Assessing Low Carbon Transitions

A Conceptual Model

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Preface

This report has been developed within the Horizon 2020 project REINVENT (grant no 730053). REINVENT is an EU-funded research project analysing decarbonisation in four industrial sectors: meat/dairy, paper, plastic and steel. The project is transdisciplinary and studies the entire value chains of these sectors in order to understand the opportunities for low carbon transitions.

One task in the project, was to develop a feasible and novel approach to transition policy evaluation. The approach should provide a complementary understanding to conventional climate policy evaluations, which often have focus on direct emission reductions and short-term cost effectiveness of specific instruments. This report is one of the contributions to this task which also included a workshop and a policy brief.

Summary

The present report presents a conceptual assessment model or framework for policy relevant analysis of low carbon transitions. The aim of the study is not to present specific guidelines for how to design assessments of low carbon transitions, but rather to give food for thought on aspects that should be regarded in the design process. The exact design would then depend on the purpose of the assessment, the scope and priorities set for the assessment, and the resources (personal and financial) available for the assessments.

We find that there are at least three elements of an assessment model that are important to provide policy relevant knowledge: i) monitoring, ii) policy evaluation, and iii) domain knowledge building processes, including research. Monitoring is here understood as a process that is intended to inform whether society is on track on meeting set-up political priorities. Policy evaluation concentrates on the effects of low carbon transition policies and effects of other policies. Domain knowledge building through research and other processes is important both for identifying relevant assessment criteria and designing monitoring systems, as well as for policy evaluations.

A domain knowledge base can include knowledge of i) drivers and barriers for low carbon transitions, ii) the sustainability of various technologies, policies and practices, iii) previous policy experiences, and iv) contextual knowledge of the market, actors, mitigation technologies and pathways, etc. in various sectors. This information and background knowledge will help inform how policies can be redesigned for overcoming the barriers and enable change in various contexts while safeguarding that the changes are not in conflict with other key societal goals and sustainability aspects.

Monitoring can cover *direct outcomes* such as greenhouse gas emissions or diffusion of low carbon technologies. But with a long-term transitions perspective it is also important to look into the *preparedness for change* with regard to existence of factors such as visions and expectations, knowledge, feasible policies and policy instruments (taking into account stringency as well as coverage and policy coherence), societal norms, innovation networks, or the readiness of key technologies.

Evaluation of policies can in turn cover several aspects beyond policy relevance and effectiveness including synergies and conflicts with other objectives. It could also evaluate the consistency of targets with overarching objectives as well as specific strategies, policy instruments or policy packages.

In the conceptual assessment model, policy adjustments are expected to be informed by the monitoring process regarding what is needed and by policy evaluation with regard to what works. Together these processes can inform on how both the stringency and the design of policies could be developed over time.

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1 Introduction

To reach a low carbon society, profound changes of production and consumption patterns will be required. Infrastructures and institutions will have to be re-designed and the changes will have to involve a broad variety of actors, including individual consumers, companies, universities, and policy makers. A broad palette of polices and measures will be needed to overcome different barriers and enable a transition throughout our economies (Grin et al, 2010). But what are the existing barriers in different sectors and how can they be removed? How well prepared are various societies or sectors to start the necessary transition processes? What policies work and what are the economic, social and political consequences of implementing them? These are examples of aspects that need to be assessed in order to be able to design feasible policies for the future.

In this report we discuss how the *conditions* for low carbon transitions can be assessed, how the *developments* towards low carbon transitions can be monitored and projected, and how various *policies* can be evaluated. All these three different aspects are important for policy development but provide different perspectives on low carbon transition.

There are several reasons for conducting such assessments. Firstly, the assessments and foresights can be important for problem formulation. They can provide answers to the question why we have to act and what the barriers and opportunities for action are. Secondly, policy evaluation is important as a means for learning and for capacity building in how to design and implement feasible policies. A third motivation is that assessments and evaluations can strengthen transparency and political accountability (for different roles for policy evaluation see e.g. Mickwitz, 2006).

Mickwitz (2006, p.15) notes that the evaluation of environmental problems – including climate change – has a number of key characteristics: the problems are often complex, have long time frames, concern geographically remote areas and their causes as well as consequences are unequally distributed. Furthermore, they are formulated as problems largely by scientists, may involve large uncertainties, and involve stakeholders with different belief systems and conflicting goals.

Many effects of greenhouse gas (GHG) emissions will occur in a long-distant future due to the long atmospheric lifetime of many of the GHGs and the inertia of the climate system. The balance of interests between current and future generations is a politically contested issue which includes how economic gains and losses should be discounted (see e.g. Sterner and Persson, 2008; Weisbach and Sunstein, 2008). In addition, although the emissions' contribution to climate change is well known on a general level, the exact impact on nature and societies in the future still involves major uncertainties. The character of non-linearity and discontinuity and the existence of potential thresholds also constitute challenges for evaluation (Hildén, 2009).

In addition, the process from research and development to diffusion of new mitigation technologies usually takes a significant amount of time. This means that the development towards a low carbon future is not only manifested in direct reductions of GHG emissions, but also in how the societal and technological conditions for future change develop – the potential sustainability of all development is to a high degree dynamic (Leach et al., 2010). This means that as important as monitoring on-going emission developments would be to assess other factors such as research advancements, patents, on-going experiments, network

expansions, changes in institutional arrangements, norms, expectations, and cognitions. All these factors are important for improving the opportunities for change in the future. [1]

Furthermore, during low carbon transitions many other societal changes will occur. These could include effects of major technical changes such as artificial intelligence but also changes in values and norms throughout society. Such changes will affect both transition trajectories and the feasibility of various policies. To what degree historical experiences will be valid also in the future is not evident. The role and importance of scenario thinking can therefore be significant when conducting ex-ante assessments and evaluations. All these uncertainties stress the advantages of adaptive evaluation (Hildén, 2009), i.e. to be reflexive, adjust, and carry out evaluation repeatedly.

The global character of the climate problem collides with the often national or state-centred character of policy making. This implies specific challenges for evaluation. While the climate effects of policies would be most relevant to address with a global perspective, the policies to be evaluated are often regional and national. Within the UNFCCC[2], much of the responsibilities fall on nation states that are the parties to the convention. Furthermore, national governments are often responsible for policy areas where potential side-effects of climate policy will occur (e.g. industrial competitiveness, jobs and welfare). These aspects often have impact on views how transition processes should be designed in order to not lose competitiveness and even more ambitiously if the they could increase competitiveness – a perspective that is prevalent in the green growth thinking. Lost competitiveness due to stringent policies can lead to transfer of production facilities or increased imports of carbon intensive goods and services (carbon leakage). This aspect will have implications on monitoring, where reductions in territorial emissions can be detected while a country's contribution to global emissions increases. In addition, what is considered non-climate policy in other domains (e.g. consumer taxes, regional development strategies, spatial planning) often have implications for GHG emissions.

National policies can also give positive spill-overs through technology transfer, an area that is highlighted in the UNFCCC. The development of a strong national innovation system that fosters new technologies could ultimately lead to emission reductions both within the country and abroad. How this should be considered and accounted for in assessments and policy evaluations is not evident.

Technology transfer is not only a process from more industrialised to less industrialised countries but could also reflect technological specialisation among countries. This leads to the question of to what degree a country or a region can have the full width of technological systems represented in the innovation system and to what degree specialisation is to prefer. In addition to technology spill-overs, it has been argued that implementing domestic policies can be important reasons for other countries to be regarded as a leaders in climate action and negotiations (see e.g. Karlsson et al., 2012).

Traditionally, climate change monitoring and policy evaluation have focused on measuring changes in emissions. For example, the reporting of policies and measures within the European Union has a focus on direct emission reductions (Dauwe et al., 2019). However, it could also be argued that due to the long-term perspective, measuring other factors indicating the preparedness for future reductions is in fact as important as measuring recent emission reductions (see e.g. Swedish EPA, 2006). Other factors such as procedural aspects

[1] Bergek el al. (2008) discuss the importance of understanding the technological innovation systems in order to understand the conditions for change.
[2] United Nations Framework Convention on Climate Change.

of policies of importance for their legitimacy and side-effects of policies can also be included in evaluations (see e.g. Mickwitz, 2006).

It is at this point not possible to say exactly what an assessment should include or how it should be designed. That is contingent on the specific *purpose* of the assessment task and the *resources* assigned. Assessments and evaluations rarely provide simple and instrumental answers and the advantage of applying different perspectives and approaches to evaluation are widely cited in the evaluation literature (see e.g. Stirling, 2011; Turnheim et al., 2015; Sandin et al, 2019). Triangulation in the form of using multiple methods, multiple sources within one method, multiple analysts, and multiple theories can help widening the perspectives (see eg. Mickwitz, 2006). That resources are limited and must be prioritized in most practical evaluation situations is an issue that is less widely acknowledged or discussed but which must be stressed, as it is otherwise easy to end up with an endless but unfeasible list of perspectives and methods to be included in an assessment.

In this report we develop a model that can helpful when seeking to assess low carbon transitions. We will not recommend a specific method or present a generic check list, as which factors to include will depend on the purpose of the assessments, the contexts defined by the sectors studied (as many factors are context based), and the resources available for evaluation.

Even though a low carbon transition will have a broad impact on several policy areas it is often, from an analytical perspective, advantageous to take a specific vantage point from which to start the analysis. In this report, policies for low carbon transitions are argued to be mainly motivated by environmental concerns. Consequently, it is therefore motivated to take a starting point in the literature on environmental policy and policy evaluation.

2 Transitions, policies and evaluation

The major changes necessary in society to respond to the climate change challenges are sometimes presented under the concept of *low carbon transition*, sometimes under the concept of *low carbon transformation*. The difference between transition and transformation is not always clear cut. One way to define the different concepts could be:

Transition is a concept used extensively in the sustainability transitions research field to denote fundamental social, technological, institutional, and economic change from one societal regime to another (Hölscher et al., 2018). Transitions can be described as driven by technological innovation and ideally managed under orderly control towards a known and shared end (Stirling, 2014). The transition concept has been used to analyse societal subsystems such as energy, mobility, and cities with a focus on social, technological, and institutional interactions. In short, transitions (compared to transformations) denote relatively managed and orderly changes in socio-technical systems towards a certain goal. Linnér and Wibeck (2020) note that the transition concept primarily addresses technologically defined systems, whereas societal transformation also addresses a broader range of social practices and knowledge.

Transformation is a concept used for example in the resilience research field, referring to the need for broader and deeper shifts in human and environmental interactions and feedbacks (Hölscher et al., 2018). Linnér and Wibeck (2020) suggest transformation to be defined as a deep and sustained, nonlinear systemic change, and generally involving cultural, political, technological, economic, social and/or environmental processes. Transformations entail plural, emergent and unruly political realignments involving both social and technological innovations that are more challenging to incumbent structures and possibly pursuing competing ends (Stirling, 2014).

In this study we relate both to broader societal transformations and more sectoral-oriented socio-technical transitions. In the text we will, for simplicity, use the term transition to encapsulate both broader societal transformations and more specific transitions of socio-technical systems.

2.1 Assessing transitions or transition policies

There is a difference between assessing *low carbon transitions* and *policies for low carbon transitions*. Whereas the first activity monitors and assesses the development towards a low carbon future, regardless of whether it is policy driven or not, the latter specifically addresses the role of various policies and policy instruments in driving this transition and the consequences they have on society. Low carbon transitions depend on several factors. Although specific policies for the low carbon transition play a central role, factors such as general technology development, social structures and preferences, education levels, geopolitical developments, and other aspects may also be important and should be considered when assessing low carbon transitions.

Policy assessments specifically focus on the impact of policies and the policy development processes. Here, the interventions of public actors and decision makers are in focus including how and to what degree they affect transitions. Also in this case, factors not driven by the studied policies such as generic technology developments, policy styles and rationalities (e.g. market or regulation), social structures and geopolitical developments could be taken into account, but then as *contextual factors*.

Another issue is to determine which policies are to be classified as low carbon transition policies. Is it policies dedicated to low carbon transitions or is it policies that affect the low carbon transitions regardless of their intention? Lundqvist (1996) differentiated between approaches based on functions, institutions and purpose when separating environmental policies from other policies. A *functional approach* has its focus on whether the environment is affected by policies, an *institutional approach* is interested in whether it is developed by an environmental institution, and the *purpose approach* takes its starting point in the purpose of the policy, i.e. that environment should be improved. The purpose approach is the perspective Mickwitz (2006) chooses when evaluating environmental policies, except when studying policy integration, and it seems to be feasible also when assessing and evaluating low carbon transition policies. The functional approach, however, seems a valuable complement when monitoring low carbon transitions.

2.2 How can we understand policies for low carbon transitions?

Policies can be analysed from several perspectives. Rogge and Reichardt (2016) described a fruitful perspective on policy mixes which includes:

- *Policy processes*. Policy processes include both policy making and policy implementation. According to the authors, all parts of the policy cycle are included. This includes problem identification, agenda setting, policy formulation, legitimisation and adoption, implementation, evaluation or assessment, policy adaptation, succession, and termination.
- *Elements*. They are in turn divided in policy strategies and policy instruments. The policy strategies are divided in objectives and principal plans whereas the instruments are characterised by their goal, type and purposes and their specific design features.
- *Characteristics*. The characteristics are described as consistency of elements, coherence of processes, credibility, and comprehensiveness.

All these parts of the policy mix can, but must not, be included in an evaluation. In addition to the three parts presented above, Rogge and Reichardt (2016) also relate to a number of different *dimensions* of policies such as the policy field, governance level, geography and time.

Another, more simplified perspective, which is often employed in practical policy making processes, is to see objectives, policy instruments, and measures as the defining parts of policy. The objectives define what the policies are planned to achieve. To reach these objectives, material measures (e.g. efficiency improvements and fuel substitution) have to be carried out by a variety of actors. Finally, the policy instruments are the tools that the policy maker (usually a public sector actor) use to incentivise or force the actors to carry out the measures. Policy instruments often interact with each other and can also be studied as policy packages.

Different typologies are available that structure policy instruments. They can for example focus on the forms and rationalities of governance (Kronsell and Bäckstrand, 2010), whether they are based on coercion, remuneration or deprivation of material resources, or intellectual and moral appeals (Vedung, 1998), or how they affect material conditions for companies (Johansson et al, 2018). The usefulness of the typologies largely depends of the purpose of the study. Worth noting is that the characteristics (e.g., the efficiency) of a certain instrument do not depend only on the type of instrument but also on features such as stringency, legitimacy, comprehensiveness, and implementation method.

From an evaluation perspective, it can be fruitful to distinguish between policies or policy instruments that are expected to have direct effect on the targets studied, e.g. technology

uptake or GHG emission, and those that contribute to capacity building and enabling future change. For example Bulkeley and Stripple (2018) propose a model for intervention capacities consisting of four parts: competency, legibility, authorisation, and distinction. These intervention capacities can be important for both the preparedness and acceptance for future interventions.

Environmental policies usually have not only intended effects such as CO_2 emission reductions but also indirect effects on several aspects of society. That is especially evident when the policies are of the transformative nature studied here. Sometimes the primary effects of the policies are lost by counteracting effects, such as the rebound effect[3] of energy efficiency which is well-described in the energy policy literature. The transformative requirements following from ambitious climate policies imply that they will affect several policy areas and that the interaction between policies in different domains becomes evident. The integration of climate impact in other policies (policy integration) will be even more important than previously.

2.3 Perspectives on evaluation and assessments

There are different perspectives regarding what the concept of evaluation means. In a narrow sense the concept includes only ex-post assessments of specific policies along specific criteria, but can also be used to describe a much broader variety of assessments. Stockman argues that the concept of evaluation in everyday language today denotes almost any form of assessment (Stockman, 2012).

As mentioned previously, the approach to monitoring and evaluation differ if focus is to investigate if society is on the right way towards a low carbon transition or to learn about the feasibility of certain transition policies or policy instruments. Both approaches are relevant but not always for all purposes. Regardless it is important to decide what the field of study is. Mickwitz and Birnbaum (2009) note the importance of deciding on what should be evaluated and what should be the context.

Monitoring usually focus on whether society is developing on a path corresponding to certain objectives. The use of indicators covering the most important criteria could play important roles (see e.g. Gudmundsson et al., 2015). Indicators could according to Lehtonen (2012) be seen as variables that are constructed or selected to operationally represent properties of more or less well defined "representation targets".

The assessment can investigate both primary outcomes (e.g. carbon emissions) and the state of drivers and barriers (both non-policy and policy) towards the transition. Descriptions of different functional patterns of technological innovation systems (cf. Bergek et al., 2008) could indicate the preparedness for change.[4] The monitoring of transitions can also take its starting point in the four stages of interventions (innovation dynamics, governance initiatives, intervention capacities and uptake) suggested by Bulkeley and Stripple (2018) within the REINVENT project as an analytical approach when analysing how interventions are developed and deployed and with what consequences.

Focus in *evaluations* of transition policies would be on what impacts the policies and policy instruments have on the parameters of interest. These parameters could be similar to those used in monitoring but here more focus would be on reference cases, non-policy scenarios

[3] The rebound effect means that some of the energy savings reached by the efficiency measures are lost by increased use following the lower energy costs achieved by the efficiency measures.

[4] Bergek et al. (2008) mentions the following functions: i) knowledge development and diffusion, ii) influence on the direction of search, iii) entrepreneurial experimentation, iv) market formation, v) legitimation, vi) resource mobilization, and vii) development of positive externalities.

etc. in order to distinguish the effects of the policies. Both intended and unintended effects of policies are of interest. Looking into the consistency of various targets with more overarching objectives such as implementation targets for renewables and long-term climate objectives is also relevant. In this study we argue that both ex post and ex ante evaluations are relevant and important.

As mentioned previously there are at least two reasons for evaluation: i) learning about the merits and disadvantages of different policies, policy instruments or policy packages and ii) increasing transparency of existing policies and thus increase political accountability. Stockman (2012) argues that evaluation could be used to improve the management of programmes, support implementing broader policy strategies and increase their legitimacy but also contribute to enlightenment and reflexivity, enabling a critique of modern society. Stockman (2012, p.15) distinguishes between i) evaluations of the implementation of programmes at micro level with the purpose to improve the management, ii) the evaluation of the effectiveness of policy strategies at micro and macro levels and iii) the evaluation of whether the developments are in accordance with sustainability criteria at a macro level.

Several researchers argue that there is not one approach to evaluation. For example, according to Sandin et al. (2019), evaluation theory brings attention to the need for broad and reflexive methods, value judgements that reflect multiple stakeholders' concerns, and facilitation of use of evaluation through stakeholder involvement. Also Mickwitz and Birnbaum (2009) argue for pluralism in evaluation in the environmental field. The openness of evaluation does not mean that every evaluation must include all perspectives but rather being open to contrasting different evaluations to each other. Stirling (2011) notes that the "benefits of creative coherence in diverse understandings of environmental innovation and societal transitions, may lie more in performed relations between interacting research communities, than in settled multidisciplinary articulations".

An important starting point of this report is that the adequate design and content of assessments and evaluations depends on why and by whom they are carried out, what the study objects are and the specific context. Not all interesting aspects or perspectives can in practice be included in every evaluation but different evaluations from different stakeholders can complement each other and contribute to the policy discourse. The availability of resources will be key for describing what could be included in a specific assessment.

As mentioned above it is essential to decide the general purpose of the assessment before deciding what aspects that should be evaluated. Four potential fields could be summarised as:

- Monitoring low carbon transitions
- Evaluation of policies for low carbon transitions
- Sustainability assessments of low carbon solutions
- Identifying drivers and barriers for low carbon transitions

These fields are interrelated and will be further explored in chapter 3 taking the starting point in a proposed conceptual knowledge model.

There are many ways to set up a monitoring or evaluation scheme. These include both quantitative (e.g. using indicators and modelling) and qualitative approaches (more qualitative results based on for example interviews) which provide different types of information.

Monitoring, although demanding in terms of data collection, is simple compared to evaluation as there is less need to attribute certain developments to specific processes or

interventions. Here the most important aspect is to decide what to monitor. What are the relevant factors for a low carbon transition? In that sense a theoretical understanding is necessary regarding driving forces, interactions, cause effects etc. This knowledge may be gathered through research and previous evaluations of policies and measures. Thus, evaluations can feed back to the construction of monitoring and evaluations frameworks.

Evaluations of interventions are more complicated as they require the separation of effects of the intervention from other developments. The use of counterfactual thinking may be critical for evaluating the impact of historic interventions (Ferraro, 2009). There is an additional difficulty with attribution as causal relations are commonly complicated in societal developments.

For ex ante evaluations, different pathways (Bauer et al., 2019) and intervention scenarios can be used to describe potential developments. External scenarios can in turn be used to evaluate the robustness of various intervention scenarios. The scenario literature describes different ways to develop such scenarios in order to make them consistent and relevant for decision making. The role of scenarios is discussed in section 3.5.

Governments, governmental agencies, researchers, political parties, NGOs and business organisations are examples of different organisations that can be expected to carry out assessments of different policies and measures. Their capacities to do so may differ as a result of the availability of resources and competences which can affect e.g. how comprehensive they can be. Their respective motivations can also be different due to different roles in society. For example, a governmental body might want to make the evaluation to learn how policies can be changed in order to meet governmental objectives more effectively. An NGO may want to use the assessment to criticise existing objectives and policies, while a researcher may be more interested in learning about the barriers and opportunities for change or how the policy processes work. The scope for challenging political decisions is more difficult for government bodies as it can undermine the legitimacy of the bureaucratic system and its relation to the decision makers.

Different perspectives can be integrated in evaluations through stakeholder involvement but stakeholder interests can also feed into policy processes as a result of that different stakeholders conduct or commission their own evaluations. The various evaluators and stakeholders can use different criteria and starting points from which the evaluation should be carried out and how different aspects should be prioritised but could also provide different experiences and knowledge in how adequate certain targets and measures are and on what effects different policies have on activities, technology developments etc. Multiplicity and diversity are valuable aspects to include in the process, not least for building knowledge.

3 A conceptual knowledge model for assessing low carbon transitions

In this chapter, a conceptual model for assessments of low carbon transitions is presented. As argued previously, the actual design of the assessment should depend on its specific purpose and the resources that are allocated to it. Second, the details of the assessment can differ depending on the scope of the study, such as specific productions systems (e.g. steel production from iron ore), individual sectors (e.g. forestry or steel), or the whole economy. Sectors and economies can in turn be studied on multiple geographical scales – regional, national, or global.

To make an assessment framework practically feasible in terms of resources and oversight, the setting of relevant delimitations is a key factor. In the present report, the main focus is on sustainability and more specifically on low carbon transitions, but it is not the only relevant perspective on societal or industrial transitions (another may be, for example, contribution to business development). The choice of focus will necessarily have an impact on what should be monitored and evaluated.

In Figure 1 we present a conceptual knowledge model of what role different types of low carbon transition assessments can have, and how the different assessment types interrelate to each other. The model takes its starting point in a perspective that recognises that policies are important for realising a low carbon transition. It does not, however, restrict itself to policy evaluation per se but includes other knowledge building processes as well. However, it is the roles of these processes in providing *policy relevant knowledge* that are of interest here. Three different assessment categories are identified and presented in Figure 1:

- Monitoring
- Policy evaluation
- Building domain knowledge

The two first categories could be seen as activities driven by policy cycles, whereas domain knowledge building would typically be expected to be more freely related to on-going policy processes, even though research priorities are often affected by values and priorities existing in society.

As mentioned above, the conceptual understanding starts from an assumption that the assessments are in one way or another expected to be of policy relevance. It means that overarching assessment criteria are affected but not necessarily determined by political priorities and targets and policies.[5]

In this context monitoring, policy evaluation and knowledge building through research and other activities each, in different ways, can contribute to the development of "better" policies for achieving a *desired* low carbon transition. That said, it is recognised that knowledge building can have many other purposes than supporting policies.

[5] They could be decided or suggested by governments or other political actors (political parties, NGOs or business groups). Although government priorities would often be chosen as the criteria for assessments, this is not necessary but depends on the purpose of the assessments (they could for example be critical to current governmental views.).

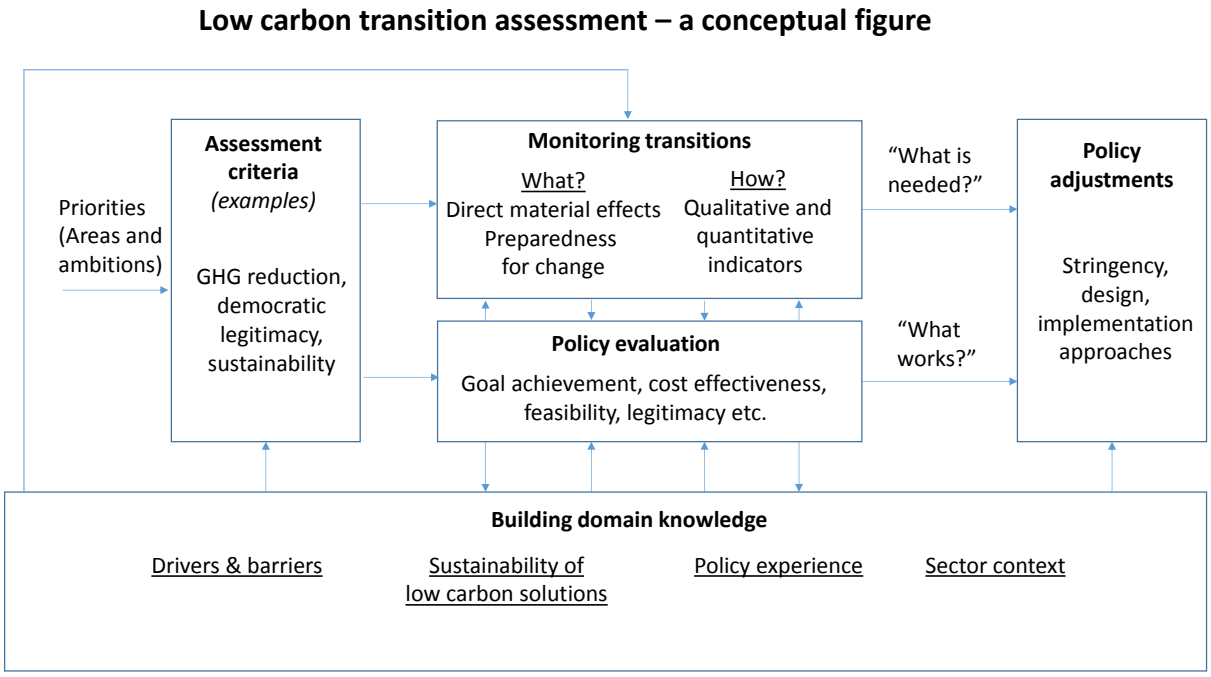

Figure 1. Conceptual figure illustrating how the different types of knowledge production fits a policy context and how the different types relate to each other. The arrows illustrates interactions between different fields but do not illustrate a specific policy process.

Monitoring is here understood as a process that is intended to inform whether society is on track to meet the political priorities that are set up. To do so indicators in the broader sense as suggested in Chapter 2 have to be developed. The indicators can be both quantitative and qualitative and look into direct achievements (e.g. CO_2 reduction), indirect parameters indicating the preparedness for reaching long-term targets, negative and positive side-effects, and more procedural aspects. The choice of indicators can be based on *assessment criteria* coming from the political priorities as well as the domain knowledge base. Although monitoring is often seen as a process looking into the current situation the same type of monitoring criteria could be used for forward looking assessments using scenarios, see section 3.5.

Domain knowledge is important for monitoring and policy evaluation as it describes social processes and contexts, the drivers and barriers for change, the sustainability of technologies and practices, and the feasibilities of different policies. This information will be of substantial help for identifying what should be studied in the monitoring phase and help designing policy evaluations. Both research and other knowledge building processes (including evaluation and monitoring) can contribute to build the domain knowledge base.

Policy evaluation is, in this conceptual model, looking more specifically into policies and their effects. It could concentrate on material effects such as goal achievement, cost effectiveness and side-effects but also on more procedural aspects such as stake holder involvement, transparency, legitimacy etc. Policy evaluation, as mentioned, both contributes to increased domain knowledge but would also directly feed into the process of policy adjustments.

In the conceptual assessment model, policy adjustments are driven by information from the monitoring process of *what is needed* combined with information from policy evaluation with regard to *what works*. Together they can inform on how both the *stringency* and the *design* of policies can be altered.

The conceptual model is for practical purposes simplified. For example, political priorities are not an independent variable but can change in response to on-going policy processes, increased knowledge etc. The model is intended to be a heuristic or structuring device for the potential multiplicity of low carbon transition assessments. The remainder of the chapter elaborates on each of the elements of the model.

3.1 Assessment areas and criteria

The purpose of the assessment will be very important in determining what fields are to be investigated and to what criteria the assessments are to relate. In this study, focusing on low carbon transitions, GHG emissions is an evident assessment criterion. In addition, to a higher or lower degree, depending on political priorities, there are several other factors that can be of relevance such as:

- Industrial competitiveness
- Impact on innovation
- Impact on other environmental areas
- Cost efficiency
- Distributional aspects and social inclusion
- Political involvement and democracy
- Legal aspects (rule of law, risk for corruption etc.)

The ground for prioritising these factors could both be because of their *intrinsic values* and their *instrumentality* in reaching the main aim of a low carbon transition. For example, the distributional aspect could be important for a policy maker who sees equity as an intrinsic value but also as instrumental in that suggested policies will be politically unfeasible if distributional impacts are seen as unfair.

Often, targets exist for the different assessment areas to which the monitoring and evaluation activities can be related, however, it is not a necessary condition. The effects of policies on the different study areas can be monitored and evaluated also in the absence of specific targets.

3.2 Building the domain knowledge base

In order to determine what is important for achieving a low carbon transition (and thus also what is worth studying in monitoring and evaluation), factual knowledge of how different factors affect the areas in focus is necessary. Such knowledge can be gathered through research, other investigations, and practical experiences but also through policy evaluation. Thus, there is interaction between domain knowledge building and policy evaluation. For example, the domain knowledge can provide policy evaluation with necessary information on e.g. causal interrelations and how various contextual conditions have impact on the effectiveness and side effects of policies. On the other hand, the experiences from policy evaluations can provide improved empirical knowledge of these causal interrelations and conditional aspects as well as on specific implementation issues.

3.2.1 Drivers and barriers

Drivers and barriers can be structured in a number of different ways. Both drivers and barriers can be divided in technological, economic, political, organisational and social where the latter includes e.g. knowledge, cognitions and norms. Sometimes the barriers mirror drivers as they could be formulated as the non-existent or too weak drivers. As a part of the REINVENT project drivers and barriers for innovation in a number of sectors have been

mapped providing valuable information of both commonalities and specificities for the individual sectors (Knoop et al., 2019).

Knowledge of the drivers and barriers for transitions is key when designing monitoring and policy evaluation. Indicators for the main drivers for successful change, as well as for important barriers could, in the monitoring processes, be a way to identify the opportunities to change in the future. If enough drivers are in place, there might not be a case for more or adjusted policies even though a primary factor such as GHG emissions still have not reached set targets. On the other hand, if significant barriers exist, according to the monitoring process, it could be argued that more policies are needed. Detailed knowledge on how these drivers and barriers work would help understanding of how policies can nurture the drivers and remove the barriers.

3.2.2 Sustainability of technologies, policies and practices

Many indicators that could be useful for monitoring low carbon transitions are based on the presumption that the solutions they reflect are sustainable and therefore feasible for contributing to a sustainable transition. Knowledge of the sustainability of technologies, practices, and policies and measures is important in order to determine their relevance for monitoring, as well as to provide information regarding side-effects in policy evaluation. This would provide important support for policy makers as not all of the technologies and practices that are expected to contribute to a low carbon transition are in reality doing so, when looking at the full lifecycle, their scalability, or have such significant negative side-effects to sustainable development that they should not be implemented. Often the problems are not the technologies per se but the combination of poor practices and poor governance (cf. Hildingsson and Johansson, 2016).

3.2.3 Policy experience

General knowledge of how various policies work and what their potential side effects are is important both when monitoring whether relevant policies are in place, and when designing policy evaluations adapted to national or regional conditions. This knowledge can be based on theoretical and logical reasoning, taking into account the understanding of the barriers and drivers, as well as experiences from empirical studies that evaluate impacts in the real world. Such experiences can be gathered from research studies as well as different policy evaluations.

3.2.4 Other contextual knowledge

Important contextual knowledge could be about the availability of low carbon technologies. For example, in some fields, technologies are available and could be implemented instantly if the market conditions were correct, while in others significant technology development would be required. As a consequence, the policy approaches should differ between these fields.

Market conditions will also affect policy approaches. While some sectors meet external competition others are more protected. The prospects for implementing e.g. economic policy instruments are quite different between these two cases. Also, the type of actor (size, resources etc.) will be important regarding what roles they can take in a transition process. In addition to these sectorial differences, it is important to have knowledge of current and potential interactions between these sectors to identify potential synergies and solutions that can be captured by a broader strategy.

Finally, understanding of the historical context is important in order to be able to understand how different policies can be implemented. Historical experiences that will decrease the acceptance of new policies or strong interests that will hinder specific solutions are phenomena that maintain lock-ins and decelerate transitions.

3.3 Monitoring low carbon transitions

In order to cover both short-term and long-term effects, a monitoring model should take into account both current outcomes and their consistency with existing priorities and the preparedness for making necessary changes to meet more long-term aspirations. Many of the indicators for monitoring low carbon systems can, as previously mentioned, be used not only for mapping the current situation but also for investigating future potential developments through scenario analysis, see section 3.5. Monitoring can be resource consuming and the choice of indicators have to be made with care. In the following sections, we present examples of indicators that could be useful when monitoring low carbon transitions on a technology, sectoral and societal scale.

3.3.1 Monitoring direct outcomes

GHG emissions are of course evident parameters when monitoring low carbon transitions. It could be in the form of total emissions, total emissions in sectors as well as specific emissions in relation to economic value or physical amount of a product.

Other parameters would indirectly reflect changes in emissions but be more concretely related to developments that are important drivers for low carbon emissions. This could be, e.g., share of low carbon energy technologies, energy efficiency levels, and fraction of products based on recycled material. The importance of these factors for reaching more overarching targets are expected to be known through the domain knowledge.

In addition to territorial and production based indicators, consumer based indicators can also be important to follow in order to detect if emission reductions are achieved by moving carbon intensive production to other countries. Example of potential indicators for direct outcomes are presented below:

- GHG emissions (society wide or sector)
- Energy efficiency improvement (%)
- Energy intensity
- Share of renewable energy
- Share of renewable transportation fuel
- Share of electric vehicles
- Consumer based emissions
- Fractions of renewable materials in final products
- Fraction of recycled materials in final products
- Share of low carbon production technology
- Carbon intensity of steel production
- Carbon intensity of cement production

3.3.2 Monitoring the preparedness for socio-technical transitions

Monitoring the preparedness for future change could include a broad variety of factors that are key for enabling future transitions of the system, see examples below:

- Existence of deeply anchored visions of future transition pathways

- Widespread support for low carbon transitions and specific technologies (legitimacy) (cognition)
- RDI funding (public and private)
- Technology development status
- Beliefs in growth potential
- Experimentation
- Market building potential for existing policies
- Policy stringency, consistency, coherence, and comprehensiveness
- Resource availability

The importance of visions and expectations are often highlighted as important for successful transitions (see e.g. Bergek et al., 2008; Patterson et al. 2017; Nikoleris, 2018). The existence of such common visions and positive expectations of change could be indicators of the opportunities for change. Existing attitudes towards change and the priority of low carbon transitions could also be important for the possibility to implement necessary policies and in individual decisions.

The existence of "technology networks" and on-going experimentations are also indications of supportive activities for change (Bergek et al., 2008; Patterson et al., 2017), but also more widespread knowledge of technical solutions can be important.

A more directly technological perspective is to monitor the status or readiness of different key technologies. Have they moved from basic research to pilots or reached a market compatible status? To what degree have associated and necessary infrastructures (e.g., for hydrogen or battery-charging) been diffused throughout society?

The number of and stringency of potentially important policy instruments could also be indicators of how well society is institutionally prepared for supporting the development and diffusion of new technologies and practises. Examples of such policy instruments could be standards, feasible procurement regulation, economic instruments, research funding etc. Depending on the maturity of technologies, the implementation of these policies may already have led to measurable changes in outcome (see above) but they may also indicate that such changes can occur as soon as the technologies reaches technological maturity. What policy instruments to monitor could be known from policy evaluation and research based domain knowledge on effective and feasible policy instruments.

On a higher structural level, factors such as policy coherence, consistency and comprehensiveness can be important for how well policies will be able to support change. With policy coherence, Rogge and Reichardt (2016) mean the level of alignment between different policy fields and between policy levels. This could for example be the alignment of environment, energy, and fiscal policies. It is quite clear that an effective low carbon policy will be more difficult to implement if policies in different policy areas work in the opposite directions. Rogge and Reichardt (2016) uses policy consistency for determining how well different elements of policy fits together such as the alignment of policy objectives, how well policy instruments or mixes of policy instruments works together and how policy instruments are working in line with objectives. I.e., high policy consistency means, with this definition, that objectives and instruments work in the same direction with only minor trade-offs. This would enable effective policy implementation. Finally, policy comprehensiveness means to what degree policies cover all relevant market, system and institutional failures as well as the different barriers and bottlenecks.

3.4 Policy evaluation

Policy evaluation is in this report seen as something different from but closely related to monitoring. Policy evaluation focuses on what can be attributed to the policies with regard to outputs and outcomes[6] but can also have a significant focus on procedure. There are several criteria, in addition to effectiveness, that policies can be evaluated from such as:

- Policy relevance and effectiveness
- Economy efficiency
- Equity
- Environmental side-effects
- Synergies and conflicts with Sustainable Development Goals (SDGs)
- Policy coherence
- Policy consistence
- Policy comprehensiveness.
- Transparency
- Legitimacy
- Level of stakeholder involvement

Which factors that should be included depends on the priorities of the evaluation. Is the main interest in identifying policies that would meet the main goal most efficiently or should they have a focus on a broader array of policy objectives? Several of aspects above can be seen as interests in themselves for example the distribution of benefits and cost (equity) or involvement in policy development and implementation (democracy), but they can also be seen as prerequisites for good policy making. For example, the involvement of citizens and other stakeholders in policy making could make the policies more informed on potential effects, and recognising equity issues in can help design policies that are perceived as fair.

Policy evaluation can both be in the form of ex-post learning from how existing policies and policy instruments work and ex ante where future effects are estimated. Methods for estimating these future effects can be based either on historical experiences or logical reasoning. To determine the role of policy instruments in both ex-post and ex-ante evaluations, it is necessary to relate to a reference scenario. A specific challenge is to determine future developments as there are several broad development lines why it could be argued that strategies and policies should be evaluated under several external and exploratory scenarios. Bauer et al. (2019) argue that transitions could be seen as potential developments along a multitude of potential pathways, instead of as a development along a historically determined and well mapped road. This perspective is a way of acknowledging the uncertainty underlying future developments.

Policy evaluation can be more or less focused on the whole or the parts (individual instruments vs. policy instrument packages, policy instruments packages vs. total policies) and focus on different implementation levels. These can be at different geographical (national, regional, local) and organisational (economy wide, sector, policy programme) scales. The choice will affect the design. Specific targets can be challenged in terms of their consistency with existing broader objectives, e.g. when comparing sector targets' consistency with the targets of the Paris agreement. Targets for specific measures could also be challenged with regard to their sustainability. Finally, depending on the institutional position of the evaluation also the broader political objectives can be challenged depending on the priority the evaluators. For example the objectives of the Paris agreement may by one actor

[6] Outputs can be understood as what the administration produces and the targets groups are faced with, whereas outcomes are the consequences that follow the actions taken by the target groups in response to the outputs (cf. Mickwitz, 2006).

be challenged for not being ambitious enough from a certain climate risk perspective (level of risk aversion) or by another for being too stringent if it is assumed to hamper economic development.

The policy evaluation could either be analytical focusing on understanding how the policies work or more normative relating it to specific goals and targets. Focus could be on identifying *cause-effect relations* of policies or provide broader explanatory discussions why things take place.

3.5 The use of scenarios for foresight and policy evaluation

Different types of scenarios can play a role in foresight exercises trying to predict or investigate the conditions for a low carbon transitions and to conduct policy evaluation. Useful scenarios can be both internal, i.e. focusing on changes within the studied system, and external which directs its interest to developments outside the system limits (see e.g., Börjesson et al., 2006).

Monitoring potential developments through foresights can use similar assessment criteria as monitoring current situations. The main difference is that while the latter can be based on empirical data, "monitoring" of the futures has to be based on assumptions and estimates of future developments. There is a broad set up of methodologies that sometimes, but not always, use more or less complex models. Depending on the purpose, the approach can be predictive, exploratory or normative. Some aspects can be analysed from studying the internal scenarios alone, others can be better understood combining the internal scenarios with external. Exploring the consistency of the internal and external scenarios can be informative.

Policy evaluations, trying to identify the effects and consequences of specific policies or policy packages, also have to relate to scenarios. Ex-post evaluation would like to separate what effects follow from the policies from what would have happened anyway, i.e. a contra-factual scenario perspective can be fruitful. Also ex-ante studies of policies would be helped by using "what if" scenarios for comparing the effects of different policy packages with a reference scenario or with each other. These effects can be analysed under different external scenarios (e.g. with regard to the level of climate ambition within or outside the studied geographical areas, geopolitical developments etc.) and the robustness of various policy approaches under different external developments can then be analysed.

4 Discussion

A conceptual approach identifying three main categories of assessments has been presented. The assessment categories start from different perspectives but are still clearly interrelated. The results from all of the assessment types have policy relevance for understanding and guiding the low carbon transition, but in different ways. The distinction between different assessment perspectives has in this report been applied to low carbon transitions, but it could be also used for other assessments inside or outside the field of sustainability studies.

Stakeholder involvement is often highlighted as important for evaluation. It is, however, important to recognise the different functions such involvement can have. Firstly it can be seen as having a democratic role, improving the opportunities to include different perspectives, values and priorities into the evaluation. Secondly, stakeholder involvement can lead to contextual learning that allows the evaluator to learn e.g. about drivers and barriers for transition in specific sectors, thus making it possible to increase the knowledge base on which the evaluator relies. Finally, the stakeholder involvement can help increasing the legitimacy of transition and transition policies, making them easier to implement.

Many assessments of low carbon transitions focus on changes manifested in society in the form of emission reductions or increased use of renewable energy. This information is important, but it must be complemented with assessments of factors that reflects the preparedness for future change. It could be factors reflecting changing norms and cognitions, technology readiness levels, policy implementation etc. Such knowledge seems essential in order to be able to determine whether the development is on the right way to meet more long-term targets.

As mentioned previously, the list of aspects that could be valuable to study and perspectives to apply in an assessment could expand almost infinitely. Delimitations will therefore be necessary and depend on the purpose of the study and the resources that can be allocated to the assessments.

5 Key findings

From the report the following key findings could be identified:

- Assessments of low carbon transitions are important in order to learn about the feasibility of various low carbon policies. Assessments also increase transparency and the accountability of policy makers and other actors.
- It is important that the assessments not only study what has happened or will occur in the nearest future in terms of emission reductions or technology diffusion. Assessments must also analyse the degree to which the innovation and other social systems develop capabilities to respond to long-term challenges.
- Feasible approaches to evaluate transitions to a near-zero emissions society are not the same as approaches to evaluate marginal changes in the near-term. Too much focus on near-term low cost abatement solutions might risk missing solutions necessary for reaching future zero emissions.
- There are many different possible pathways for reaching zero emissions and many significant changes in society will occur in parallel to the low carbon transitions. Applying a scenario perspective, can help understand the opportunities and problems of different solutions in a changing future landscape.
- We find that there are at least three different categories of assessments that can provide policy relevant knowledge: i) monitoring, ii) policy evaluation, and iii) domain knowledge building processes (including research).
- These assessment categories provide different types of knowledge and can be conducted as a part of on-going policy processes and by different actors to provide different perspectives.
- Although the inclusion of a broad variety of factors and stakeholders can improve the quality of the assessments it should be noted that assessments are resource intensive and delimitations must be made. It is important that the choices are communicated in a transparent way as they will have impact on the conclusions possible to draw.

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