and its outcomes that can be further explored and clustered for analysis via the interviews.

Table 7: Initial characterisation of adaptation decision-making and decision outcomes.

Decision-making	Decision outcomes
Barriers: multi-scales and governance structures; philosophical, cultural, social and technological; cognitive	Monitoring and evaluation even for no-regrets (same type and extent regardless of uncertainty driver)
Adaptation responses (type + extent); connection to uncertainty drivers (whatever or no-regrets; uncertainty dependent, different in different scenarios)	Monitoring and evaluation that provide plenty of lead time, especially for more transformative change (may need to include higher levels of decision-making)
Different analytical framing issues equate to different decisions from a decision-maker perspective?	Monitoring and evaluation indicators to allow identification of ‘switching timings’ or ‘key decision turning points’
Different degrees of ‘typologies of context’ have different outcomes from a decision-maker perspective? Uncertainty in knowledge + ambivalence in goals + distribution of power play a critical role?	

3. Implementation of WP1 CFR: caveats, needs and further steps

Clearly we cannot attempt to map all the individual contexts where adaptation decisions are made. This means accepting that there can be decisions that are made without explicit external scientific support (e.g. those related to autonomous adaptation) or, that many decisions can be biased by a multitude of factors that have nothing to do with the adaptation problem. It also means that there will be cases where the information that is provided to a decision-maker may not be the most relevant or that science may not always be able to perfectly inform complex processes such as these.

Despite such limitations, the application of a CFR in the analysis of different types of adaptation decision objectives and of the research approaches used to inform them provides a further step in the understanding of how to design and apply novel decision-making frameworks (e.g. the role of different information needs vs. different decision-making approaches). However, it should also be recognised that site- and culture-specificity of adaptation situations makes generalised conclusions difficult. The implementation of this sort of framework in IMPRESSIONS is complex as it has to deal with a multitude of both science-based and stakeholder-driven activities and objectives. Thus a balance has to be struck between these sometimes different objectives.

This document provides a CFR that will be further developed with the project partners, in line with the multiple processes underway both at the WP and case study level. In particular, it will be refined after the full analysis of the interviews with decision-makers in each of the case studies. This may allow the emergence of valuable empirical evidence for identifying the critical needs, capacities, drivers and barriers for considering HES and their associated uncertainties in the development of adaptation policy and practice.

The relationship of the CFR with conceptual frameworks currently under development within other IMPRESSIONS WPs will also be subject of further work during the project lifetime. In this respect, the CFR should evolve in a way which is able to map out, analyse and guide the multiple kinds of complex decisions that occur during the various iterative stages of the science-policy-societal learning processes, according to the different goals. For example, work based on future developments of the CFR would need to make explicit how the various kinds of IA tools and methods within the IMPRESSIONS project can be best used to support decision making regarding HES, how to improve them, and in particular to how to link the development of visions, pathways, strategies and systemic solutions, e.g., via the use of complexity-based approach and agent-based modelling.

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