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Scenario types and techniques: Towards a user's guide

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Abstract

Various scenario typologies have been suggested in attempts to make the field of futures studies easier to overview. Our typology is based on the scenario user's need to know what will happen, what can happen, and/or how a predefined target can be achieved. We discuss the applicability of various generating, integrating and consistency techniques for developing scenarios that provide the required knowledge. The paper is intended as a step towards a guide as to how scenarios can be developed and used.

1. Introduction

Futures studies consist of a vast array of studies and approaches and the area has been called a 'very fuzzy multi-field' [1]. One of the most basic, although contested, concepts in this field is 'scenario'. It can denote both descriptions of possible future states and descriptions of developments. We have chosen to use a broad scenario concept that also covers predictive approaches with sensitivity testing, despite the fact that early scenario developers such as Kahn and Wiener [2, p. 6] would reject such a use of the term. The reason for our choice is that many practitioners use the term in this sense.

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Various typologies have been suggested in attempts to make the field of futures studies easier to overview. Typologies can be important tools for communicating, understanding, comparing and developing methods for futures studies. Without a common language among researchers, all those tasks become much harder.

There is no consensus on the scenario typologies. However, several typologies reflect the view that futures studies explore possible, probable and/or preferable futures. For example, Amara [3] divides futures studies into these three categories [3]. Marien [1] adds the categories 'identifying present trends', 'panoramic view' and 'questioning all the others'. Masini [4, pp. 45–46] identifies three approaches: extrapolation, utopian and vision. The utopian approach includes both positive and negative futures and is characterised by the difference to the probable. The visionary approach has to do with how the utopias could come about. Dreborg [5, p. 19–20] identifies three modes of thinking: predictive, eventualities and visionary. To each of these, Dreborg assigns methodologies to study the future. Forecasting, external scenarios and backcasting are examples of methodologies that are quite 'pure' forms of the predictive, eventualities and visionary modes of thinking, respectively.

In another typology, built on Habermas, different futures studies are distinguished by the function of the knowledge generated: technical, hermeneutic/practical and emancipatory [6–8]. Technical studies focus on objective trends. Hermeneutic studies aim at increasing a common understanding of social reality, whereas emancipatory studies aim at widening the perceived scope of options. Another typology was later presented by Mannermaa [9]: descriptive, scenario paradigm and evolutionary. The descriptive here means the same as the technical. In the scenario paradigm, the main purpose does not lie in predicting, but in constructing several different futures and paths to them. The evolutionary approach adopts a world-view of society developing in phases with good predictability combined with phases of chaotic bifurcations. The challenge here is to make future assessments in the bifurcations and to forecast in linear phases.

Inayatullah [10] identifies three perspectives to futures studies: predictive-empirical, cultural-interpretative and critical-post-structuralist. The cultural-interpretative perspective includes an emphasis on understanding, negotiating and acting in order to achieve a desired future. In the Faucault-inspired critical perspective, the focus is on analysing historical context and power relations and on emphasising the difficulties in statements regarding future developments.

Bell [11] formed three epistemologies: positivism, critical realism and post-positivism. The first is similar to Amara's "probable" and the third shows similarities to Inayatullah's critical post-structural approach. The second represents an approach where the aim is to find the objectively good. The focus is on the evaluation of various possible futures according to objective facts.

Tapio and Hietanen [12] include six paradigms in their typology: Comtean positivism, optimistic humanism, pluralistic humanism, polling democracy, critical pragmatism, relativistic pragmatism and democratic anarchism. The paradigms are defined by the view on knowledge and values, with a gliding scale from the Comtean positivist belief in objectivity to the democratic anarchist's rejections of any policy recommendations, due to the belief that all knowledge is biased and all values too subjective.

van Notten et al. [13] divide scenarios into overarching themes. These are the project goal (why?), process design (how?) and scenario content (what?). The project goal can be explorative or decision support, the process design intuitive or formal and the scenario content complex or simple. The overarching themes are then further divided into more detailed characteristics.

The different typologies above all have their merits. Obviously, it can be useful to have more than one typology of futures studies, since different typologies have different objectives. This paper presents a typology that resembles that presented by Amara [3]. Like Dreborg [5, p. 19–20], we discuss methods that are suitable for developing different scenario types. However, our aim is to describe the methods and procedures on a more operational level, and our starting point is the purpose of the futures studies. The paper is intended as a first step towards a guide to how scenarios can be developed and used. Scenario users, in our terminology, can be those who generate scenarios, those who use already existing scenarios and those to whom scenarios are directed, even though they may not have asked for them. The paper also includes a discussion on different types of scenario techniques and examples are used to illustrate the typology.

2. A scenario typology

Several of the nine typologies presented above build on variants of the categories probable, possible and preferable. We essentially join this tradition because we believe these categories reflect three basically different modes of thinking about the future [5]. However, we adjust the typology in order to emphasise our basis as to how the scenarios are used.

We distinguish between three main categories of scenario studies. The classification is based on the principal questions we believe a user may want to pose about the future. These are *What will happen?*, *What can happen?* and *How can a specific target be reached?*. The resolution is then increased by letting each category contain two different scenario types, see Fig. 1. These are distinguished by different angles of approach to the questions defining the categories.

In addition to the principal questions above, there are two more aspects of the system under study that we consider to be particularly important when characterising scenarios. The first of these is the concept of *system structure*, by which we mean the connections and relationships between the different parts of the system, and also the boundary conditions, which govern a system's development. When it is possible to build a mathematical model of a system under study, the equations are an interpretation of the system's structure (it could e.g. be linear or non-linear). The second important aspect of the system is the distinction between internal and external factors. By internal factors we mean factors that

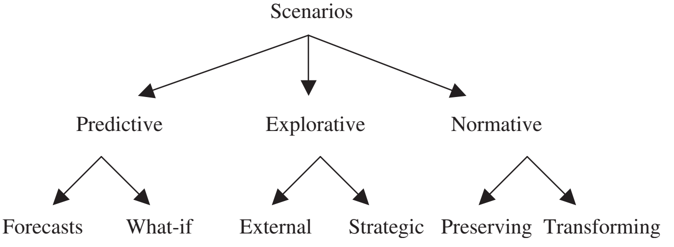

Fig. 1. Scenario typology with three categories and six types.

are controllable by the actor in question, while external factors are outside the scope of influence of the actor.

The first of the questions above, *What will happen?,* is responded to by *Predictive scenarios*. Predictive scenarios consist of two different types, distinguished by the conditions they place on what will happen. *Forecasts* respond to the question: What will happen, on the condition that the likely development unfolds? *What-if scenarios* respond to the question: What will happen, on the condition of some specified events?

The aim of predictive scenarios is to make an attempt to predict what is going to happen in the future. The concepts of probability and likelihood are closely related to predictive scenarios since trying to foresee what will happen in the future in one way or another has to relate to the (subjectively) estimated likelihood of the outcome.

Predictive scenarios are primarily drawn up to make it possible to plan and adapt to situations that are expected to occur. They are useful to planners and investors, who need to deal with foreseeable challenges and take advantage of foreseeable opportunities. Predictions can also be used to make decision-makers aware of problems that are likely to arise if some condition on the development is fulfilled.

Predictions are usually made within one structure of the predicted system, i.e. it is assumed that the laws governing a system's development will prevail during the relevant time period. Historical data many times play an important role when outlining the scenarios. The focus is on causalities, which in a step-wise manner lead to an outcome.

Predictions can also be self-fulfilling. Predicted traffic growth may, for instance, lead to the building of more roads, which stimulates an increase in traffic. The self-fulfilling aspect of predictions makes it possible to use them also for long-term planning and investments in infrastructure. However, the fact that predictions can contribute to preserving past and present trends can also make it more difficult to change undesirable trends.

Forecasts are conditioned by what will happen if the most likely development unfolds, i.e. when making a forecast the basic supposition is that the resulting scenario is the most likely development. Forecasts give one reference result which may be accompanied by results of the type 'high' and 'low ', indicating a span. Forecasts can be used as an aid for planning in, for example, the business environment [14, p. 3]. In such cases, forecasts are made of external factors. These can be economic events, natural phenomena and organisational statistics. Those forecasts are most suited to the short term, when the uncertainty in the development of the external factors is not too great.

What-if scenarios investigate what will happen on the condition of some specified near-future events of great importance for future development. The specified events can be external events, internal decisions or both external events and internal decisions. What-if scenarios can be said to consist of a group of forecasts, where the difference between the forecasts is more than a matter of degree regarding a single exogenous variable. The differences are more like a 'bifurcation'[1] where the event is the bifurcation point. The difference is fundamental and obvious, e.g. 'yes' or 'no' in an important referendum. None of the scenarios is necessarily considered as the most likely development. The resulting what-if scenarios hence reflect what will happen, provided one of two or more events happens. A similar case is when sets of decisions or outcomes are collected in packages, or policy packages. The bifurcation point is less significant in such cases, but if the differences

[1]The "bifurcation" in what-if scenarios can however split development into more than two paths.

between the packages are of vital importance for the further development of the system studied, it is still a case of what-if-scenarios. So-called probabilistic scenarios, in which probabilities of some important outcomes are estimated and then followed by a forecast for each outcome, can be seen as yet another special kind of what-if scenario.

In World Energy Outlook 2002 [15, p. 502], adjustments to parameters of the energy model are sometimes made to take into account expected structural changes in the not so distant future. The purpose of the projections is to analyse the possible evolution of energy markets [15]. Two assumption sets are used as input to the model; a scenario called Reference Scenario and one called OECD Alternative Policy Scenario. The assumptions of the scenarios are generally based on historical values and trends. The difference between the two is that the OECD Alternative Policy Scenario includes new policies on environmental issues and the Reference Scenario only existing ones [15, pp. 38–55]. Hence, in our terminology, the World Energy Outlook 2002 is an example of predictive what-if scenarios of the 'package-kind'.

An advantage with defining what-if scenarios as a group of their own, and not letting them be part of the forecasting type in the typology, is that the outcome is of a different character than the outcome from an ordinary forecast. From a user's perspective, it is a completely different thing to handle a forecast with a sensitivity span and to handle a result consisting of distinctly different outcomes.

The *explorative scenarios* are defined by the fact that they respond to the question *What can happen?* We distinguish between the two types, external scenarios and strategic scenarios. External scenarios respond to the user's question: What can happen to the development of external factors? Strategic scenarios respond to the question: What can happen if we act in a certain way?

The aim with explorative scenarios is to explore situations or developments that are regarded as possible to happen, usually from a variety of perspectives. Typically a *set* of scenarios are worked out in order to span a wide scope of possible developments. In this, explorative scenarios resemble what-if scenarios, but the explorative scenarios are elaborated with a long time-horizon to explicitly allow for structural, and hence more profound, changes. Furthermore, the explorative scenarios more often take their starting point in the future, compared to what-if scenarios, which are usually developed from the present situation. However, long-term predictions, denoted surprise-free scenarios, are often used as reference scenarios in such studies.

Explorative scenarios can help explore developments that the intended target group in one way or another may have to take into consideration. This can be in situations when the structure to build scenarios around is unknown, e.g. in times of rapid and irregular changes or when the mechanisms that will lead to some kind of threatening future scenario are not fully known. Explorative scenarios can also be useful in cases when the user may have fairly good knowledge regarding how the system works at present, but is interested in exploring the consequences of alternative developments. Explorative scenarios are mainly useful in the case of strategic issues [16, p. 86].

External scenarios focus only on factors beyond the control of the relevant actors. They are typically used to inform strategy development of a planning entity. Policies are not part of the scenarios but the scenarios provide a framework for the development and assessment of policies and strategies. The external scenarios can then help the user to develop robust strategies, i.e. strategies that will survive several kinds of external development.

External scenarios can be produced with a rather broad target group, since the scenarios generated are often rather general, e.g. global energy or climate scenarios. When it comes to certain types of climate modelling, for example, the outcome depends on assumptions regarding how the atmosphere and the sea absorb climate gases. Completely different developments are possible depending on how those ecosystems react. The result then forms a basis for discussions on different measures.

External scenarios can also be produced within a specific company or organisation. Some advantages with external scenarios are that they open up the possibility to find flexible and adaptive solutions for an actor whose influence on external factors is small. One specific way of doing this is through the use of scenario planning, a methodology initially aimed at creating business strategies that are robust across a range of different possible future developments [16,17]. External scenarios may also make the organisation more receptive to weak signals of radical changes in the actor's environment. Furthermore, external scenarios, as in the process of scenario planning, have demonstrated an ability to contribute to the creation of a common understanding in organisations and when people from different backgrounds and with different goals meet [16, p. 86].

Strategic scenarios incorporate policy measures at the hand of the intended scenario user to cope with the issue at stake. The aim of strategic scenarios is to describe a range of possible consequences of strategic decisions. Strategic scenarios focus on internal factors (i.e. factors it can possibly affect), and take external aspects into account. They describe how the consequences of a decision can vary depending on which future development unfolds. In these scenarios, the goals are not absolute but target variables are defined. Different policies are typically tested and their impact on the target variables is studied. The strategic scenarios are not only relevant to decision makers, they are also useful as inspiration for interested parties, such as policy analysts or research groups.

The final question, *How can a specific target be reached?,* is responded to by *Normative scenarios*. Normative scenarios consist of two different types, distinguished by how the system structure is treated. *Preserving scenarios* respond to the question: How can the target be reached, by adjustments to current situation? *Transforming scenarios* respond to the question: How can the target be reached, when the prevailing structure blocks necessary changes?

In the case of normative scenarios, the study has explicitly normative starting points, and the focus of interest is on certain future situations or objectives and how these could be realised. When it seems possible to reach the target within a prevailing structure of the system, the preserving scenario approach would be appropriate. On the other hand, if a transformation into a structurally different system is supposed to be necessary in order for the goal to be attained, transforming scenarios can be useful. In the transforming scenario approach, the idea of modelling the structure of the system is often rejected. Trends are thought to go in the wrong direction and the current structure to be part of the problem.

In normative *preserving scenarios*, the task is to find out how a certain target can be efficiently met, with efficiently usually meaning cost-efficiently. This can be done either with some kind of optimising modelling, such as using the optimising energy model MARKAL [18], or in a more qualitative way. One example when this is done in a qualitative way is in regional planning, where the starting point for a new plan is often a group of targets concerning environmental, social, economic and cultural factors. Planners or experts then make judgements on which is the most efficient path to reach a specific target or several targets. This path could be seen as a preserving normative scenario. Such scenarios are not optimising in a mathematical sense, but merely ‘satisfying’.

In *transforming scenario* studies, such as backcasting, the starting point is a high-level and highly prioritised target, but this target seems to be unreachable if the ongoing development continues [19, p. 13]. A marginal adjustment of current development is not sufficient, and a trend break is necessary to reach the target. The result of a backcasting study is typically a number of target-fulfilling images of the future, which present a solution to a societal problem, together with a discussion of what changes would be needed in order to reach the images. It has a rather long time-perspective of 25–50 years [20]. Dreborg [21] stresses the importance of elaborate images of the future as a foundation for discussing goals and taking decisions in policy-forming processes. Höjer and Mattson [22] believe that the point of backcasting is to encourage searches for new paths along which development can take place.

Höjer [19, p. 14–15] claims that a distinction between external and internal factors is not important in a backcasting study. Keeping all the factors internal to the backcast itself can in fact help to display factors that may be crucial for reaching the targets, which is one idea of the backcasting study. Hence, all solutions are kept open and no restrictions are imposed by initially defining some factors as external [19].

From a user’s perspective, an important difference between backcasting and optimising scenarios is that optimising scenarios serve to find efficient solutions, whereas backcasting scenarios focus on finding options that satisfy long-term targets. A problem with the backcasting approach is that it can result in decisions that are expensive in the short term and that the long-term target, or available options, can change before the target year is reached. Optimising has the potential drawback that the life-cycle of an investment may be much longer than the time period for which the key aspects for investment decisions (such as technology and fuel prices) are predictable and that near-term investment decisions can counteract the fulfilment of long-term targets. Therefore, it can be reasonable to choose backcasting and not optimising scenarios when the long-term target is perceived as more important than short-term efficiency and/or when the user perceives the long-term target to be easier to predict than fuel prices, etc. If the converse is the case, optimising scenarios are preferable to backcasting.

We conclude this section by using two IPCC reports as illustrative examples. In order to span a wide range of various possible changes, four qualitative world scenarios are described in *Emissions Scenarios* [23]. They exhibit partly different drivers of the development and, therefore, must be classified as structurally different. These are thus of an explorative character. The report then focuses on the subsystems that generate emissions of greenhouse gases. Here, several research teams with different emissions models analysed emissions in the respective world scenarios. The models represent partly different interpretations of the systems’ structures. The reason for this approach is that there is a structural uncertainty as regards the mechanisms that generate emissions. The resulting emissions scenarios, thus, were structurally different.

Based on the qualitative world scenarios, each group made its quantifications of relevant exogenous variables to be fed into the models. Hence, the resulting emissions scenarios of the different teams normally differed both as a result of different interpretations of exogenous variable values and different interpretations of system structure. In order to make possible a separation of these effects, all teams were instructed to use a common set of exogenous variable values as a reference case, in addition to runs based on their own interpretations of input data. In this way, the report entails explorative scenarios in order to cope with structural uncertainty, as well as a sensitivity analysis in order to cope with uncertainties related to input data. It seems reasonable to say that the approach of IPCC [23] combines the methodologies of What-if scenarios and explorative external scenarios.

The emissions scenarios do not entail any specific emissions reducing policies. In the report *Mitigations Scenarios* [24], such policies are added to the emissions scenarios with the aim of attaining stabilisation of CO_2 concentration in the atmosphere at targeted levels. The clearly stated aim of stabilising CO_2 concentration makes these scenarios normative. Some of the scenario building groups utilised optimisation models, optimising the set of technology and policy measures based on the constraint on CO_2 emission concentrations. Two modelling teams used recursive simulation-type models, while other teams used other types of integrated models. Hence, all groups used a modelling approach but just one-third used an optimisation model. One of the major results of the mitigation study was the identification of robust climate policy options across the different qualitative and quantitative scenarios [24] and in our terminology those were of the preserving scenario type.

According to Marien [1], most futures studies belong to just one of the categories probable, possible and preferable, which roughly correspond to the triad predictive, explorative and normative used in this paper. However, according to Robinson [25], there is a tendency for studies to use more complex methodologies. The IPCC case is a good illustration of a mixed highly complex methodology covering predictive, explorative and normative elements and also qualitative and quantitative approaches.

3. Techniques

The process of scenario development includes various parts or elements, i.e. there are a number of identifiable tasks to handle in scenario studies. First, there is an element consisting of the *generation of ideas* and gathering of data. Second, there is an element of *integration* where parts are combined into wholes. Third, there is an element of *checking the consistency* of scenarios.

Below we discuss different techniques under the headings of *generating, integrating* and *consistency*. Table 1 presents an overview of some techniques we suggest as useful for development of different types of scenarios. The aspiration was to select techniques that are being used and that are regarded as important. Several techniques are useful in more than one of the phases of scenario development. In such cases, they are listed according to their main contribution to our understanding, and they are also explained in the section corresponding to their listing in Table 1. However, in the text, the broader applicability of the techniques is described.

3.1. Generating

Generating techniques are techniques for generating and collecting ideas, knowledge and views regarding some part of the future. Examples of such techniques are workshops, panels and surveys. Interviews or parts of interviews can be elements in all of these techniques. Such techniques can be used for generating additional information to quantitative models. They can also be used for generating and reviewing model structures, assumptions, input data, model calculations and model results [26].

Table 1
Contribution of techniques in the phases of scenario development

Scenario types	Techniques		
	Generating	Integrating	Consistency
Predictive			
Forecasts	• Surveys • Workshops • Original Delphi method	• Time series analysis • Explanatory modelling • Optimising modeling	
What-if	• Surveys • Workshops • Delphi methods	• Explanatory modelling • Optimising modeling	
Explorative			
External	• Surveys • Workshops • Delphi modified	• Explanatory modelling • Optimising modeling	• Morphological field analysis • Cross impact
Strategic	• Surveys • Workshops • Delphi methods	• Explanatory modelling • Optimising modeling	• Morphological field analysis
Normative			
Preserving	• Surveys • Workshops	• Optimising modeling	• Morphological field analysis
Transforming	• Surveys • Workshops • Backcasting Delphi		• Morphological field analysis

All techniques can be used in several phases but only their main contribution is mentioned in this table.

Workshops can facilitate broadening of the perspectives, since decision-makers, stakeholders and experts can be included in the process. Moreover, workshops can increase the acceptance of decisions or scenarios among the participants. In the workshop process, it is also possible to include techniques that liberate the creativity of the human mind.

Another widely used technique is the Delphi method, which exists in various variants. The main idea of a classical Delphi study is to collect and harmonise the opinions of a panel of experts on the issue at stake. It recognises human judgement as a legitimate input to forecasts and also that the judgement of a number of informed people is likely to be better than the judgement of a single individual [27, p. 118–119]. In the original Delphi method, questions are sent to a panel of experts in various rounds.

Bell [11, p. 272] claims that the Delphi technique was created and survives because it is a cheap and quick way of getting the information needed for making decisions. It is at hand when there is a shortage of data, inadequate models and lack of time or resources to make a thorough scientific study [28, p. 102]. Hence, the Delphi method is primarily useful when other studies cannot be done due to lack of data, time or resources. It can also be useful when the complexity of the problem at stake is too big for ordinary forecasting. According to Simmonds [29], the key weakness of a Delphi study is that certain questions might not be asked, because they did not seem important when the study was initiated.

The result is a consensus forecast or judgement [27, p. 119]. The technique has been used to produce forecasts in the form of a list of potential future occurrences, likely dates of their occurrences and their probability [30]. Bell [11, p. 271] states that as a predictive technique, the Delphi method contributes additional information to data from other sources such as trend analysis from objective data or simulation.

A modified Delphi method was devised by Best et al. [31]. In this modified version, different groups of opinions are identified after the first round of questionnaires. Within these groups, a procedure similar to a conventional Delphi method is performed with a view to producing meaningfully different but cohesive alternative futures. The point is that the study results in different possible futures, while still being subjugated to the Delphi process. The study concerns factors in the future environment that could have an impact on the system under analysis.

A backcasting Delphi method, which is a combination of backcasting and Delphi studies, has been developed by Höjer [32]. The backcasting Delphi method starts with the first part of a backcasting study, i.e. formulating scenarios of a future that is desirable in some sense. The second part, examining the path to the images of the future, is left out of the study. Instead, a Delphi-like process is initiated where experts are asked to evaluate and improve the scenarios in respect of their feasibility and coherence to the defined targets.

Scenarios are sometimes elaborated in what we call internal scenario project work. In this kind of scenario study, one researcher, a group of researchers or a scenario project team produce the scenarios back-office. We refer the think-tank model, primarily pioneered by the RAND Corporation [27, p. 85], to this kind of technique. The think-tank model is a label for a multidisciplinary research team addressing a certain problem.

With expert and stakeholders panels, the results and the thinking can be effectively spread [11, p. 258]. Moreover, several opinions may be heard, including more extreme positions [33]. One drawback of working with panels is that it is more time-consuming than working with, e.g. the think-tank model.

In practice, most of the techniques described can be used to generate scenarios of all types, as indicated in Table 1. However, there are some differences. In predictive scenarios, the generating phase is rather subordinate. For what-if scenarios, some generating techniques may be useful when investigating which events the study should take into account when replying to the question 'What will happen on the condition of some specified events?'.

In explorative scenarios, the generating phase is very important. Generating techniques such as workshops have been frequently used in scenario planning [16]. There are also ambitious studies that combine narrative storylines with several models of different dynamics, e.g. IPCC's Emission Scenarios [23]. Here, the workshop technique is used for idea generation as well as for integration. The generating techniques in explorative strategic scenarios may be used both for generating options for strategic decisions and for exploring the consequences of a predefined set of possible decisions.

All normative scenarios work towards some kind of target. When using generating techniques in preserving scenarios, panels could assist in accumulation of knowledge and surveys could be made to collect people's opinions on the matter. Workshops and panels can also increase the acceptance of the results and disseminate knowledge among the stakeholders involved in the process.

In normative transforming scenarios, such as the scenarios in a backcasting study, the changes required to reach that target are profound. Therefore, generating techniques are the basis of backcasting studies. The think-tank model was usually utilised in the early backcasting studies in the 1970s [5, p. 25] and has been applied in most 'soft energy' and 'sustainable society' backcasting studies [25]. Structured brainstorming in a workshop format is often used. In some recent backcasting studies, there has been a tendency to involve stakeholders in the process, e.g. [25,34]. In the backcasting Delphi method [32], the Delphi procedure with repeated rounds provides an opportunity for incorporating criticism and new suggestions into the scenarios, thereby hopefully improving the scenarios.

3.2. Integrating

Modelling includes a number of different techniques for *integrating* parts into wholes. A model structure also facilitates the systematic collection of data, which helps to ensure that the different parts of the system are consistently described. These kinds of techniques are frequently based on mathematical modelling. We distinguish three subgroups of such mathematical models: time-series analysis, explanatory modelling and optimising modelling. The focus in these techniques is on projecting some kind of development with more or less explicit constraints. Assumptions can be simple, such as a simple extrapolation of a variable, or more complex, such as assuming causal relationships between variables. One advantage with a computer model is that it is more rigorous and precise than a conceptual model. Furthermore, it is logically coherent and can include and process large amounts of information [11, p. 281]. Another benefit of model simulation is that more measures can be examined at a lower cost, or tested at all, compared to a real-world analysis.

Modelling techniques provide quantitative, clear and consistent predictions, often accompanied by a quantified uncertainty. However, the quantification of uncertainty often depends on subjective assessments of the likeliness of various events. Human action is part of many predicted systems. Other parts of the systems, such as weather systems, are chaotic. It is typically difficult or impossible to calculate the statistical likeliness of the behaviour of human individuals and chaotic systems.

Modelling techniques are natural tools for making predictions within a given structure. Time-series analysis and explanatory modelling are both commonly used for this purpose. Optimising models have also been used for making predictions. For example, the MARKAL-Nordic model, a model of the stationary Nordic energy system, has been used to predict how the energy system responds to Nordic trade in electricity and natural gas, emission trade permits and tradable green certificates [35–37]. When MARKAL and similar models are used for predicting the future development, the prediction is based on various assumptions regarding future fuel prices, investment costs, etc. It is also based on the rather strong assumption that the system will succeed in developing in an economically optimal fashion.

Explanatory models, as defined here, are based on causal links in the form of equations connecting variables. A specific model can thus only produce scenarios within a given structure. By changing the causal links, a new model with possibly a new system structure can be developed. It is possible to use both explanatory models and optimisation models for generation of external scenarios. Whether they create explorative or predictive scenarios depends on the assumptions underpinning the models. Time-series analyses are difficult to use for developing explorative scenarios. This is since they are explicitly based on historical values, which developed within a system structure.

An example of a combined approach is the STEEDS project [5]. In this case, explanatory models producing predictions form one part of a decision support tool for policy analysts. In the STEEDS tool, external scenarios developed according to the scenario planning tradition of Shell and GBN are linked to the models through quantified variables. Policy variables are also input fed into the parameters to the model system [5, pp. 43–44]. Dreborg [5, p. 43] argues that the methodology in the STEEDS project differs from ordinary sensitivity testing by the input variables from the external scenarios adjusting the default way of working of the modelling systems. It is possible to think of using explanatory modelling as well as optimising modelling when building strategic scenarios.

Optimising models can be used in normative preserving scenarios to find e.g. the most cost-efficient energy technology mixes. They are also important as a learning tool. Optimising models such as MARKAL have been used many times to look several decades into the future [35,36]. Optimising modelling may be used as an aid to discover efficient paths towards certain goals, e.g. certain limits on emissions to the environment or merely the cheapest energy system. The fact that the model can choose the cheapest solution and handle a large quantity of data is an important learning component.

One risk with optimising modelling is that the thinking might be entrenched in present solutions, possibilities and limitations. When an optimising model is used in a normative way, the model might miss solutions that are just a little more expensive but better in some other respect, e.g. the environmental or the security performance [38, p. 46]. Steen and Agrell [39] also argue that it is pointless to optimise an energy system for several decades, e.g. due to uncertainty in input data. As a response to the criticism of Steen and Agrell, Unger [26] primarily argues that optimisation models rather intend to increase understanding of the evolution of man-made energy systems over time than to present an optimised energy future per se.

Time-series analysis and explanatory modelling are not directly applicable for preserving scenarios since they do not explicitly optimise the system in an exogenously determined manner. However time-series analysis and explanatory modelling can be used to produce forecasts of the development of external factors. These forecasts may be utilised to provide background information for qualitative preserving scenarios since they give a hint of the direction of current development.

The modelling techniques are not well suited to elaborating the images of the future of a normative transforming scenario study, because they do not consider large changes. However, they can contribute by indicating the direction of present trends, describing certain parts of the investigated system, and thereby founding a basis for transformative studies.

3.3. Consistency

The third group of techniques we would like to highlight here are *consistency techniques*. Although these are also used for idea generation and/or integration, their usefulness for ensuring consistency between or within scenarios could be seen as their main advantage. Cross-Impact Analysis [40] and Morphological Field Analysis (MFA) [41] are examples of formalised, qualitative consistency techniques.

The consistency techniques do not themselves create forecasts but both the Cross-Impact Analysis and the MFA might be used to check the consistency among different forecasts, the Cross-Impact Analysis focusing on causality and the MFA on possible co-existence. This should hold for different predictions within the same structure and evidently also for predictions of a change of system structure.

The consistency checking technique MFA may be used to develop scenarios of factors external to the actor in question. As the results consist of different possible internally consistent scenarios, they are an answer to the question 'What can happen to the development of external factors?'. One advantage with a morphological analysis is that it may help to uncover new relationships or configurations, which may not be so evident, since it compels people to think of all combinations of included variables [41]. Another point is that this method manages some methodological problems inherent in developing futures scenarios and risk-management strategies: unquantifiable variables, uncertainty that is not possible to specify, and the lack of transparency in the process to reach conclusions. According to Ritchey [42], scenario development by MFA puts judgments on a formalised, traceable and solid methodological ground. He points out one criticism against MFA, that it is too structured and might inhibit free, creative thinking. If the external scenarios are developed by another method than MFA, it is still possible to use the latter to check the internal consistency of the scenarios, e.g. when a generating technique has been used to create the scenarios. The Cross-Impact Analysis could possibly be used to check the internal causal consistency within external scenarios if probabilities are attached to components in the scenarios.

The MFA could be used to check the internal consistency of the qualitatively determined preserving scenarios. Together with the CASPER tool they can treat policies and can, hence, be used to construct strategic scenarios [42]. It might also be possible to use the MFA to test the consistency of strategic scenarios elaborated with another technique. In transformative studies, MFA could be used to check the internal consistency of the images of the future, and perhaps also the consistency of the paths towards these futures. In practice, consistency testing is often carried out in a qualitative and sometimes implicit way, e.g. by using expert panels to get critique and suggestions for improvement.

4. Concluding discussion

As stated in Section 2, we distinguished three scenario categories based on the type of question that is posed about the future: *What will happen?*, *What can happen?* and *How can a specific target be reached?* Within each category, we identified two scenario types (see Fig. 1). Different scenario types can be contained in the same study.[2] It can also be

[2]As an example, an energy report from IEA and OECD includes three external energy scenarios and one preserving scenario [43].

difficult to clearly categorise scenarios in practical applications. There is, e.g., a grey area between forecasts and what-if scenarios, as well as between what-if scenarios and explorative scenarios. However, even if it is sometimes hard to clearly identify the type of a specific scenario, the categories and types can still work as landmarks identifying different kinds of studies. Such landmarks are necessary for anyone who wants to find their way in scenario studies.

In this paper, we adopted a user's perspective to scenario studies. Users include people who develop scenarios, use already existing scenarios and/or receive information about scenario results (see Section 1). In scenario development, Section 2 can assist in structuring questions about the future, and Section 3 can provide some advice in the selection of scenario techniques. For people who use or receive information about existing scenarios, the report can assist in interpreting and evaluating the scenarios.

In this paper, we make a distinction between scenario types and techniques for building scenarios. Perhaps too often, a certain technique is chosen without much consideration when instead an initial discussion should concern the desired products, i.e. the types of scenarios that are wanted and needed. Table 2 summarises some of the discussions in the previous sections.

The characteristics described in Table 2 can be employed as a user's guide to help understand the type of scenario that is wanted and needed. This can be matched with Section 3 in order to choose between different types of techniques and better understand how the technique can be used in order to obtain the desired type of scenario. From Table 1, it can be noted that the same type of technique can be used in different ways in order to produce different types of scenarios.

If the user wants to predict the future, forecasts and what-if scenarios are of interest. If the user wants to think in terms of several possible futures, perhaps in order to be able to

Table 2
Summary of key aspects of scenario types

Scenario category/type	Quantitative/qualitative	Time-frame	System structure	Focus on internal or external factors
PREDICTIVE—what will happen?				
Forecasts	Typically quantitative, sometimes qualitative	Often short	Typically one	Typically external
What-if	Typically quantitative, sometimes qualitative	Often short	One to several	External and, possibly, internal
EXPLORATIVE—what can happen?				
External	Typically qualitative, quantitatively possible	Often long	Often several	External
Strategic	Qualitative and quantitative	Often long	Often several	Internal under influence of the external
NORMATIVE—how can a certain target be reached?				
Preserving	Typically quantitative	Often long	One	Both external and internal
Transforming	Typically qualitative with quantitative elements	Often very long	Changing, can be several	Not applicable

adapt to several different types of outcomes, explorative scenarios may be useful. If the user wants to search for scenarios fulfilling specific targets, and perhaps link this to actions that can be taken towards the visions, normative scenarios should be the choice. These three approaches to scenario studies are different. By emphasising the user's perspective to scenario studies, we argue that the choice of scenario category is not only a question of the character of the studied system. Instead, the user's worldview, perceptions and aims for the study can be even more important for the choice of approach.

Different views on the possibilities of predicting the future can also influence the choice of scenario types. For example, many forecasting and optimising models need input data in the form of prices and price elasticities. Some will claim that since these are uncertain, it is meaningless to use forecasting and optimising models for long-time perspectives [39]. Others may argue that such forecasts and optimising scenarios can still stimulate thoughts and debates and, hence, contribute to decision-making processes. As stated in Section 2, the choice between preserving and transforming types of normative scenario (optimising and backcasting) can depend on whether long-term targets are perceived as more important than short-term efficiency, and on whether the user perceives the long-term targets as being easier to predict than fuel prices, etc.

For example, a researcher at a manufacturing industry and two researchers at the national Environmental Protection Agency (EPA) may all wish to study the energy system. The manufacturing company has little influence over the energy system, but may still be sensitive to changes in it. In such a case, explorative studies of the energy system can be valuable. One EPA researcher may argue that key aspects of the system seem predictable and that the possibilities to influence the system are small. If so, the reasonable way to study the future is to make predictions. The other EPA researcher may argue that there are good possibilities to influence the system. To such a person a normative study is more relevant. The types of knowledge that these three persons are interested in differ and the resulting scenarios are also likely to differ. This is not a problem as long as the user is aware of it, and states the starting points of the study clearly.

Moreover, there is sometimes a tension between the aim and the perspectives on the possibilities of influencing the future and the possibilities of predicting the future, e.g. when a user wants to investigate how a certain target can be reached, but does not know how, or if, the development could be influenced. Or when the user wants to predict something, but knows that the user's own actions will influence the actions of others, in a game-like situation. Both those situations are common and should not be disguised. They are not easily solved, but they occur and they should at least be openly declared.

It is possible, and sometimes preferable, to use a combination of techniques to create the desired scenario type. A technique with mainly qualitative elements and a technique with mainly quantitative elements can, e.g. be combined to make a forecast. As for external scenarios, a generating technique might be used to provide input to different models. In strategic scenarios, one technique is usually utilised to generate external scenarios that form the basis for the strategic scenarios. In a second step, another technique may be used to identify and describe the available policy options.

The optimising models can be regarded as a combination of techniques. To make a model run, forecasts or assumptions of external parameters have to provide input to the model. Perhaps a refinement of assumptions of the future state of requested parameters would make the results of the tool more accurate or could expand the applicability of an optimising model as a planning tool. For example, if external scenarios elaborated with the scenario planning technique are the basis for the input to the model, the optimising model could contribute a more rigorous and precise development in the different external scenarios. This information would also be quantified, which is a necessary prerequisite for many other applications. It must be remembered, however, that the quantitative results are typically very uncertain.

In this paper, we suggest a typology of scenario studies and discuss techniques to generate scenarios. We base our typology on the idea that the scenarios should be of use to someone. As has been shown, such users can have widely different ideas on what kind of product, i.e. scenario, is desired. Therefore, continued work is needed in which potential users of the scenarios are given the opportunity to comment upon typology and technique discussions and to give their input on the demands of a user-orientated scenario guide. However, our hope is that the guidance already provided in this paper can be useful. One of the most important factors identified is probably the emphasis on the importance of the user's own rationale for using a scenario study.

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