Chapter 16
Methodological Challenges in Combining Quantitative and Qualitative Foresight Methods for Sustainable Energy Futures: The SEPIA Project

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16.1 Introduction

This chapter presents a reflection on the challenges of combining participatory fuzzy-set multi-criteria analysis (MCA) with narrative scenario building and energy modelling, in the context of the SEPIA project.[1] SEPIA aims to investigate participatory decision support systems for sustainable energy policymaking. More precisely, SEPIA elaborates on aspects of sustainability assessment (SA) in the energy policy context in order to reach consensus among the stakeholders involved. SEPIA provides the basis for an SA procedure adapted to the context of Belgian energy governance.

The authors wish to dedicate this chapter to the memory of our friend and colleague Da Ruan. We will remember Da as a motivated scientist with an indefatigable but also very congenial personality.

[1] The SEPIA project is being carried out by five partners: the University of Antwerp (UA, acting as the coordinator), the Free University of Brussels (VUB), the University of Liège (ULg), the Flemish Institute for Technological Research (VITO) and the Belgian Nuclear Research Centre (SCK•CEN). It is funded by the Belgian Office of Science Policy. Further details on this project can be found at the project's website www.ua.ac.be/sepia.

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This chapter addresses methodological challenges phased in SEPIA, as follows. First Sect. 16.2 presents the 'state of the art' in sustainability assessment, foresight methodologies and multi-criteria analysis. Sect. 16.3 discusses how these three domains were combined in the SEPIA project. The chapter ends in Sect. 16.4 with some preliminary conclusions and observations.

16.2 Methods for Strategic Decision Making on Sustainable Energy Development

16.2.1 Sustainability Assessment

The different approaches to integrated sustainability assessment can be illustrated when placed in the broader governance framework. Paredis et al. (2006) make a useful distinction between two ideal-typical governance 'styles', called, respectively, 'policy as calculus' and 'policy as discourse'. These 'styles' illustrate the two extremes of a spectrum of choices available to policymakers interested in setting up governance mechanisms for sustainability. They see sustainable development as a process of change engaging an entire network of actors, institutions, technical artefacts, etc. However, both perspectives differ in the way they approach the generation of strategic knowledge needed for steering this process of change towards a sustainable future. In brief, 'policy as calculus' represents a 'closed' process heavily predicated on expert input and agreement, whereas 'policy as discourse' 'opens up' to a wider range of actors, disciplines and concerns. Both perspectives are compared with a number of attributes in Table 16.1 and a SWOT analysis presented in Table 16.2 below.

'Policy as calculus' assumes that knowledge-based decision support – and the decision processes built on this support – can be conceptualised separately from its 'socio-technical object' (e.g. the energy system). For recommending how to steer socio-technical change in more sustainable directions, expert analysts should 'step outside' the system to objectify its workings.

Governance is characterised in terms of exogenous 'mechanistic' interventions. In all of this, an important role is attributed to 'expert input'. This does not exclude stakeholder involvement for providing 'inputs' to the assessment process.

But separate stakeholders are each assumed to hold a piece of the 'jigsaw puzzle' that experts collect and lay out to compose a picture of the 'socio-technical object'.

Stakeholders as such are nothing more than 'carriers' of policy alternatives, information and value judgements. It is assumed that all stakeholders observe 'the same' object, but each of them tends to focus on a limited set of aspects related to this object. Once the relevant pieces of the puzzle are collected (i.e. objectives are clearly defined and agreed upon, all necessary data are available, cause-effect

Table 16.1 Two different views on governance for sustainability (Based on Paredis et al. 2006; Smith and Stirling 2007)

	Policy as calculus	Policy as discourse
Role of sustainability assessment	Sustainability assessment as a tool for selecting the best alternatives in order to reduce negative sustainability impacts	Sustainability assessment as a framing process of deliberation on ends and means
What matters for political planning?	Uniform solutions based on technical and economic expertise	'Framings', deliberation and perspective-based testing of hypotheses involving a wide range of disciplines (including but not limited to economics and engineering)
Leading actors (networking)	Context dependent, with a focus on academics (with demonstrable expertise in the relevant scientific disciplines) and government actors	Context dependent, with a focus on experts (e.g. academics, professionals with experience in relevant fields), stakeholders (representative of the different 'problem framings') and government actors
Foresight methods	Mostly quantitative (i.e. modelling), explorative trend analysis (based on 'what if' reasoning) Government actors and/or stakeholders as 'clients'	Mostly qualitative (i.e. sociological) analysis (based on 'what is desirable' reasoning) with quantitative analysis as a support Government actors and/or stakeholders providing crucial inputs
Methods and tools (futuring, planning, networking)	'Standard' scientific methods, for example, mathematical models, cost-benefit analysis, cost-effectiveness analysis, checklists, matrices	Deliberative methods (e.g. scenario workshops, expert panels, focus groups) with 'standard' scientific methods as supportive
What is maximised?	Planning – that is, simple answers to complex problems and clear-cut recommendations about specific proposals	Networking – that is, interdisciplinary scientific knowledge, participation, deliberation, individual and societal learning effects
Procedurally effective if…	The optimal alternative has been identified Trade-offs are based on scientifically tested methodologies The proposal is of better quality (in the sense that negative impacts are avoided or mitigated) after the realisation of the assessment	Ideally, the deliberative process produces consensus by actually changing minds through reasoned argument A political community has been created around an issue Decision-making culture and practice have changed Sustainability assessment is iterative and fully integrated within the policy process, giving adequate and timely inputs to policy formation Transformative effect – acceptance of new goals and guiding principles for the energy transition

(continued)

Table 16.1 (continued)

	Policy as calculus	Policy as discourse
Procedurally efficient if…	A solution is found with minimum expenditure of available resources (time, money) and expertise (state-of-the-art knowledge) for the sustainability assessment	The sustainability assessment is carried out according to a clear and achievable timetable, giving enough time and resources for preparation of the process and stakeholder engagement
Procedurally fair if…	The recommended alternative(s) is justified by established expert authority, for example, accredited research institutes, peer review and lauded academics	No legitimate point of view is excluded a priori from the assessment Power differentials between social actors are neutralised

Source: Based on Paredis et al. (2006); Smith and Stirling (2007)

Table 16.2 SWOT of 'policy as calculus' and 'policy as discourse'

	Policy as calculus	Policy as discourse
Strengths	Practical instrument resulting in univocal recommendations from a 'narrow' framing perspective Part of the existing decision-making process in many countries	Sustainability raised as a collective concern Improved decision-making process
Opportunities	Political demand for this kind of exercises Use of existing knowledge and know-how Practical experience with similar exercises (environmental impact assessment, regulatory impact assessment)	Can build on existing participatory arrangements Scientific and political momentum in favour of sustainable development; acceleration of global change signals calls for ambitious action
Weaknesses	Attempt to include all aspects of sustainability in quantitative models faced with difficulties: unavailable data, uncertainties, etc. Environmental, governance and equity concerns are marginalised Acceptance of unlimited substitutability implies 'weak sustainability'	Representativeness of involved and missing stakeholders Potential to yield practical recommendations in due time Difficult to institutionalise Additional (and multidisciplinary) expertise, data, tools and time required compared with 'policy as calculus'
Threats	Technocracy and bureaucracy Reductionist perspectives are encouraged Risk of imbalance towards incremental approaches and consequent marginalisation of long-term sustainable development objectives	Lack of practical experience in conducting sustainability assessment exercises, leading to unrealistic expectations Manipulative interventions by some participants, eventually ending in demagogy Resistance against potentially transformative power of the sustainability assessment

relations are established), the 'solution' to the governance problem follows 'logically' from aggregating the different perspectives by using economic optimisation models, multi-attribute utility theory, etc.

The appraisal process 'closes down' on the single socio-technical object – that is, it is about '…finding the right questions, recruiting the appropriate actors (actors with "relevant" insights), highlighting the most likely outcomes and therefore also defining the best options…' (Smith and Stirling 2007: p. 6).

Once the appraisal procedure has aggregated all relevant information, the instruments for intervening in the dynamics of socio-technical objects follow mechanically (e.g. when economic evaluation finds nuclear power as the 'best option', policy instruments must clear the 'barriers' of a full nuclear deployment). Politically, this approach implies that 'relevant actors' bring their commitments in line with the recommendations from the appraisal. The alignment job is left to the political decision makers, in devising appropriate tools to persuade, entice or simply force actors to realise the path set out by 'the experts'.

'Policy as discourse' starts from the premise that there is no unique 'objectively rational' position from which a 'socio-technical object' (e.g. the energy system) can be observed. System boundaries, interrelations between system components, opinions on what causes change, etc., (in short: 'framings') vary according the actors' perspectives and may change during various stages of the appraisal. Because different 'framings' imply different methodologies for arriving at 'relevant' knowledge about the 'socio-technical object', input to the sustainability assessment cannot be 'imposed', but has to be negotiated. The same applies for the criteria guiding the sustainability assessment, which have to be checked for legitimacy and acceptance. Assessment does not identify the 'best possible' pathway for the evolution of the 'socio-technical object', but rather tests its evolution under the different 'framings' brought to the table by stakeholders. As a consequence, no unique set of ideal policy instruments can be identified; recommendations will always be much more 'conditional' (e.g. 'option x is the preferred option under framings a and b, but does not score well under framing c', 'option y scores rather well under all framings, and can therefore be considered as a robust option').

A word of caution is warranted here. The difference between 'policy as calculus' and 'policy as discourse' should not be conceived along the lines of a stark dichotomy between '…established, narrow, rigid, quantitative, opaque, exclusive, expert-based, analytic procedures tending to privilege economic considerations and incumbent interests…' and the '…new, relatively unconstrained, qualitative, sensitive, inclusive, transparent, deliberative, democratically legitimate, participatory processes promising greater emphasis on otherwise marginal issues and interests such as the environment, health, and fairness…' (Stirling 2008: p. 267). In other words, according to Stirling (2008), the detailed context and implementation of a particular governance approach are more important factors to understand what happens in practice. Instead of an illustration of the opposition between an 'expert-based' and a 'deliberative' governance approach, the difference between 'policy as calculus' and 'policy as discourse' should be seen as an illustration of how assessments and/or commitments can be 'closed down' (in the case of 'policy as calculus') or 'opened up' (in the case of 'policy as discourse') in an institutional environment which is structured and pervaded by power relationships. If appraisal is about 'closing down' the formation of commitments to policy instruments or technological options, then the aim of the assessment is to assist policymakers by providing a direct means to justify their choices. If, on the other hand, the assessment is aimed at 'opening up' a process of social choice, then the emphasis lies on revealing to the wider policy discourse any inherent indeterminacies, contingencies or capacities for action. Of course, expert-based analytic approaches such as cost-benefit or cost-effectiveness assessment are frequently practised as part of a 'policy as calculus' approach, but these techniques might equally lend themselves to an 'opening up' philosophy (Stagl 2009).

In order to define adequately the features SEPIA adopts, a thorough analysis of the existing energy policy context and the institutional landscape is necessary. In practice, the dominant approach in Belgium to decision support in energy policy has followed more or less the 'policy as calculus' philosophy. Therefore, we consider there is both in academic discussion and in policy practice some scope for a more symmetrical interest in processes for 'opening up' the debate on long-term sustainable energy strategies. SEPIA had to find an adequate balance between assessments of 'opening up' and 'closing down' and choose the appropriate methods accordingly. These methodological choices are explained further in Sect. 16.3.

16.2.2 Foresight Methodology

Sustainability assessment is necessarily predicated (to a greater or lesser extent) on 'foresight' abilities, that is, abilities of thinking, shaping or debating the future. In practice, foresight comes in many different shapes and forms (van Notten et al. 2003). A first distinction is between *predicting* and *exploring* the future. Earlier attempts at forecasting have proven to be largely unsuccessful (particularly in the case of long-term energy foresight) and are increasingly being abandoned by foresight practitioners – although expectations of correct prediction on the part of policymakers are still apparent. Next, there is the difference between *quantitative* (modelling) and qualitative (narrative) traditions, with the former prevailing in the field of energy. Hybrid approaches combine narrative scenario development with quantitative modelling. Also there are those futuring approaches distinguished as *descriptive* or *exploratory* which describe possible developments starting from what is known about current conditions and trends and from normative, *anticipatory* or backcasting approaches constructing scenario pathways to a desirable future.

Neither approach is 'value free', since both embody extra-scientific judgements, for example, about 'reasonable' assumptions. But the objectives of the scenario development exercise determine the choice between exploratory and anticipatory approaches. Exploratory (or 'what if') analysis articulates different plausible future outcomes and explores their consequences. By prioritising technological choices, technical and economic experts perform the analysis in a relatively closed process, with government actors mostly assuming the role of clients (they 'order' the analysis).

Anticipatory scenarios represent organised attempts to evaluate the feasibility and consequences of achieving certain desired outcomes or avoiding undesirable ones.

Finally, *trend* scenarios based on extrapolations of (perceived) dominant trends differ from *peripheral* scenarios focusing on unexpected developments and genuine 'surprising' events. Several choices on the most suitable foresight methodology need to be made. The SEPIA choices are elucidated later in Sect. 16.3.1.

16.2.3 Multi-criteria Decision Support

By accepting the view that energy systems are multidimensional in nature, it has also to be accepted that the evaluation of public plans or strategic decisions has to be based on procedures that explicitly require the integration of a broad set of (possibly conflicting) points of view. Consequently, multi-criteria (MC) evaluation is the appropriate decision framework to apply in principle (Kowalski et al. 2009).

A great variety of MC decision support tools exist and can be used in the context of sustainability assessment under both the 'policy as discourse' and the 'policy as calculus' philosophy. Therefore, the choice of a particular method must be guided by its fitness for the problem characteristics and the desired scope/features of analysis. Each analysis method is based on specific assumptions and supports only a certain type of analysis. A promising start for reflection is provided by Munda (2004) and Granat and Makowski (2006).

For complex decision-making problems such as deciding on long-term energy policy strategies, Munda has developed an MC decision support technique called 'social multicriteria evaluation' (SMCE) and discusses its application to the problem of a wind farm location (Gamboa and Munda 2007). Granat and Makowski discuss the requirements of an MC decision analysis tool for an application very similar to ours – that is, a stakeholder evaluation of energy technologies and scenarios, albeit at the European level. According to these authors, MC decision support respecting the principles of the 'policy as discourse' philosophy has to show the following characteristics:

- The MC method is able to handle criterion scores of a different nature ('crisp' scores, stochastic scores, 'fuzzy' scores, etc.).
- In general, simplicity is a very desirable characteristic of the MC decision process – that is, the number of ad hoc parameters used should be limited (preferably only information on weights and scores should be used as exogenous inputs).
- Criterion weights should be seen as 'importance coefficients' (and not as numerical values allowing for full compensability between criteria or as indicators of a 'trade-off' between different criteria).
- Information on all possible rankings for each actor should be given (and not only on the 'optimal' one, since taking into account second-best or third-best options can reveal a space for compromise solutions compared with other actors' rankings).

- The MC appraisal should include a 'conflict analysis' (i.e. an analysis of the 'distance' between the different actor perspectives, revealing possible groupings into major 'world views'). As win-win situations are not always achievable, some trade-offs will have to be made. These trade-offs will then appear in the discussions on values stimulated by the use of the MC appraisal and will give normative input to the consequences of selecting one alternative over another. Mathematical models can then be of assistance in the selection of the most consensual alternative, the regrouping of alternatives according to the results of the conflict analysis, etc.

Section 16.3 below gives further details on the particular approach adopted in the SEPIA project.

16.3 Towards a Sustainable Energy Policy Integrated Assessment in Belgium

16.3.1 Foresight Methodology

Following SEPIA's 'opening up' logic, the foresight methodology explicitly acknowledges the possibility of different 'framings' of the energy system (the 'socio-technical object' under consideration) and of the factors that cause long-term changes in this system. Narrative scenario building is particularly well suited for 'opening up' the system description to, and for the exploration of, fundamental complexities and uncertainties (Bunn and Salo 1993). The construction of scenarios for exploring alternative future developments under a set of assumed 'driving forces' has a long tradition in strategic decision making, especially in the context of energy policy (Kowalski et al. 2009). Exploratory scenario building is criticised for its propensity to limit the space of the possible to only a few probable 'storylines' (Granger Morgan and Keith 2008). The backcasting approach is more suited for long-term and complex problems – such as sustainable development – requiring solutions which shift society away from business-as-usual trends. Backcasting is, however, often criticised for defining utopian futures with little value for decision makers in the 'real world'.

For combining the strengths of explorative and (traditional) backcasting methodologies, SEPIA developed a 'hybrid backcasting' approach. Following a hybrid backcasting approach, scenario building takes place starting from a systematic exploration of futures, by studying many combinations resulting from the breakdown of the energy system. The process of 'breaking down' the system implies the definition of a set of factors, which could each influence the development of the energy system in different directions. These possible developments are formulated as 'hypotheses' or 'possible configurations'. The total number of combinations represents a 'morphological space', which must then be reduced to a number of coherent sets by formulating transition conditions ('exclusions' and 'compromises') congruent with reaching sustainability visions defined by the stakeholder panel

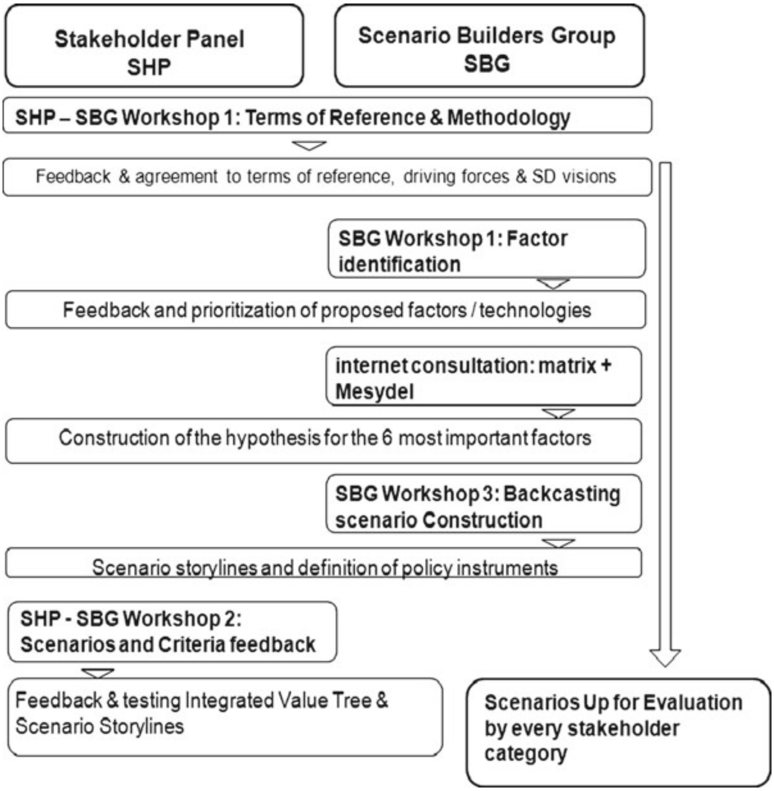


Fig. 16.1 Scenario-building steps in the context of the SEPIA project

(SHP). For this process, we proceeded in a number of separate steps (see Fig. 16.1). These steps are explained in Sects. 16.3.1.1, 16.3.1.2, 16.3.1.3, 16.3.1.4, 16.3.1.5, and 16.3.1.6. The scenario-building phase relied on qualitative in-depth deliberative workshops with the scenario builders group (SBG), where the SEPIA team acted as 'scientific secretariat', delivering input materials for the workshops (e.g. information sheets) and processing the outcomes. Scenarios were reviewed by the SHP.

Social mapping was used for composing the SBG and SHP groups, meeting the following criteria:

- *Scenario builders group (SBG)*: The SBG is responsible for developing the long-term energy scenarios describing the different possible visions of a sustainable energy future (horizon 2050) and the pathways (including policy instruments) needed to realise those visions. We expected each participant to contribute their expertise and personal experience to the discussions. The scenario builders were asked to participate in their personal capacity and not as a representative of the organisation in which they are active. The participants were generally willing to engage in an open, creative, non-judgemental foresight process. Members of the SBG are contacted by the SEPIA team and submitted for approval to the steering committee.

- *Stakeholder panel (SHP)*: The SHP is mainly responsible for evaluating the long-term energy scenarios developed by the SBG though they will also be given an important role in setting the general directions for these scenarios and providing feedback on scenario assumptions before the LEAP modelling will take place. This group aims to be representative of the 'stakes' in the Belgian energy sector. Therefore, it was important to ensure that all the potential social groups with a current or potential interest in the problem had the possibility of being included in the process. When deciding on the composition of groups taking part in participative processes, inclusiveness refers to ideas of *representativeness*, although *not in a statistical sense*. Rather, participants should be selected to represent constituencies that are known to have *diverse and, especially, opposing interests*. No stakeholder group should be composed of a preponderance of representatives who are known to have a similar position or who have already formed an alliance for common purpose. In the case of experts – who are presumed not to have constituencies but ideas – they should be chosen to represent whatever *differing theories or paradigms* may exist with regard to a particular task.

16.3.1.1 SHP-SBG-W1: Terms of Reference and Methodology

It is clear that, before starting to formulate sustainable energy strategies, policy makers and/or relevant stakeholder groups will already have some general ideas about the possible alternative solutions. Before entering the multi-criteria assessment phase (in which a decision about the significance of the possible impacts of the alternatives in terms of furthering the sustainable development agenda has to be made), these general ideas will already have to be worked out to a greater level of detail.

It is only as a result of the detailed 'scoping' of the sustainability assessment that the decision alternatives will take on their definitive shape – that is, the 'scoping' provides the necessary consensual ground rules for deciding what counts as a 'reasonable' alternative, the range of alternatives to be taken into account, the level of detail needed to explore each alternative, etc. Scoping is therefore an essential part of the sustainability assessment and should form the basis of a negotiated 'contract' between the project team, stakeholders, experts and steering committee involved in the project. This 'contract' is called the 'terms of reference' (TOR). The SEPIA terms of reference were thoroughly discussed in a full-day workshop.[2] Since the (hybrid) backcasting approach adopted in the project essentially relies on normative inputs for the development of desirable end points, the first workshop was for a large part devoted to finding a consensus on sustainability principles. An *integrated value tree* was developed which discusses the sustainability goals specific to the development of energy systems in more detail. A value tree identifies and organises the values of an individual or group with respect to possible decision options. It

[2] The final version of the SEPIA TOR can be downloaded from the project website (www.ua.ac.be/sepia).

structures values, criteria and corresponding attributes in a hierarchy, with general values and concerns at the top and specific attributes at the bottom. The integrated value tree integrates *fundamental sustainable development (SD) objectives* (to be reached in 2050), *SD (sub-) dimensions* (a further specification of the objectives) and *SD indicators* (quantitative or qualitative scores indicating how well a particular scenario contributes to reaching the objectives).

16.3.1.2 SBG-W1: Factor Identification

For the first SBG workshop, the SEPIA project team developed brief explanations and 'fact sheets' for about 50 major factors (trends, tendencies)/technological developments which were expected to have an impact on long-term Belgian energy system development. A 'factor' was defined as anything that could influence energy system development in the long run. This workshop was meant to explore the possible factors of change without making an opinion on the desirability of certain evolutions. Only in the later process steps were possible factor evolutions connected with desirable visions on the long-term energy future. During the workshop comments, suggestions and remarks on the current state, predictability, possible states (hypotheses) and the time horizon of change (slow evolution vs. sudden change) of different factors were elicited.

The afternoon session of the workshop continued with the identification and selection of about 20 most important factors rated according to their impact on reaching sustainable development objectives in 2050.

The output of the individual point allocation (green and red dot stickers), as well as the bailout points (blue dot stickers), had as a result the definition of the guiding factors for the SEPIA exercise. The participants agreed on selecting 22 factors instead of 20 as to avoid wasting valuable time in discussions. The final list of 22 factors was accepted after the question 'Do we all agree on this?' (see Table 16.3).

16.3.1.3 Internet Consultation: Matrix Exercise

The list of 22 factors with a likely influence on energy system development was consequently submitted to the SBG in an Internet consultation in order to perform a cross-impact analysis of interdependencies between factors. The cross-impact analysis was performed by asking the members of the SBG to fill in a 22 × 22 matrix with the 22 factors represented in the rows and columns of the matrix. Each cell of the matrix represented the impact of the factor in the row on the evolution of the factor in the column (score between 0 and 3:0 = no impact; 3 = high influence). By adding together the scores of all members of the SBG, factors could be classified into the following groups:

- *Determinants*: Factors with a high influence on the development of other factors, without being influenced much in return. In other words, these factors act as 'motors' or 'restraints' for the development of energy systems.

Table 16.3 List of 22 factors selected during SBG-W1

T8 Advances in energy storage technologies
P2 EU internal energy market policy
T1 Competitiveness of energy conservation technologies for stationary end uses
Ex3 Structural changes to the Belgian economy in a globalised environment
Ex13 Location
P1 EU energy vulnerability strategy
P3 EU energy RD&D strategy
P4 Price instruments to internalise externalities
T13 The 'hydrogen economy'
T6 Advances in renewable energy technologies
T14 The 'electric economy'
Ex 11 Ecological and health constraints
T10 ICT technology innovations
B5 Active public involvement in environmental issues
Ex 12 Market environment
Ex 9 Energy price dynamics
P9 Land-use policies
B6 Risk perception and evaluation
B8 Shifts in demands for housing and living space/comfort
P8 Stranded assets and lock-in
P7 Importance of social policy
T2 Energy efficiency of various transport modes: technological progress

Note: RD&D = research development and deployment

- *Strategic variables*: Factors with both a high influence and dependence on other factors. These factors are likely candidates for the development of broad strategic actions plans, provided they can be 'steered' by political interventions.
- *Regulatory variables*: Factors with both a mid- to low influence and dependence on other factors. These factors can be taken into consideration when designing specific policy instruments, provided they can be 'steered' by political interventions.
- *Dependent variables*: Factors which are highly dependent on the evolution of other factors. These factors can be likely candidates for monitoring efforts.
- *Autonomous variables*: Factors which evolve largely independently of other factors.

Based on this matrix exercise, six factors were selected (three determinants and three strategic variables) that would serve as the 'backbone' for the scenario storylines (developed in SBG-W3):

– Ecological and health constraints
– Energy price dynamics
– Market environment
– Use of price instruments to internalise externalities
– EU energy research development and deployment (RD&D) strategy
– EU energy vulnerability strategy

16.3.1.4 Internet Consultation: Mesydel

At the start of the second phase of the Internet consultation, the project team developed two to three hypotheses with regard to the long-term evolution for each of the six most influential factors. These hypotheses were submitted to deliberative feedback by members of the SBG with the aid of the 'Mesydel' tool.[3] With Mesydel, questions are encoded on a central computer and access to the software is given to each expert. At any time, they could come back to the software and amend or augment their answers. The mediator, for his part, has access to a series of answers classification tools and the ability to mark the answer's relevance, to note if he will or will not work later on the question, to comment on the answers (these comments are for his exclusive use) and – the most interesting feature – to give 'tags' (keywords) to answers. These tags could then be classified according to topics selected by the mediator. These classification tools allow the mediator to have huge flexibility in his work and help to optimise his results by allowing him to find all relevant messages on a given topic very quickly. The 'Mesydel' round thus resulted in amended versions of the hypotheses developed for each of the factors.

16.3.1.5 SBG-W3: Construction of Scenario 'Skeletons' as Combinations of 'Favourable' Factor Projections for Different Sustainability World Views

Starting from the processed results of the Internet consultation (priority factors and a short description of possible alternative hypotheses for their evolution), the members of the SBG developed three scenario 'skeletons' composed of factor hypotheses and technological developments congruent with the logic of reaching the fundamental sustainability objectives. This can be done by a formal consistency check; however – in view of the highly resource-intensive mathematical character of this procedure (and the need for supporting software) – we chose a more *intuitive* manner of proceeding. Starting from a certain factor, a hypothesis was selected and then connected to other hypotheses (for the other factors) that were deemed to be consistent with the initial hypothesis. This combination of hypotheses could then be regarded as an alternative 'solution' to the problem of moving towards the attainment of the sustainability objectives in 2050. These combinations were then taken as a basis for the construction of a scenario, and the procedure was repeated until the SBG felt that they had covered the range of possibilities with their scenarios.

For each of the scenario skeletons (which both enable and constrain certain developments), the SBG group had to explore in which other factors (taken from the original list resulting from SBG-W1; see Sect. 16.3.1.1) – that is, technologies, behavioural changes, broad policy choices, etc., – 'critical' changes had to be achieved (compared with now) in order to achieve a certain vision of a Belgian energy system in 2050 which is supportive of the sustainability objectives. They

[3] For more information, see http://www.mesydel.com/mesydel.php.

also had to indicate an approximate timing of the changes needed in the 'critical' factors. Finally, in order to complete the pathways, the SBG group had to *backcast* the necessary policy interventions needed on the Belgian level for reaching the sustainability objectives, given a certain combination of a vision and pathway elements as the policy context. The backcast had to give an answer to the question: '*What is needed at the Belgian (*i.e. *federal and regional) level in order to realize the changes in the factors within the time frame indicated by a particular pathway*?' Although the workshop discussions led to many interesting suggestions, we did not succeed in constructing pathways in sufficient detail to serve as an input to the LEAP energy system model. A detailed backcast also proved to be too demanding a task, mainly due to the rather low attendance. A lot of decisions still had to be made. As a consequence, the project team decided to change the format of the final workshop to some extent, dedicating it also to the further construction of scenarios storylines.

16.3.1.6 SHP-SBG Workshop 2: Deliberative Feedback on Scenario Storylines and Proposed Value Tree Before Evaluation

The last workshop, which combined inputs from the SHP and SBG, served a dual purpose: deliberation and feedback on a draft value tree as proposed by the project team (with 'fact sheets' unequivocally explaining each indicator, potential data sources and possible measurements (e.g. quantitative/qualitative), taking into account uncertainties) and feedback and further development of the 'scenario skeletons' developed by the SBG in the previous workshops. The value tree was modified according to the feedback received.[4] Deliberative feedback on the scenario skeletons resulted in more detailed specifications on the scenarios to serve as an input into the LEAP modelling exercise; however, a lot of 'room for interpretation' was still left for the project team. At the time of writing this chapter, the SEPIA scenarios were still under development. Therefore, for the time being, we can only give a qualitative description of the three scenario storylines serving as an input for further modelling.

A first storyline called 'global consensus' starts from the assumption that climate change concerns dominate energy system development, in the sense that early and drastic emission cuts are called for (e.g. an EU target of −30% in 2020 compared with 1990). Energy RD&D spending on the EU level is increased substantially and is geared towards realising a common European vision – a low-carbon energy system with maximum penetration of renewable and distributed energy sources. RD&D focuses on technological 'breakthroughs' for the achievement of the common energy system vision (e.g. advances in ICT, large offshore wind parks, smart grids, energy storage technologies, nanotechnology). Those solutions mostly require big investments in new supply technology and/or new infrastructures (cf. the 'SuperSmart Grid').[5] Technologies that are labelled as 'risky' encounter strong public and politi-

[4] The final version can be downloaded from the project website (www.ua.ac.be/sepia).

[5] More information on the 'SuperSmart Grid' concept can be downloaded from www.supersmart-grid.net.

cal opposition. A combination of low public acceptance and unresolved waste, safety and proliferation issues leads to a rejection of the nuclear option: without public backing, investments in new nuclear power plants simply become too risky for private investors. Existing plants are shut down as they reach the end of their projected lifetime, and lifetime extensions are not considered. Public support for carbon capture and storage (CCS) is also reluctant. By 2050, energy supply is largely based on renewable energy sources.

In the 'oil shock(s)' storyline, the oil (and possibly also the gas) market goes through a series of crises in the period 2010–2030, caused by physical (peak production or refinery capacities are surpassed) or political factors (e.g. crisis in the Middle East), resulting in sudden and unpredictable price increments. Leading powers try to control the remaining resources by engaging in strategic alliances, as energy policy is to a large extent dictated by foreign policy and security considerations. Energy security is the main concern over the short to midterm, leading to a focus on energy efficiency (on the demand side) and on available technologies that alleviate the dependence on imported oil and gas (on the supply side): renewables (mainly wind energy and biofuels), coal (later equipped with carbon capture and storage) and prolonging the lifetime of existing nuclear power plants. Thanks to these measures, energy security concerns are alleviated over the period 2030–2050, allowing the climate change agenda to take over as a priority issue.

Finally, the 'confidence in RD&D' storyline stands for a scenario where a combination of high oil (and gas) prices, climate policy and competitive energy markets decisively influences the pace of transition to a low-carbon energy future in the OECD countries. In the EU, the Lisbon agenda (and possible successors) carries high priority. The EU protects and expands its previous economic achievements, including the internal energy markets. However, governments are still heavily involved in securing their external energy supplies (this goes for 'government', as well as on the EU and on the national level in Europe), albeit in a more subtle and indirect way than in the 'oil shock(s)' scenario. In general, market forces determine the investments choices made by the energy industry between renewables, 'clean coal' and nuclear power, but public and/or political perceptions sometimes lead to targeted interventions. The use of the nuclear option is especially closely associated to national preferences. Independently from the developments in the fields of nuclear energy, Europe is on its way to a smooth and accelerated transition towards renewable energy. The process is quite similar to the one described in 'global consensus', although the share of renewable energy sources is smaller. Large offshore wind farms are the most important renewable source for electricity production, and biomass is playing a major role in heating or cogeneration. In addition, because of the higher demand, highly efficient gas- and coal-fired power plants with CCS are needed in this scenario. Decentralised power generation is a growing trend in the coming 50 years. The increase in energy efficiency is also determined by market forces as new energy end-use technologies emerge in electricity use, space heating, 'smart' decentralised energy systems and transportation.

16.3.2 Fuzzy-Set Multi-criteria Decision Support

As mentioned in Sects. 16.1 and 16.2, the scenarios developed for the SEPIA project have not yet been evaluated with the aid of the multi-criteria decision support tool at the time of writing this chapter. To clarify the motivation for the use of fuzzy-set multi-criteria analysis, we briefly illustrate here the features of the fuzzy-logic multi-criteria group decision support tool called DECIDER used in SEPIA (Ruan et al. 2010).

16.3.2.1 Application of Fuzzy-Logic to Multi-criteria Analysis

Multi-criteria analysis (MCA) with linguistic variables, commonly known as fuzzy-set multi-criteria decision support, has been one of the fastest growing areas in decision making and operations research during the last three decades. The motivation for such a development is the large number of criteria that decision makers are expected to incorporate in their actions and the difficulty in practice of expressing decision makers' opinions by means of precise values. Group decision making takes into account how people work together in reaching a decision. Uncertain factors often appear in a group decision process: namely, with regard to decision makers' roles (weights), preferences (scores) for alternatives (scenarios) and judgements (weights) for criteria (indicators) (Lu et al. 2007). Moreover, MCA aims at supporting decision makers who are faced with making numerous and conflicting evaluations. It highlights these conflicts and derives a way to come to a compromise or to illustrate irreducible value conflicts in a transparent process. Firstly, as decision-aiding tools, such methods do not replace decision makers with a pure mathematical model, but support them to construct their solution by describing and evaluating their options. Secondly, instead of using a unique criterion capturing all aspects of the problem, in the multi-criteria decision-aid methods, one seeks to build multiple criteria, representing several points of view. In particular, fuzzy-set multi-criteria decision support respects the principles of the 'policy as discourse' approach as set out in Sect. 16.2.1. This will be illustrated next in Sect. 16.3.2.2 by illustrating one feature of the DECIDER software – that is, the possibility of opinion clustering.

16.3.2.2 Clustering of Opinions

Suppose we have 10 people (P1–P10) who have scored scenarios on the different (sub-) criteria and have given weights to these (sub-) criteria (the example here is taken from an earlier application of the DECIDER model). Mathematical functions allow us to calculate the 'distance' between the revealed preferences of the different people. This is represented graphically in Fig. 16.2, which gives us the following information:

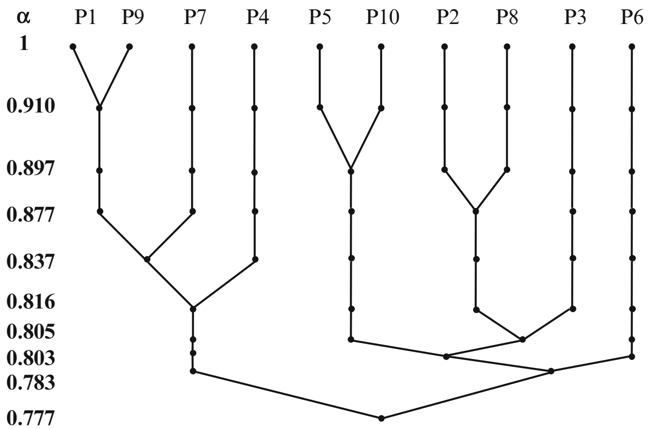


Fig. 16.2 Dendrogram of the cluster formation process

- The opinions of P1 and P9 are closest to each other (as expressed by the value of the parameter α). Therefore, they are the most likely candidates for a 'coalition'. Therefore, if we want to simplify the decision process and work with just 9 opinions instead of the original 10, P1 and P9 are the most likely candidates to be taken together without major conflicts (i.e. represented by an 'average opinion').
- The opinions of P5 and P10 are the second closest to each other. Therefore, if we want to simplify the decision process and work with just 8 opinions instead of the original 10, P5 and P10 can probably be taken together without major conflicts (i.e. represented by an 'average opinion'), next to P1 and P9.
- The list below indicates which 'coalitions' have to be considered if we want to represent just one opinion (i.e. the average for the whole group) concerning the ranking of scenarios, 10 different opinions (the original individual scores and weights) or any possible number of 'coalitions' between 1 and 10.

1. {P1, P2, P3, P4, P5, P6, P7, P8, P9, P10}
2. {P1, P4, P7, P9}, {P2, P3, P5, P6, P8, P10}
3. {P1, P4, P7, P9}, {P2, P3, P5, P8, P10}, {P6}
4. {P1, P4, P7, P9}, {P2, P3, P8}, {P5, P10}, {P6}
5. {P1, P4, P7, P9}, {P2, P8}, {P3}, {P5, P10}, {P6}
6. {P1, P7, P9}, {P2, P8}, {P3}, {P4}, {P5, P10}, {P6}
7. {P1, P9}, {P2, P8}, {P3}, {P4}, {P5, P10}, {P6}, {P7}
8. {P1, P9}, {P2}, {P3}, {P4}, {P5, P10}, {P6}, {P7}, {P8}
9. {P1, P9}, {P2}, {P3}, {P4}, {P5}, {P6}, {P7}, {P8}, {P10}
10. {P1}, {P2}, {P3}, {P4}, {P5}, {P6}, {P7}, {P8}, {P9}, {P10}

This 'clustering process' can be an important tool for policymakers. Instead of just relying on the average result for the whole group (which hides important value conflicts) or individual opinions (which give no information on a collectively preferred scenario), clustering can be used to investigate different possible rankings of scenarios based on different decision principles, such as:

- What happens if we give different weights to the different individuals or coalitions (i.e. policymakers might attach more importance to the opinion of some people over others)?
- What happens if we respect the majority principle?
- What happens if we give veto power to minority opinions (e.g. they can veto the scenario they prefer least)?
- Which scenarios provoke the strongest conflicts of opinion?

16.3.2.3 Further Development of the DECIDER Model in the Context of SEPIA

Owing to the potential difficulties of evaluating the quantitative and qualitative information (or data) obtained by different experts, the MCA in the above-mentioned DECIDER tool for decision support was further developed to suit the purpose of the SEPIA project.

Such quantitative and qualitative information (or data) by experts is of a very different nature; it may be heuristic or incomplete or data that is either of unknown origin, or may be out of date or imprecise, or not fully reliable, or conflicting, and even irrelevant. In order to allow an adequate interpretation of the information from the experts' evaluation and to reach a conclusion, there was a need to update the DECIDER tool so that it is able to deal with various uncertainties that result in various data formats in practice.

It was considered advantageous to have a sound and reliable mathematical framework available that provides a basis for synthesis across multidimensional information of varying quality, especially to deal with information that is not quantifiable due to its nature and that is too complex and ill defined, for which the traditional quantitative approach (e.g. the statistical approach) does not give an adequate answer.

Within the SEPIA project, DECIDER was further developed to deal with the following issues:

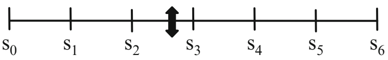
I. Information (data) presentation with different formats

Type A. *Numerical value* – It is the most common way of indicating information scale. Any information α takes values in a [0, C] interval, where 0 is the lowest and predetermined C value is the highest level of possible judgements. $C=1$ and $C=100$ cases are the most frequently used ones.

Type B. *Interval value* – Any interval of [0, C] may give sufficient information.

Type C. *Linguistic value* – It is sometimes more appropriate to indicate information with linguistic terms (fuzzy sets) instead of numerical values. In type C, α takes values from a predetermined linguistic terms set. Let $S=\{Si\}$, $i=\{0,\ldots, m\}$ be a finite and totally ordered term set. Any label, si, represents a possible value for a linguistic variable. The semantics of the finite term set S is given by fuzzy numbers defined in the [0, 1] interval, which are described by their membership functions. For instance, S = {Si}, i = {0,…, 6}, in which the following meanings are assigned to the terms: S0: none, S1: very low, S2: low, S3: medium, S4: high, S5: very high and S6: excellent.

Type D. *2-tuple (continuous linguistic value)* – When it is hard to make information with discrete linguistic terms, then one can indicate some information between S2 and S3 below.



Type E. *Distribution over linguistic values*

A belief structure could be used, for instance, to represent general belief of the information with a given situation, such that to evaluate a performance of, say, scenarios vs. criteria, an expert may state that he is 20% sure it (the relationship between scenario x and criterion y) is S1, 50% sure it is S2 and 30% sure it is S3. In this statement, S1, S2 and S3 are linguistic evaluation grades, and percentage values of 20%, 50% and 30% are referred to as the belief degrees, which indicate the extents to which the corresponding grades are assessed.

II. Information aggregation with various certain and uncertain theories

After having obtained all formats of information, one can transfer all information from the types A, B, C and D to the type E. Thus all well-known theories such as set theory, probability theory, possibility theory, fuzzy-set theory and evidence theory can be selected and applied depending on the nature of uncertainty of the information. Different aggregation techniques can be also applied for different needs of the decision analysis support.

III. Final decision support scenarios

By using the type E-based approach in (I), one can deal with efficient uncertain information, especially when missing information appears during the decision analysis within the project. Typically, missing information could be as follows: (a) experts do not know/understand the information; (b) experts do not have any information; and (c) experts think the information is irrelevant. Most traditional approaches would have some difficulty in dealing with such missing information.

16.4 Concluding Observations

Sustainability assessment of energy policy strategies is performed at the interface between scientific theory building and political practice. Therefore, any practical implementation of a sustainability assessment will be judged by criteria related to scientific soundness, political legitimacy as well as practicability (in a real political setting). In this chapter, we have offered a reflection on how such criteria can be met, based on experiences gained in the SEPIA project. Indeed, the SEPIA project is predicated on the presumption that the issue of deciding on an appropriate (i.e. sustainable) long-term energy strategy is at least a suitable 'test case' for a more deliberative (discursive) governance arrangement, *ergo* that it is not a priori better handled by alternatives such as (a combination) of free market competition, lobbying and/or direct government regulation (top-down 'government' as opposed to bottom-up 'governance'). Further in-built presuppositions include that some particular composition of actors is thought to be capable of making decisions according to (voluntarily accepted and consensually deliberated) rules that will resolve conflicts to the maximum extent possible and (ideally) provide the resources necessary for dealing with the issue concerned and, moreover, that – the next presupposition – these decisions once implemented will be accepted as legitimate by those who did not participate and who have suffered or enjoyed their consequences. Apart from these considerations, one needs to keep in mind that unlike normal science, foresight knowledge is non-verifiable in nature, since it does not give a representation of an empirical reality. All in all, substantiating the quality of the SEPIA approach is certainly challenging, in theory as well as in practice, as demonstrated by the following observations.

Essentially, the SEPIA methodology is in line with a large body of theory building in the field of ecological economics, decision analysis, and science and technology studies, which all argue in favour of combining analytical and participatory research methods in the field of 'science for sustainability'. This view is motivated by the fact that sustainability problems are multidimensional (thus limiting the use of strictly monetary cost-benefit analysis) and of a long-term nature (thus involving significant uncertainties) and apply to complex socio-economic and biophysical systems (thus limiting the use of mono-disciplinary approaches). In principle, the advantages of combining a (hybrid backcasting) scenario approach with a (fuzzy-logic) multi-criteria decision-aiding tool are clear. Scenario exploration allows the (socio-economic and biophysical) complexities of energy system development to be taken into account so that uncertainties in the long term can be explored. Multi-criteria methods, and especially those based on fuzzy-set theory, are very useful in their ability to address problems that are characterised by conflicting assessments and have to deal with imprecise information, uncertainty and incommensurable values. Both methods are supported by a large body of scientific literature, ensuring that an effective check of 'scientific soundness' can be made through the peer review process. However, the application of these methods, and especially their participatory nature, poses significant challenges in practice. For instance, the combination of narrative scenario building and quantitative modelling in theory necessitates the need for a deliberative consensus on all parameters used in the model, which in practice turns out to be impossible to organise (the LEAP model requires hundreds of inputs). In any case, the scenario development phase had already turned out to be time intensive for stakeholder participants. We struggled with nonparticipation and dropouts of stakeholders; without proper investigation, for the time being, we cannot explain why participation fluctuated as it did. However, at least part of the explanation can probably be found in the general impression that the potential players in the Belgian energy system transition landscape – whatever their number may be – are rather scattered. In Belgium (as in many other countries), energy problems cross a varied set of policy domains and agendas, such as ensuring the correct functioning of liberalised energy markets, promoting renewables, environmental protection and climate policy. These are dealt with by different bureaucratic 'silos' and analysed by separate groups of experts and policymakers. As a result of this fragmentation, a lot of the key players struggle with overloaded agendas, organisation-specific expectations and performance criteria and hence find no time for explicit reflective/exchange moments in the context of a scientific project not directly connected to any actual decision-making process. There may be many contacts when events occur and by means of communication, but there is not a structured exchange of experiences, knowledge and mutual feedback ('structured' in the sense of embedded in a culture of working methods). This impression of fragmentation sharply contrasts with the high priority assigned to institutionalised networks and collaboration in the context of 'transition management'. Perhaps the best way to sum up the findings so far is as follows: assessing scenarios in the form of transition pathways towards a sustainable energy future with the aid of a participatory fuzzy-logic multi-criteria decision-aiding tool certainly has the potential to support a more robust and democratic decision-making process, which is able to address socio-technical complexities, and acknowledges multiple legitimate perspectives. However, these methods are time and resource intensive and require the support of adequate institutional settings for a proper functioning in real political settings. Participation in integrated energy policy assessment should therefore not be taken for granted. We hope that the experience gained so far in the context of the SEPIA project will allow future initiators of similar participatory projects to coordinate the project objectives, the participants' expectations and the political backing with each other, a prerequisite for successful participation in foresight exercises.

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