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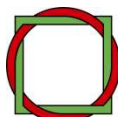
New Approaches and Recent Results of Sustainability Scenario Building and Modelling

Final Round-table Workshop – Brussels, 25 Nov. 2008

Project summary report

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1. Introduction to the project and its framework

Since the Gothenburg summit in 2001, the implementation of the concept of sustainable development has been a core challenge for policy making in the European Union. To improve the basis for policy design, and also comply with the specific needs of ex-ante impact assessments, there is a need for a forecasting framework to develop harmonised middle and long-term baseline and alternative policy scenarios. In the context of the Sustainable Development Strategy (European Commission 2001; Council of European Union, 2006¹) the forecasting framework should allow to develop scenarios that can be used for strategic policy preparation to better specify and disentangle the mutual relationships between environmental, economic and social trends.

To be effective, policy development and appraisal needs to understand the key driving forces and their cross-cutting linkages, which lead to increased pressure on different aspects of the environment. Measures which are designed to solve single problems often risk shifting the burden to other sectors, and they may be ineffective due to the complex interaction of environmental effects. The need for policies to be based on a cross-cutting approach has been highlighted in “The 2005 Review of the EU Sustainable Development Strategy: Initial Stocktaking and future orientations” (COM(2005)37 final), as well as in the Commission’s Communication on its Strategic Objectives 2005-2009 (COM (2005) 12). However, cross-cutting driving forces which are relevant for various environmental and sustainability related problems have not yet been analyzed in a systematic policy-oriented manner.

The FORESCENE project is an attempt to identify cross-cutting measures that are effective and efficient, and which have the potential to mitigate several environmental problems at the same time. As shown in Figure 1, three broad environmental themes are covered: ‘resource use and waste generation’, ‘water’, and ‘biodiversity, soils and landscape’. The aim of the project has been to capture the anthropogenic cross-cutting drivers that generate environmental pressures and the inter-linkages between them, so that an integrated forecasting framework could be constructed. It should, in turn, offer the possibility to test alternative policy strategies against some base-line. To do so, the framework used in FORESCENE was inspired and adapted from the backcasting methodology. As shown in Figure 2, the project’s framework consists of six questions that were addressed during a series of workshops. By applying the framework the project aimed to:

- determine cross-cutting (cross-thematic and cross-sectoral) driving forces for environmental problems in the three targeted fields (relates to Question 1);
- define essential elements of sustainable development in the different topic areas, particularly in the form of desired sustainability goals (relates to Question 2);

¹ Council of the European Union (2006) Review of the EU Sustainable Development Strategy (EU SDS) – Renewed Strategy. 10907/06
<http://register.consilium.europa.eu/pdf/en/06/st10/st10917.en06.pdf>

- describe cross-sectoral measures expected to exert a multi-beneficial impact over the environmental fields considered, so that the sustainability goals identified can be achieved (relates to Question 3); and,
- combine the scenario elements (driving forces, strategies, goals etc) into baseline and alternative scenarios scenario (relates to Questions 4 to 6).

The following sections describe the outcomes of the FORESCENE project using the framework presented in Figure 2.

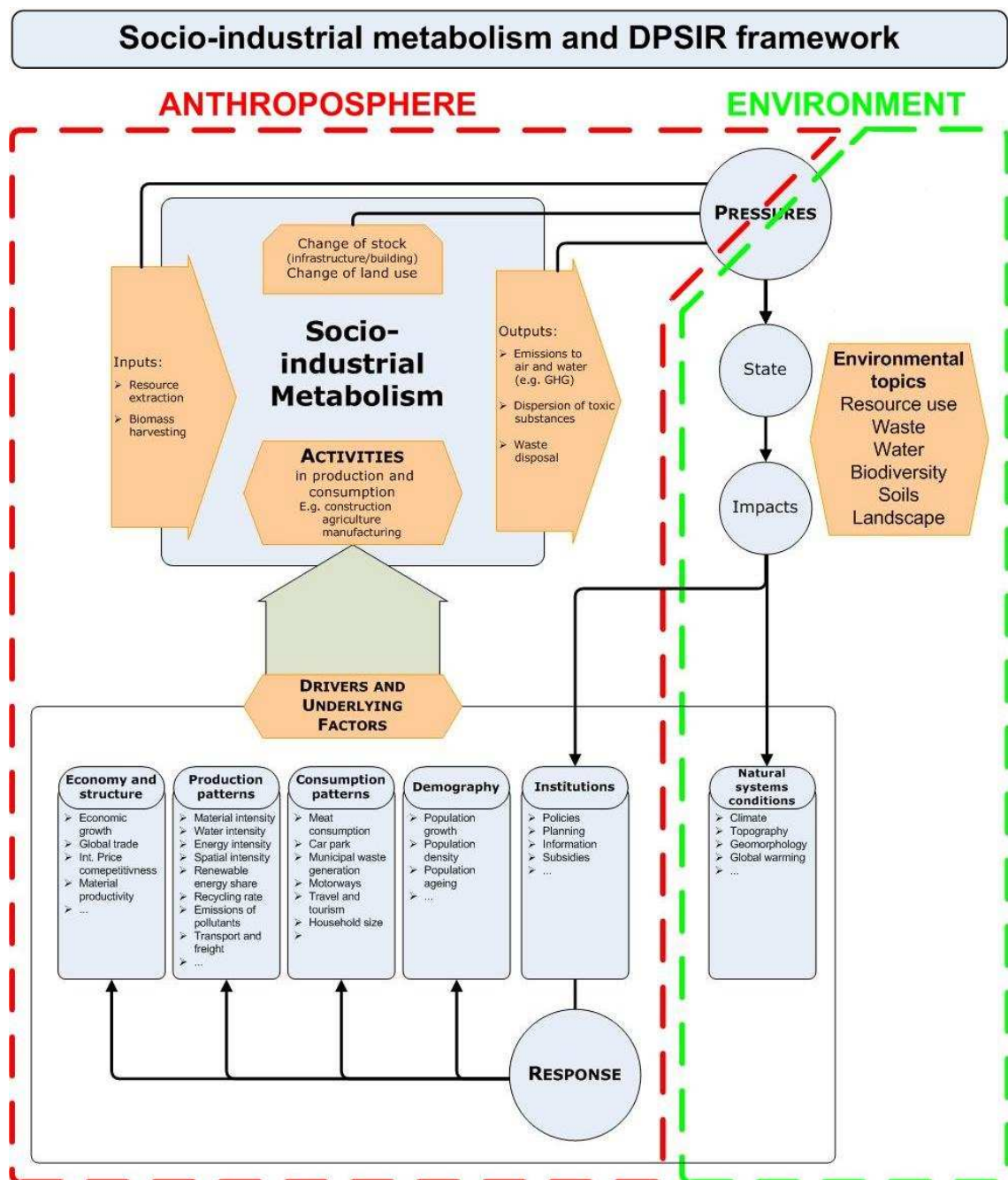


Figure 1: Socio-industrial metabolism and Driving Forces-Pressures-State-Impacts-Response (DPSIR) framework in FORESCENE

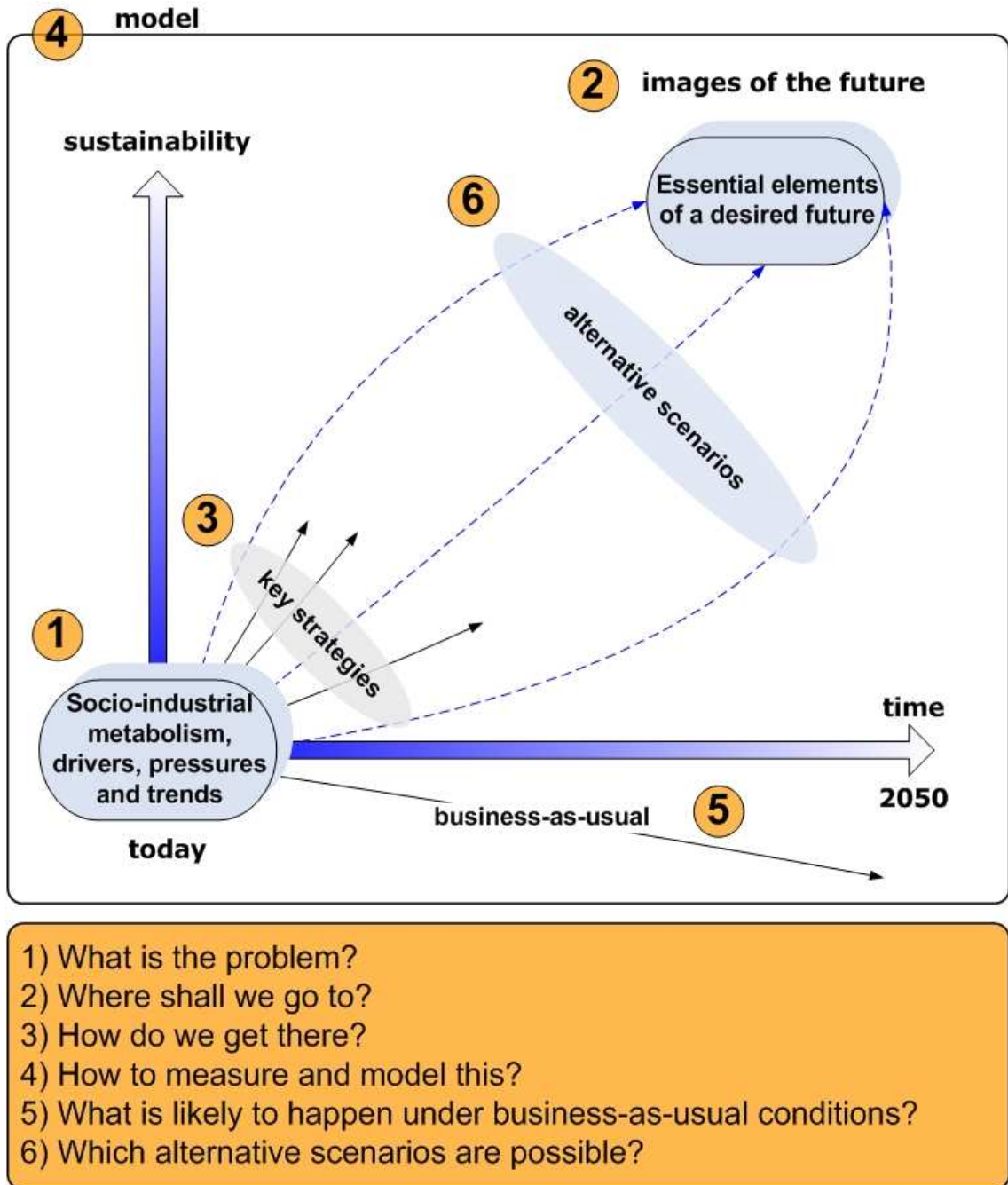


Figure 2: The six questions of the FORESCENE framework

2. Question 1: What is the problem?

At first, a plausibility check and relevance analysis for the three environmental fields ('resource use and waste', 'water' and 'biodiversity, soils and landscape') was performed regarding the major economic activities and underlying factors in order to filter out cross-cutting drivers. The result was provided as background for the stakeholder workshop (first integration workshop, in Brussels) which then led to a prioritization of the cross-cutting drivers. The purpose of the meeting was so as to define more precisely the major economic activities and underlying factors that needed to be considered in order to pinpoint cross-cutting drivers related to the sustainability issues, and how these simultaneously influence the three environmental problem areas.

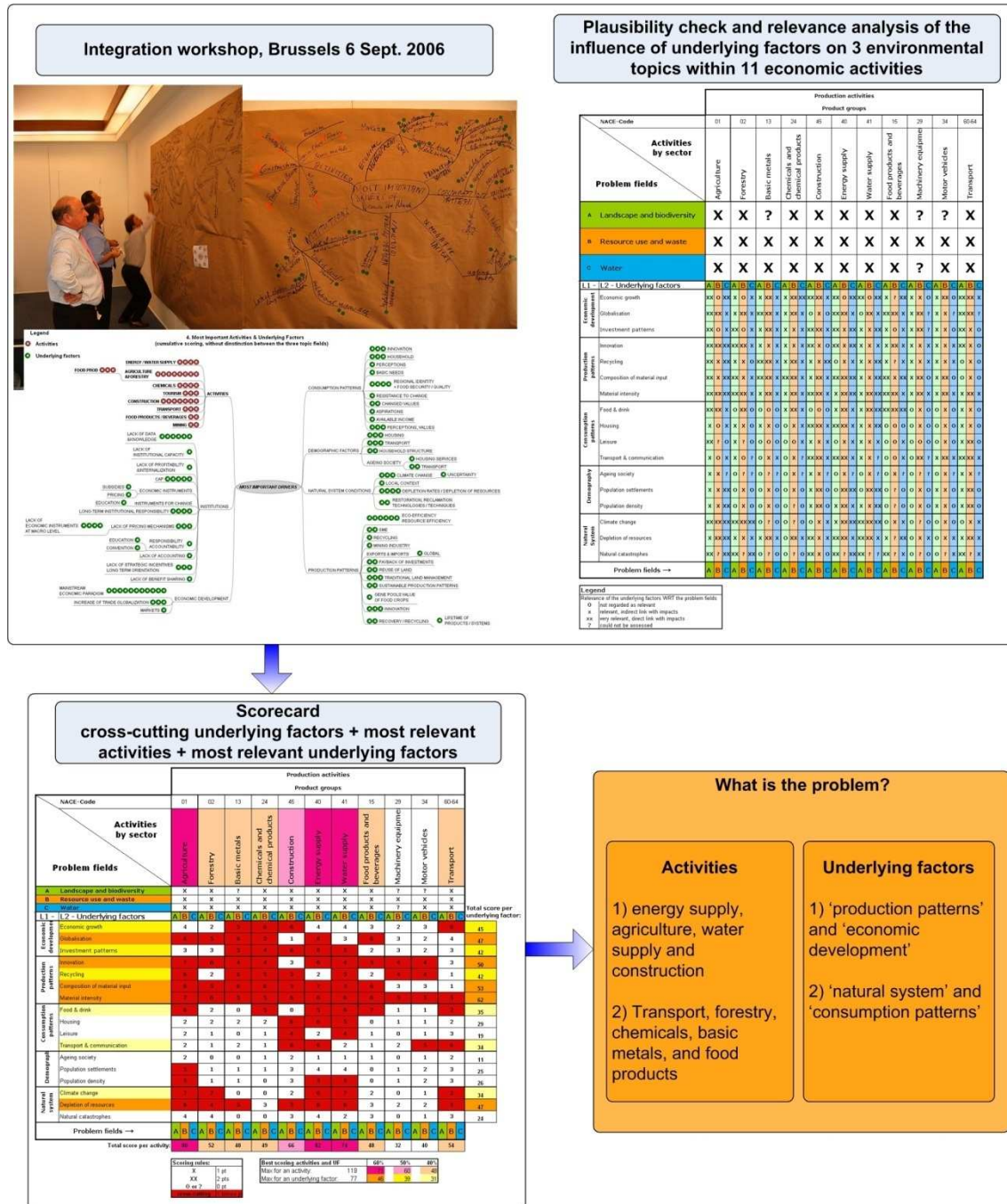
The views of the participants at the workshop were collected in the form of mind-maps (see upper left part of Figure 3). These have then been systematically analysed and organised in a matrix showing the correspondence between the three environmental fields considered, economic activities and "underlying factors" (see upper right part of Figure 3). The latter two elements constitute drivers that have been cited by the stakeholders, who also gave them weights.

The matrix representation was then turned into a scorecard which helped stakeholders pinpoint the economic activities and underlying factors that they thought were relevant (see lower left part of Figure 3). Energy supply, agriculture, water supply and construction appeared to be the activities most likely to cause pressures and impacts on the three environmental themes. Transport, forestry, chemicals, basic metals, and food products were also activities or product groups that stakeholders thought as potentially important to consider.

The underlying factors were sorted into five categories: economic development, production patterns, consumption patterns, demography and natural system. The categories 'production patterns' and 'economic development' were the groupings of underlying factors that achieved the highest scores in the evaluation. The factors within the 'production patterns' group ('material intensity', 'composition of material input', 'innovation' and 'recycling') seem to be among the most powerful underlying factors. They were all expected to have a strong, direct and cross-cutting influence on the most important activities in relation to the three topic areas. 'Globalisation', 'economic growth' and 'investment patterns' can also have considerable influence, but only cross-cutting environmental effects within a more limited number of activities.

The underlying factor categories for the 'natural system' and 'consumption patterns' groups, follow 'production patterns' and 'economic development' in the ranking. For 'natural system', 'depletion of resources' and 'climate change' were the most relevant underlying factors, and 'food and drink' and 'transport and communication' were the most important under 'consumption patterns'. 'Natural system' and 'consumption patterns' are more indirect drivers in nature, but according to the relevance analysis they are important and should not be neglected, particularly in connection with agriculture, construction, energy and water supply, and transport. In relation to these activities, these underlying factors have a considerable cross-cutting influence.

The results from this participatory screening of cross-cutting drivers made it quite clear that, in the rest of the project indicators of 'production patterns' (such as resource intensity of manufacturing, or green vs. brown agricultural practices) and 'consumption patterns' (such as consumption of manufactured goods vs. that of services, or people's diet) need to be considered within a frame set by factors of economic development (such as economic growth, R&D investments, trade). Energy generation and use also needed to be integrated in the scenarios (especially the share of renewable energy, with a particular focus on the use of biomass for energy purposes).



3. Question 2: Where shall we go to?

The next task was to develop visions for sustainability in terms of a positively defined future. Three expert workshops were organised for the broad activity and policy fields: 'agriculture', 'infrastructure / built environment' and 'industry / economy'. Experts were invited to share their long-term vision of sustainability based on their field of expertise, considering essentials of environmental, economic and social development.

The experts took part in an interactive exercise in which they were asked to mark on several two-dimensional graphs the desired direction of future development. The aim was to specify the overall sustainability visions in the most concrete manner. It was necessary to find out which essential elements of sustainability were considered to be an integral part of the vision so that they could be used to help develop scenarios. Experts were also asked to reflect on whether current policy objectives match or could deliver their sustainability visions.

Results from the three expert workshops were then further discussed in a stakeholder-expert workshop (second integration workshop, in Brussels) to establish a list of sustainability goals that could serve as references for the subsequent scenario and modelling work. Figure 4 presents a condensed overview of the sustainability goal references. In this general formulation, the goals listed are relevant to a large span of economic activities and environmental problem fields. Clearly when the question of how to measure and model these goals arose later in the project, quantitative parameters will need to be introduced. For instance, happiness and well-being will, for the time being, remain at the qualitative level in the scenario narratives, but clearly for any modelling exercise some suitable surrogates or proxies may have to be used to try to express changes over time. The same applies in relation to the goal of 'competitiveness for the EU' as the required econometric modelling would have exceeded the scope of the FORESCENE project.

For some of the sustainability goals in Figure 4 quantitative targets have already been formulated elsewhere. For instance, according to IPCC studies, emissions of greenhouse gases should be cut by 80% in 2050 in industrial countries. Some other target values have also been suggested (e.g. the EU is committed to reducing its overall emissions to at least 20% below 1990 levels by 2020, and is ready to scale up this reduction to as much as 30% under a new global climate change agreement when other developed countries make comparable efforts. It has also set itself the target of increasing the share of renewables in energy use to 20% by 2020) which could alternatively be used for assessing the progress of the EU towards priority sustainability goals in concrete terms. For the environmental component, targets such as those arising from the Habitats and Water Framework Directives could be used.

Some goals related to resource use and waste generation can be translated in quantitative terms using existing material flow indicators, such as total material requirement (TMR)². An ambitious target for TMR could be an 80% reduction by 2050. Because TMR is a comprehensive indicator for the material basis of a society, such a

² The indicator 'Total material consumption' is currently being developed within the European Statistical System (CEC 2007). When considering also the resource requirements for the production of exports, the Total Material Requirement (TMR) seems adequate.

change would certify that the EU has adopted a resource extensive pattern of production and consumption. The different components of the TMR indicator can also be considered separately and be assigned quantitative or qualitative targets which would translate in more concrete terms the general goal reference formulation in Figure 4. For example, the reduction by 80% could be targeted only to the non-renewable part of TMR, while the use of biomass as such should not increase significantly (in order to avoid problem shifting). The ratio of foreign to domestic TMR should not increase if the issue of problem shifting across regions is to be addressed.

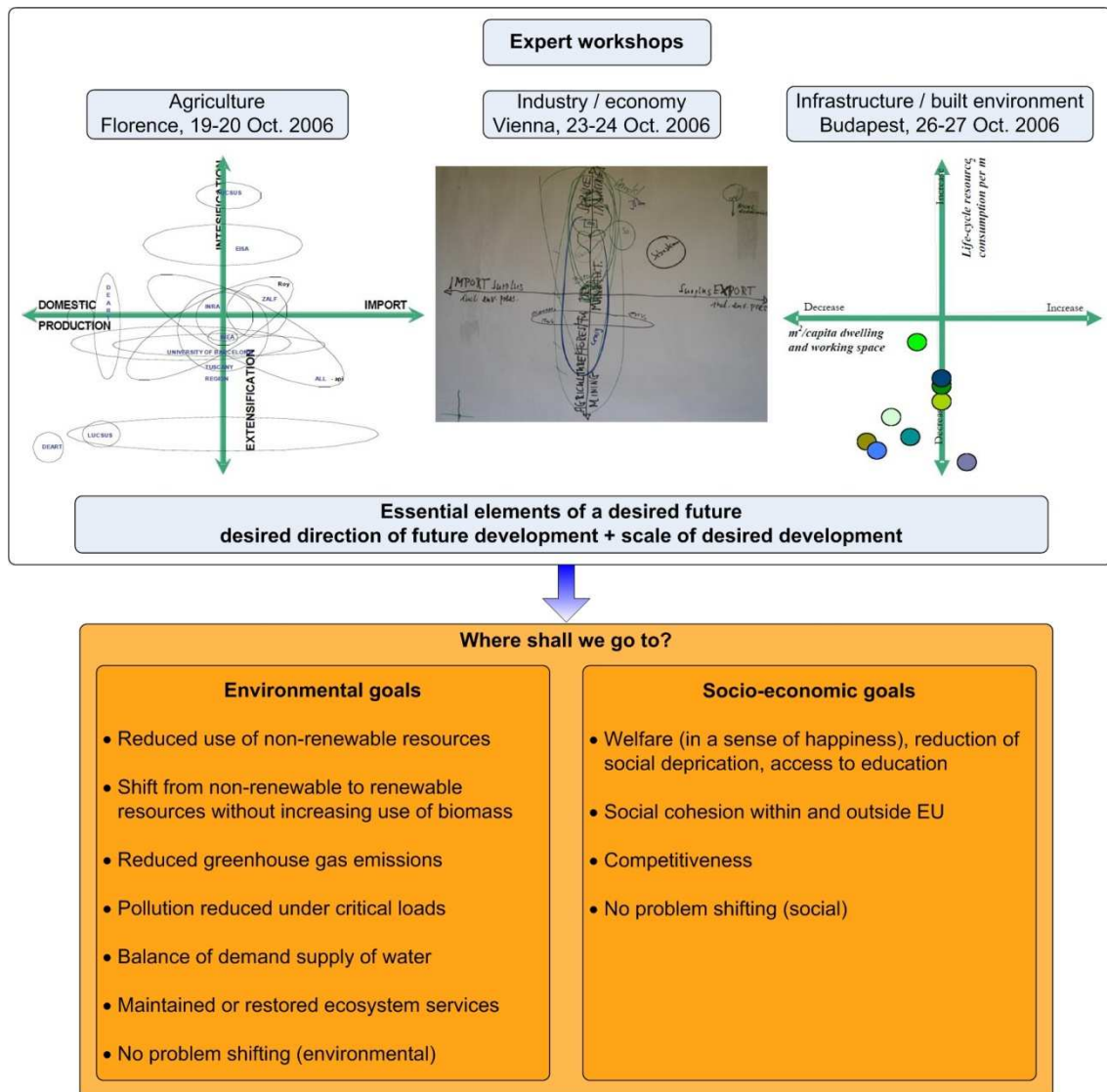


Figure 4: How FORESCENE addressed Question 2 "Where shall we go to?"

4. Question 3: How do we get there?

In order to accomplish Step 3, a backcasting approach was adopted, which explored how the previously defined sustainability goals could be reached. Therefore, during the course of the workshops described in section 3, experts were invited to identify a list of supposedly most promising strategies, policies and instruments to pursue those goals, which could become part of the instrumental mix of the European Union towards sustainability. Those lists were compiled separately for the various activity fields of 'agriculture', 'infrastructure / built environment' and 'industry / economy', and the experts were then also asked to weigh the relative importance of the listed strategies/policies.

The results from the three expert workshops were then considered together at the second integration workshop in Brussels. The aim was to highlight key strategies which could potentially show cross-sectoral and multi-beneficial effects, and at the same time minimize the risk of problem shifting. As shown in Figure 5, the workshop participants agreed on twenty-five key strategies which could be further sorted in seven broad categories: 'Improving orientation and target setting', 'Improving information and decision processes', 'Improved planning', 'Changing use of capital', 'Changing environmental performance of production and consumption', 'Improvement of product management and procurement' and 'Improving state finance and social security systems'.

The key strategies have been organised in Figure 5 along two axes representing the level of consensus among the workshop participants and/or society as a whole, and the level of specification of the measure. Most of the strategies from the set 'Changing environmental performance of production and consumption', which is closely related to the mainly environmental goals in Figure 4, are found in the top right-hand corner, which translates to high levels of both consensus and specification. For instance, there was a wide agreement on the need to foster energy/resource efficiency (which can be specified in concrete terms) through innovation, which could contribute to reduced use of non-renewable resources and the mitigation of greenhouse gas emissions. Such a strategy could be implemented by the design of appropriate economic instruments and be aligned with incentives to use a higher share of renewable energy.

Strategies in the lower parts of Figure 5 have been more controversial and address sensitive socio-economic aspects. For instance, regional food supply within the EU may reduce transport and contribute to security of food supply, but may also deprive less developed countries of an opportunity to develop through international trade. A similar case may arise in connection with bio-energy.

For the next steps within the framework, strategies characterized by a high level of consensus have been considered first. Currently, for instance, the need for increasing resource productivity and the use of renewable energy is widely acknowledged as an essential step in relation to the goals of sustainability. However, there may be important disagreements concerning appropriate and effective measures under these strategies; for example, concerning the relation between intra- vs. inter-sectoral change, and the potential contribution of biomass to renewable energies. 'Risky trade-offs' and 'problem shifting' were considered within the project when assessing the sustainability of alternative pathways compared to a 'business-as-usual' development.

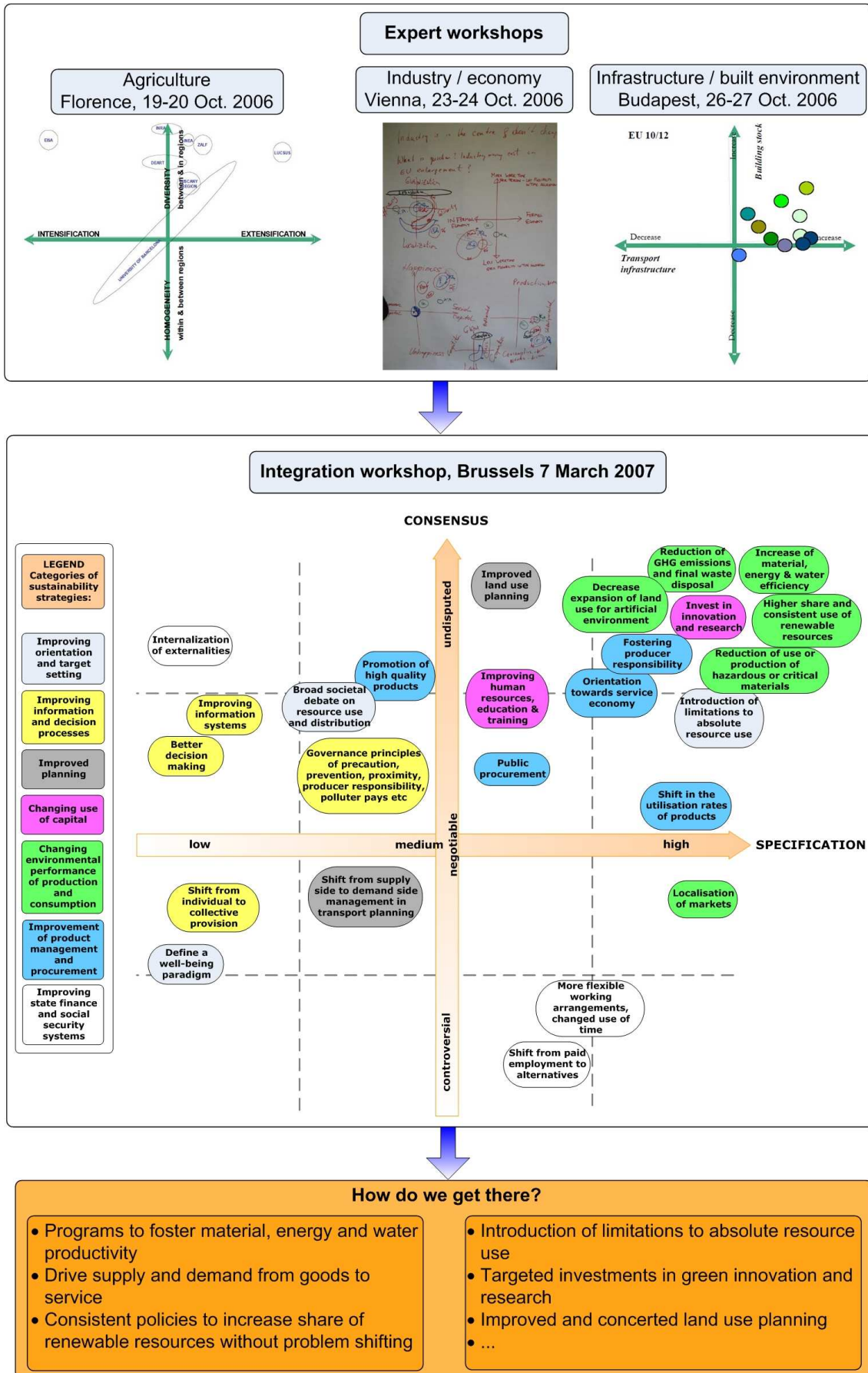


Figure 5: How FORESCENE addressed Question 3 "How do we get there?"

5. Question 4: How to measure and model this?

Following the stakeholder and expert involvement in steps 1 to 3, and the collection of sustainability elements (cross-cutting drivers, reference goals, and key strategies) deemed essential for scenario development, a review of established scenario modelling studies was conducted. Scenarios and models were selected with regard to their potential relevance and applicability for scenario construction in FORESCENE. The review primarily assessed how scenario studies and models dealt with the three environmental topics considered in the Project, and what problem areas, cross-cutting drivers, scope and time horizon have been addressed in these studies. Most existing models have been developed to deal in-depth with rather specific aspects of sustainability, whereas FORESCENE adopts a much broader perspective. Here the aim has been to integrate environmental problems and activities which have generally been treated separately with an extended spatial and temporal perspective.

Furthermore, when considering the sum of elements assembled via steps 1 to 3 from in relation to the task of scenario building and modelling, it became clear that different components were relevant at different scales, that the causal relationships could not always be expressed deterministically and that many parameters had considerable uncertainties associated with them. Data for quantifying the parameters included in the modelling and scenario exercises were also found to be very heterogeneous with regard to type of observation and accuracy.

As shown by the review of scenario studies, although many of the subjects dealt with in the FORESCENE project have been studied elsewhere, they have rarely been looked at in association with each other. Thus, it was apparent that a new modelling approach was needed, that allowed the integration of the different sustainability elements generated in the preceding steps. Therefore, the project has sought to develop a tool that:

- allowed the expression of non-deterministic relationships between parameters;
- allowed different geographical scales to be considered;
- included parameter uncertainties;
- could be expanded or simplified depending on the purpose, data base and status of knowledge;
- was oriented towards decision support;
- gave an endogenous description of the links between the cross-cutting drivers and the targeted environmental issues;
- could describe the influence of strategic policy decisions on multiple environmental problems considered; and,
- could 'back-cast' from targeted environmental goals and identify drivers that might achieved desired outcomes that are amenable to human influence.

The tool developed in the FORESCENE project was based on the Bayesian Network concept, which is an approach that allowed most of these criteria to be met. The method has shortcomings, however, such as the inability to model feedback loops and the difficulty to handle time dynamics within a single network. Nevertheless, positive

aspects such as the intrinsic graphical representation of the model, the possibility of using non-deterministic relationships (derived from expert judgement) or functional equations parameterised with probability distributions rather than point value coefficients, seemed to outweigh the limitations of the method. It is important to note that the Bayesian Network approach is **not** seen here as a replacement for other models in current use but rather as a means of integrating different forms of knowledge, whether from existing models, reported data or expert judgement. In other words, it can be used to construct a 'meta-model'.

The general structure of the meta-model developed in the FORESCENE project is shown in Figure 6 (upper left diagram). The geographical system boundaries for the driving forces are those of the EU-25, while the impacts on most of the environmental issues are considered at the global level, distinguishing between intra- and extra-EU impacts. The component parts of the model are referred to 'modules'. The following modules were developed: 'Economy', 'Mineral materials', 'Fossil fuels', 'Biofuels', 'GHG emissions', 'Agricultural land use', 'Water', 'Biodiversity' and 'Soils'.

Causal relationships between the nodes can be characterized either with functional equations or conditional probability tables (CPTs, see Annex 10.1). The first option is, however, to be preferred because the specification of functional equations between variables reduces the variability of the results. Probabilities are introduced into the functional equations by assigning probability distributions to the equation parameters, which represent knowledge uncertainty about the parameter value from a Bayesian perspective.

It is important to note that the time dimension is not explicitly present in a Bayesian network model; rather a collection of networks is necessary to represent an evolution over time. Figure 6 (central diagram) shows how the time dimension was dealt with in the model developed by FORESCENE. The networks of the time series differ from one another by the input values assigned to their marginal nodes, which corresponded to the initial input values for given years. These inputs are calculated separately and for different scenarios. The target nodes from each network can then deliver output in the form of probability distributions for each year considered, which can, in turn, be worked out into time series outside the networks (see lower part of Figure 6).

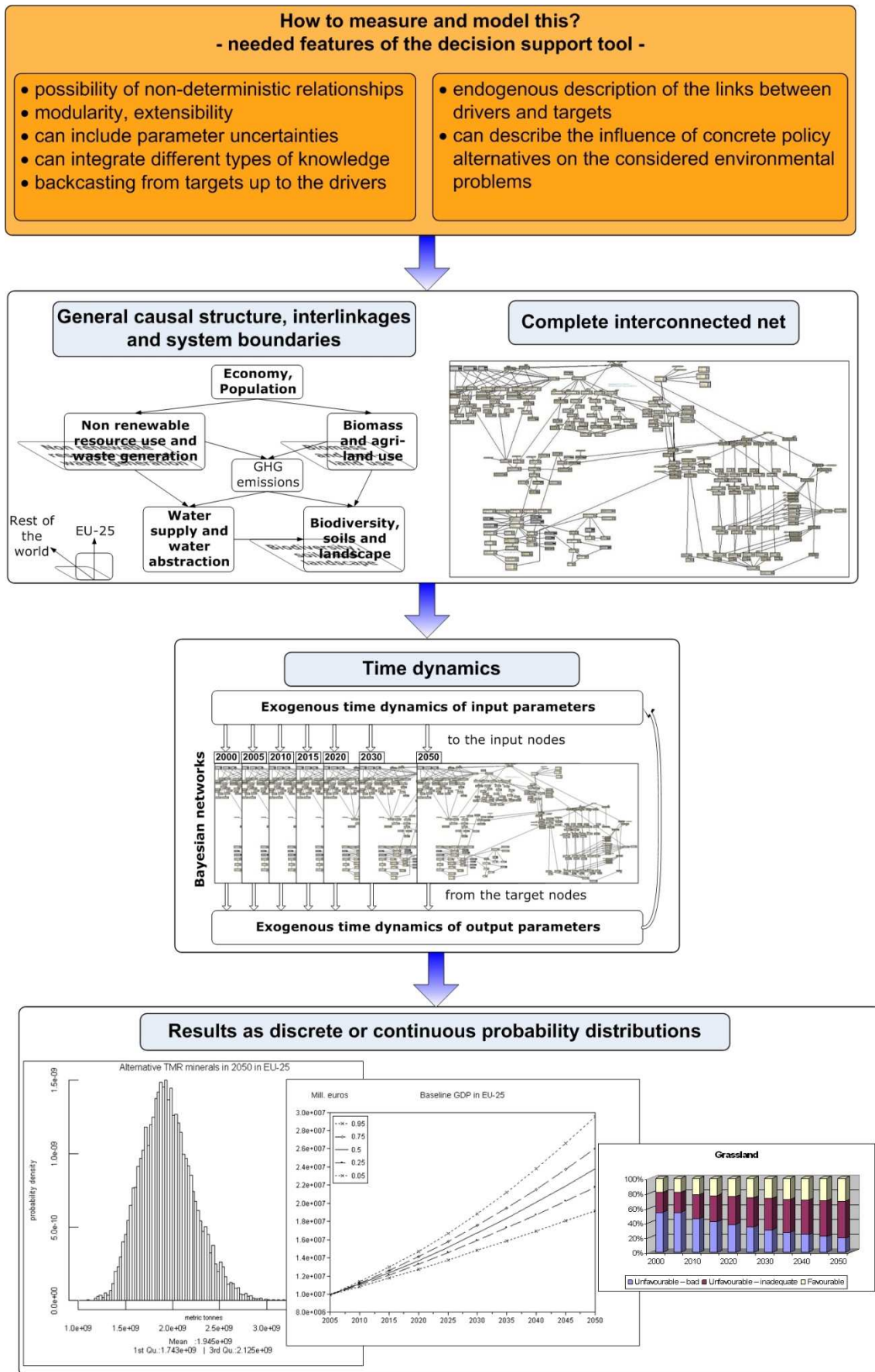


Figure 6: How FORESCENE addressed Question 4 "How to measure and model this?"

6. Question 5: What is likely to happen under business-as-usual conditions?

Having established the model structure of interconnected modules, the next task was to observe the parameters' behaviour under business-as-usual conditions. This section presents baseline assumptions for major input nodes (representing, for example, the driving forces) and modelling results for key output nodes.

The assumptions for the input nodes in the baseline scenario are derived from existing business-as-usual forecasts. The model integrates into one consistent framework assumptions and modelling results from different sources relevant for the modules' objects. If a quantification of the uncertainty is available for the data chosen, it is implemented in the model (using, for example, normal distributions). If such quantification does not exist, the chosen data are assumed to be accurate and a point value is used.

Time series of input parameters are then fed into the modules' Bayesian networks for modelling. The target nodes then deliver the modelling results that make up the 'predictions' for the baseline scenario. Results are obtained as full probability distributions in order to account for predictive uncertainty and thus both enhance theoretical understandings and inform practical decision making.

Figure 7 presents the baseline trends for the main output parameters of the model. In the economy module, for example, future growth of GDP per capita is modelled using a normal distribution centered in 2% until 2030 and in 1.5% afterwards (0.3% standard deviation in each case). The use of probability distributions instead of point values makes it possible to account of a degree of parameter uncertainty. The range defined by the normal distribution for GDP per capita was chosen to reflect differences in assumptions observed in existing European scenario studies. Other controlling or driving parameters were also assigned a normal distribution, such as material intensity coefficients used to calculate total material requirement, or self-sufficiency of Europe (i.e. share of imports in final demand) regarding mineral materials, fossil fuels and biomass.

As a result, modelling results for target indicators are shown in Figure 7 as "corridors" that represent the 90% confidence intervals of the corresponding modelling results, given the input parameter uncertainties. The width of the results' confidence intervals tend to increase the further we look into the future and the more the values of the target indicators increase.

The 90% confidence interval for TMR minerals, for example, increases from 7.8 – 9.2Gt in 2005 to 12.4 – 18Gt in 2050. Though the direct material input levels off over time, due to increasing material productivity and the assumption of a slower GDP growth after 2030, TMR keeps increasing. This can be explained by the fact that the indirect flows, especially unused extraction such as mining waste associated with direct material input, keep increasing as a result of resource depletion. Furthermore, increasingly this waste production occurs in other parts of the world that export to Europe. This worsening of the problem shifting is illustrated by the ratio foreign TMR over domestic TMR in Figure 7.

Some results have a broader distribution, such as land conversion outside Europe for its biofuel supply and greenhouse gases emission savings associated with the use of

biofuel. It reflects the uncertainty on parameters such as biofuel crop yields or the actual amount of greenhouse gases emitted per unit area of converted land. Due to the limited time dynamic capabilities of the BBN approach, the “carbon debt” (Fargione et al. 2008) associated with land use change (LUC) outside EU is accounted for all at once, in the year when land conversion occurs. It explains the large “negative savings” from biofuel use in EU in 2010 (-1.1Gt) when demand is growing, supported by political decisions. Towards the end of the modelled time period, when demand for biofuels has stabilised, and production yields and fuel efficiency have increased, the median of “GHG savings from biofuels with land use change” is close to the x-axis, meaning that the land use change induced GHG emissions are about the same order of magnitude as the savings by biofuels without LUC. The savings are, however, still “negative.

Finally, some more qualitative indicators are shown as discrete probability distributions (e.g. biodiversity status). They are linked probabilistically through the result of expert judgement elicitation to a number of drivers, either specific to that module, such as cross-compliance or agricultural management, or stemming from other modules, such as water withdrawal. Thus the framework allows the inclusion of both physically measurable data and more qualitative “ecological variables” that otherwise could not be related mechanistically to the drivers. Figure 7 shows how the probabilities associated with the discrete states used to describe European biodiversity status (Declining, Stable, Improving) and soil quality (Low, Medium, High) evolve over the modeled period.

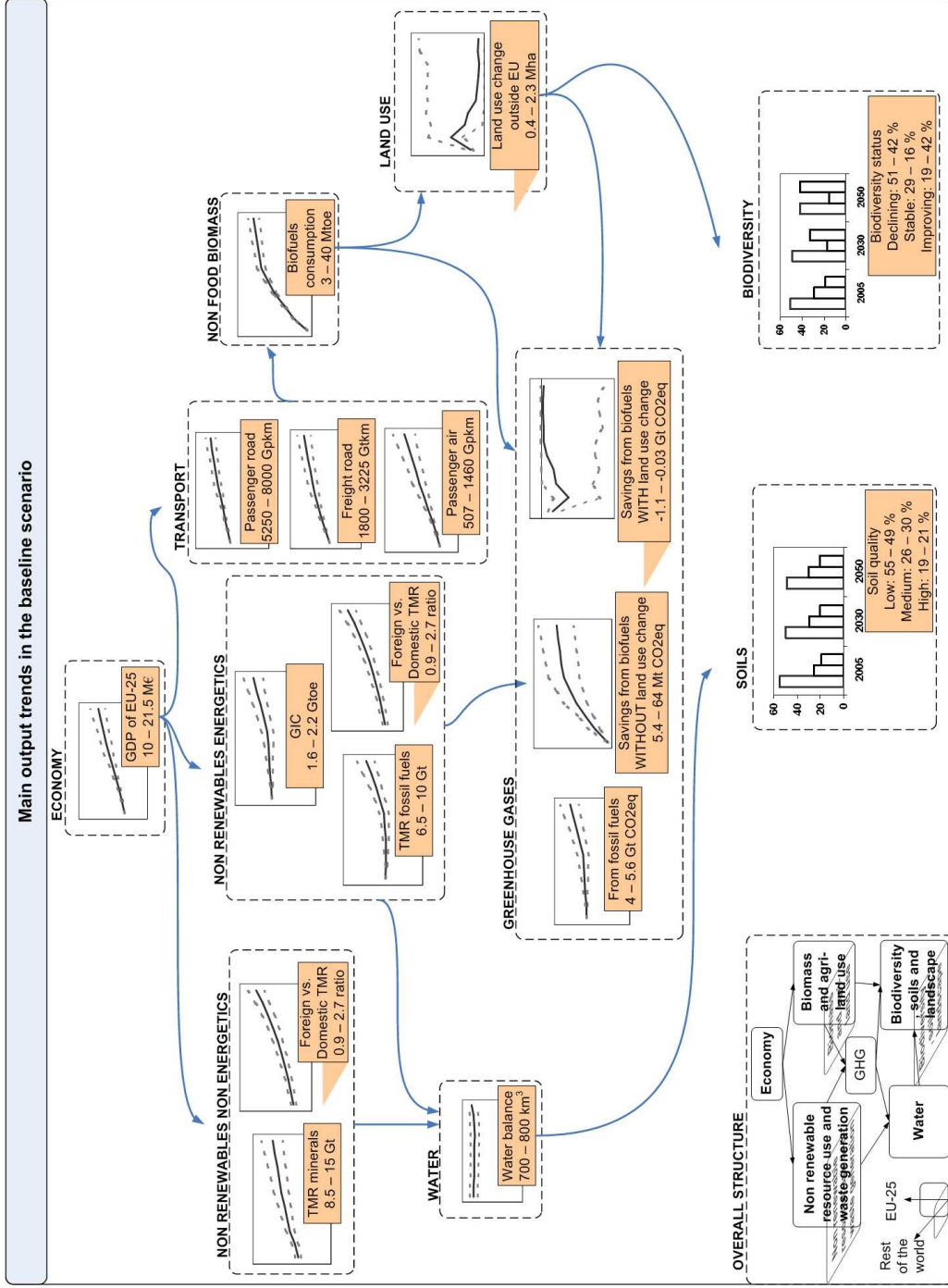


Figure 7: Overview of the modelling results from the baseline scenario. Solid lines represent median values of output parameters for the period 2005-2050. Uncertainty is summarized by 90% confidence intervals (dashed lines) of the resulting conditional probability distributions. The numbers given are the maximum and minimum values reached by the median over the period.

7. Question 6: Which alternative scenarios are possible?

As a result of Steps 3 and 4 we can define a broad set of sustainability goals and their relationships to the various types of strategy that might achieve them. Using this information a scenario framework (Figure 8) defining these alternative potential pathways to the future can be developed and compared using the FORESCENE model to the trends resulting from the ‘base-line’ assumptions defined above.

Figure 8 represents the ‘alternative scenario’ framework in terms of a set of hierarchical relationships and strategies. The elements in the diagram have been arranged so that they become increasingly more specific moving downwards (i.e. potentially measurable). The arrangement from left to right reflects the degree of consensus expressed within the groups consulted; those elements to the right of the diagram covered potential developments that were more controversial such encouraging new lifestyles that gave less emphasis to consumption as an element of well-being through, say, as finding satisfaction in alternatives to paid employment.

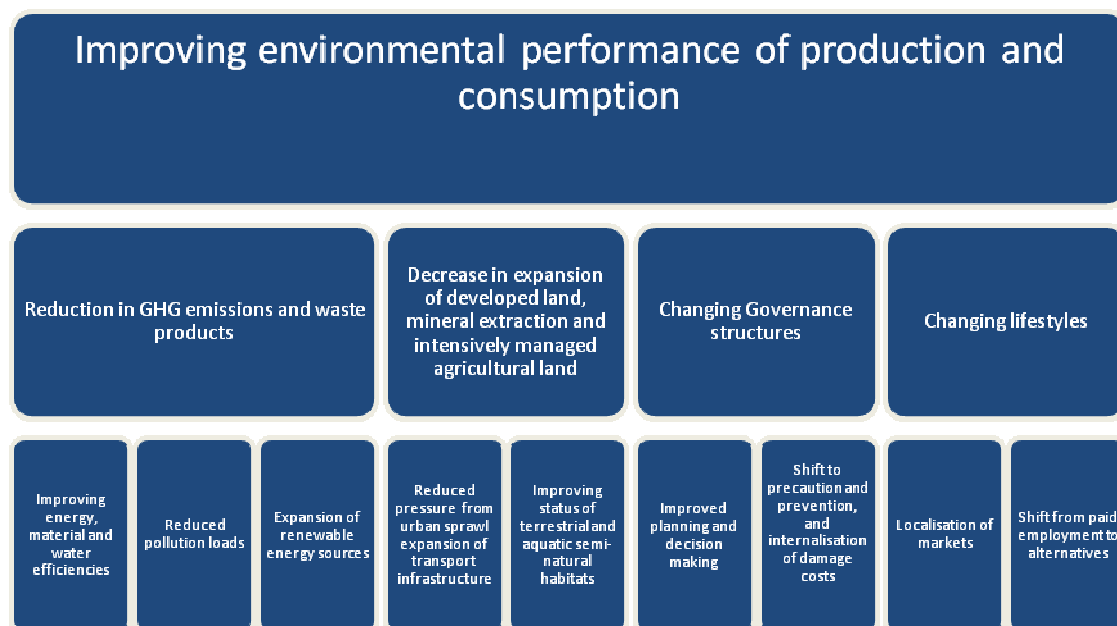


Figure 8: Framework for developing alternative sustainability scenarios

There was broad agreement amongst those consulted that most strategies for achieving sustainable development had to include an improvement in the environmental performance of consumption and production systems. All of the elements in Figure 8 below this high level strategy are consistent with this broad aim. Some, such as reduction in GHG and waste emissions are more obviously so, while others are linked more indirectly, such as the localisation of markets. The latter would reflect, for example, changing lifestyles and the development of local food markets and employment systems that reduce the need for transport of people and goods.

The framework shown in Figure 8 should be read in terms of there being a family of scenarios nested under the broad theme of improving the efficiency of consumption

and production systems. Using the combinations of the lower, more specific elements of the framework shown in Figure 8, a series of alternative scenarios can be ‘back-cast’ from the strategies identified. Although those consulted agreed on a similar, general desired future direction, a range of potential ‘futures’ might be imagined on the basis of different combinations of the elements being emphasised or down-played. Moreover individual, sectoral strategies might be implemented at different speeds, or be achieved with different levels of success by the end of the scenario period. Therefore, in an attempt to cover a range of the possible outcomes, three contrasting, alternative trajectories have been developed (see Table 1 in Annex). Two of them (‘Commitment to Change’, and ‘Muddling Through’) reflect the same broad set of ambitions derived from the workshops, and differ only in terms of the degree to which the more specific desired sustainable outcomes identified in the lower parts of Figure 8 have been attained. The third is a more pessimistic scenario in which most of the objectives have not been realised and performance across most of the areas identified in Figure 8 does not even match the base-line.

Table 1 expands each of the three scenarios in terms of the specific elements identified in the lower part of Figure 8. In developing the scenarios the aim has been to move from the general trends identified through to the specification of the states which particular nodes in the FORESCENE model would for particular time periods. Where possible we have attempted to build the alternative scenarios around the same set of nodes used for the base-line analysis. However, since some of the alternatives include the implementation of new measures (such as a Soil Framework Directive) there are also some structural differences between base-line and alternative scenarios.

The first scenario describes what might be termed an ideal outcome. Under the ‘**commitment to change**’ the foundations needed to achieve more sustainable outcomes are put in place early and to greater effect. It is imagined that there are marked improvements in the efficiencies of using energy, materials and water, and an expansion in renewable energy production. The rate of change is moderate to high and significant reductions have been achieved by 2030, with the rate of investment in R& D being mostly over 3%. The level of greenhouse gas emissions has fallen by 20% by 2020, and the 80% cut by 2050 has been attained. There is reducing pressure from the expansion of urban land and intensive agriculture from around the same time. Improvements in production of second generation fuel crops and other renewable energy technologies means that pressure from fuel crop expansion is minimised. The area for food crops is adequate to meet needs, and so EU consumption does not lead to pressure at Global scales. Regulation measures, including strong cross-compliance have been implemented, and farming and forestry management practices are predominantly green as early as 2020.

The second scenario is less promising than the first, in terms of achieving concrete sustainable outcomes. In this case while there are achievements but they are patchy. This scenario therefore represents a future that is characterised essentially as ‘**muddling through**’. As with the first scenario, improvements in the efficiencies of using energy materials and water are made, and there is expansion in renewable energy production. However, the rate of change is only moderate compared to the first scenario. The rate of investment in R& D is greater than in the first scenario, at 2-3%. However, the patchy nature of the outcome is indicated by greenhouse gas emissions

continuing to reduce only slowly. The 2020 target is not met until 2035, and only a 65% reduction is achieved by 2050. There is on-going pressure from the expansion of urban land and intensive agriculture. As with the first scenario strong regulation measures and better management practices are in place.

The final scenario is the one which sets out a pessimistic future, characterised as **'failing to deliver'**. Thus even by 2050 the transition to sustainability has not really been achieved. Increased consumption of resource intensive goods has meant that there has been less progress towards higher energy and resource efficiency. There is some expansion in renewable energy production, but the rate of change has been slow. The rate of investment in R& D has been no more than 2%. Greenhouse gas emissions have increased and there is still pressure from the expansion of urban land and intensive agriculture. Lack of improvements in efficiency of production of fuel crops means that area for food crops is insufficient and that EU consumption exerts pressure on land at Global scales. Nevertheless on the positive side regulation measures, including strong cross-compliance have been implemented, and farming and forestry management practices are mostly green.

Figure 9 shows the backcasting method applied to the scenario narratives presented above. The aim is to use the Bayesian network model to quantify the parts of the narratives that are accessible to it.

First, the quantitative desired goals and milestones considered in the narratives are assigned to the corresponding target nodes at the corresponding time slices. A path (linear, S-shaped, other) is defined from today's values for the target nodes being considered to the values set as 'desirable goals', *via* the intermediate milestones..

Second, the model is run at all time steps with different sets of input values for the input nodes representing key strategic drivers that can be influenced in some way. Then, using a graphical or analytical method, sets of input nodes' values are determined that drive the values of the target nodes along the chosen path towards the desired goals (the graphical method is shown in Figure 9, middle part).

Third and finally, the "backcasted" results are discussed. The modelled sets of inputs will certainly not be the panacea that shows *the* way towards sustainability. Instead it can be discussed whether such a development is feasible. The method should also highlight the potentially negative side-effects of the modelled sustainability path on other parts of the model, indirectly connected to the drivers considered. In case of disagreement, the process can be iterated, alternative targets or pathways can be considered. Some controversial scenario elements set aside in the previous steps of the Framework (e.g. in Questions 2 and 3) could surface again. It is also necessary to consider what modelling or consulting activities are required next to determine who should do what and when.

The first alternative scenario 'commitment to change' serves as an example to illustrate the backcasting procedure (Figure 9). The goals set are the highest among the three alternative scenarios and, as such, a strong development of the input parameters would be needed to reach them.

The main input variables considered for this modelling exercise are material productivity and the share of services in final demand for their direct influence on

mineral materials consumption, and indirectly on energy demand. Energy productivity, the share of renewables, and specifically the share of biofuels are considered for their importance in fossil fuel consumption and land use change. Drivers for the biodiversity and soils module, such as cross-compliance and farming management, are also part of the exercise.

A possible set of results is shown in Figure 9. Some, such as the strong shift towards a service oriented economy, need to be discussed with regard to their relevance, plausibility and feasibility. The answer to that question actually depends on the general frame that one is willing to adopt. If the underlying assumption is that of an economic growth which is still considerably based on manufacturing as today, so that for instance a growing car production for export would still be needed for our economy to grow, then the results would have little chance of looking acceptable. At that point one could look back at the diverse elements collected along the different steps of the FORESCENE Framework and remember that the somewhat fuzzy ideas of 'changing paradigm' or 'redefining wealth and happiness away from material possessions' came up more than once in the different workshops. One could then imagine that in a system where economic growth is sustained by growing production of education, music, art, cultural services, elder care in all their forms and at all ages, rather than by increased goods production or increased transport, then this set of backcasted results could eventually make sense.

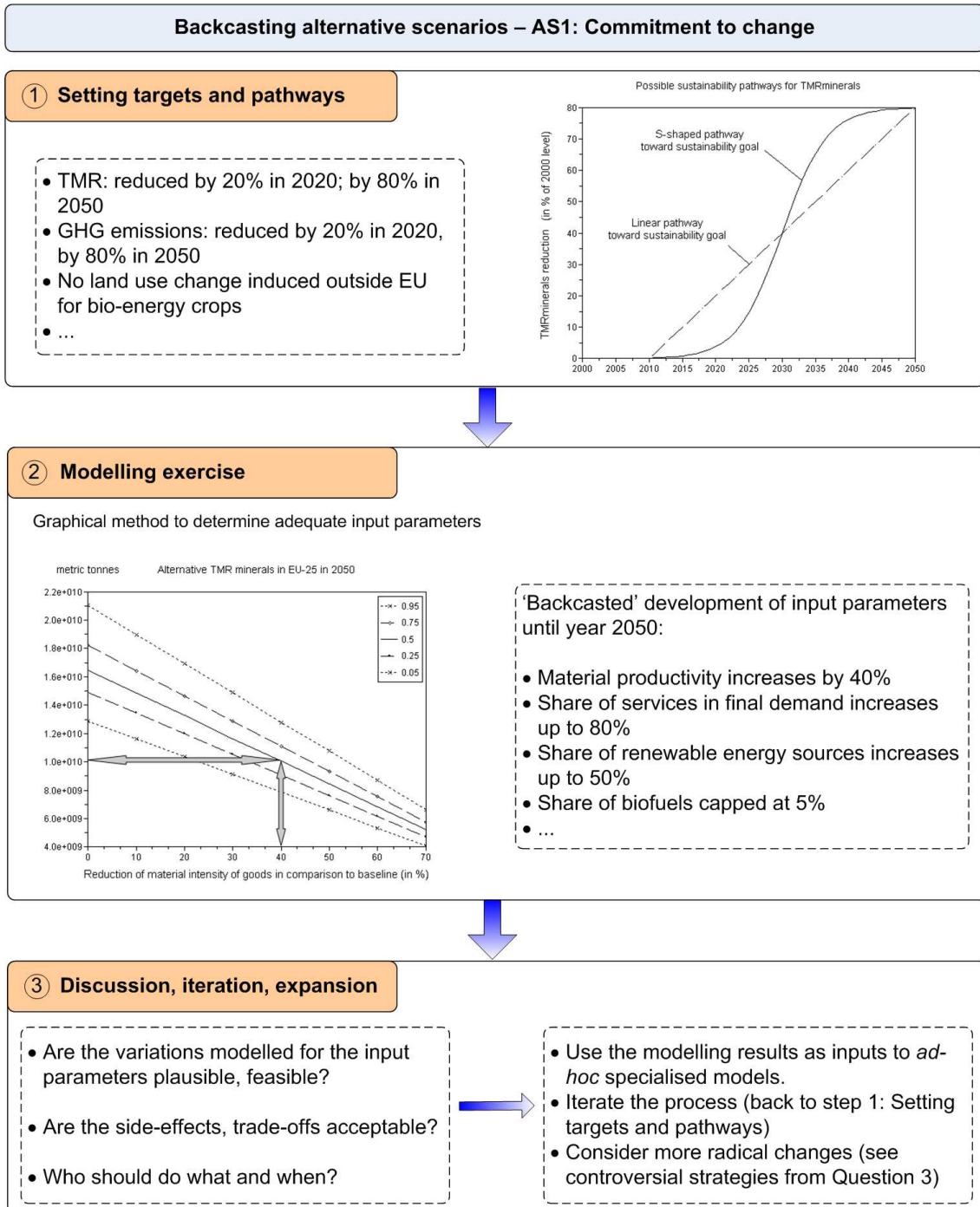


Figure 9: Modelling alternative scenarios using backcasting techniques exemplified with the first alternative scenario 'commitment to change'.

8. Possible applications in policy development and perspectives

8.1. Possible applications of FORESCENE in policy development

The FORESCENE model in its present, or slightly expanded version, can be used as a “warning tool” informing decision makers at an overview level on risks of interdependencies, problem shifting, and critical thresholds that may constrain the effectiveness of policies. Thus it may be used support strategic policy design, and the “experimental” or “scoping and screening” stage of an Integrated Sustainability Assessment. The model can also enrich policy debates about sustainability by virtue of its holistic character, showing the linkages and potential trade-offs between sectors.

The framework and the model may be further developed as a heuristic device and learning tool. Using the model in stakeholder interactions would improve the tool iteratively through interactions with experts and stakeholders. Ideally such model should be within a planning framework or one involving consultation, so as to identify the spectrum of parameters (and their potential variations) that needs to be modelled.

As a result of an expert review of the FORESCENE Project the following general observations emerged about the approach:

- That the Bayesian learning tool could be used interactively in policy exercises to support exploration and learning about the feasibility of achieving sets of policy goals, the robustness of policy outcomes to management options, performing sensitivity analysis, etc. and for helping change the culture of policy making toward a search for robust policies
- That it was useful in facilitating communication, interaction and joint working among different policy departments
- That it was useful in stressing the need for policy packages rather than individual instruments and in helping search for synergistic sets of policy options that might support the achievement of several policy objectives.
- That it was useful for long-term exploratory analyses aimed at supporting creative thinking about alternative futures, the desirability and feasibility of achieving these and ways of achieving these
- That it was useful for pinpointing areas (critical issues) that should be explored in more detail using other models.

The FORESCENE model could also be used to test individual policy proposals.

The approach used in the framework and the modelling methodology can be applied as a way of developing in-depth sub-models restricted to specific topics (e.g. soil quality, water quality) and/or specific geographical scales (e.g. a region). These could still be integrated in the broader picture because sub-nets showing different levels of detail or regarding different geographical scales can still be connected together.

These, more detailed sub-models can also be developed following the same framework for more *ad-hoc* purposes, like contributing to the impact assessment of a specific policy. The probabilistic assessment and the consideration of the intra- and

extra-EU dimension would add value to the IA process. This tool would complement rather than replacement for other tools used in IA.

8.2. Possible extensions / follow-up

A number of possible extensions to the model could also be anticipated, these include:

1. Deepening the level of detail for the economic module, i.e. differentiating between the economic sectors. This can be done in partnership with economic modellers. In its current version, the model can give insight (via forecasting and backcasting) into how much (and when) the driving parameters should be tweaked in order to reach sustainability goals. A deeper economic modelling would then be useful and necessary to address further questions such as “who should do how much?”, “which measures could make this happen?” etc.
2. Considering more social aspects. Additional modules oriented towards modelling social issues could be developed and integrated to the model. It could use both qualitative and quantitative modelling approaches.
3. Enhance public, stakeholder and expert participation. The participative approach taken in FORESCENE was adapted to building a prototype model but to expand the model or redesign it for a specific purpose (e.g. sustainability impact assessment) the level of participation for both the framing phase as well as for the data collection and generation phase could be raised. Different groups of stakeholders and/or experts could be distinguished according to their beliefs and assumptions and represented in the model.

Using the model for online consultation and Delphi processes could potentially help to reduce the need for traditional workshops, related workload and costs.

4. Opening the access to the tool to other users. For that purpose should the interface be improved and made accessible. A user manual and demonstration cases should then also be developed.

9. References

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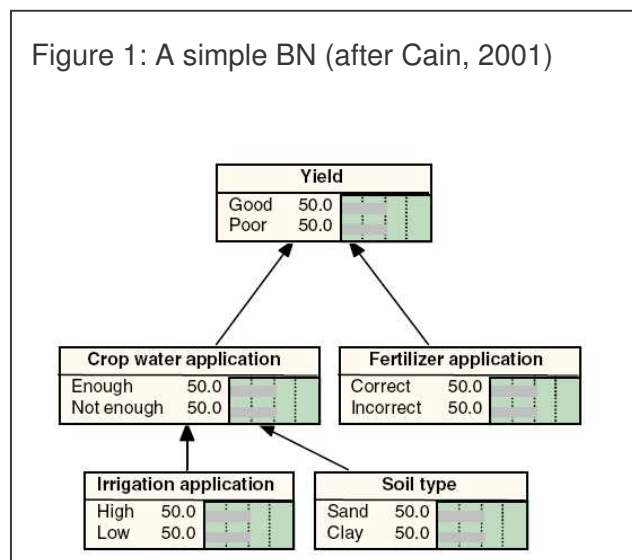
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10. Annex

10.1. CPTs

Cain (2001) defines a Bayesian Network as a ‘graphical tool for building decision support systems to help make decisions under uncertain conditions’. The key phrase to focus on in this definition is ‘uncertain conditions’. As Cain points out, BNs were originally developed to allow the impact of uncertainty in management to be accounted for. Using the tools decision makers could balance the desirability of an outcome against the chance that the management option selected might fail. The representation of a system in terms of a set of relationships that have probabilities associated with them is at the heart of the Bayesian approach. An example of a simple BN is shown in Figure 1.

If we think about the sorts of things that might influence agricultural yield, for example, then these might include water supply and fertilizer applications. The amount of water applied to the crop might, in turn, be influenced by such factors as soil type and the level of irrigation. Figure 1 shows this diagrammatically. The key variables (that is the things that can change, such as yield, fertilizer applications and soil type etc.) are shown as a set of boxes or **nodes**. The relationships between the



variables are shown as a set of arrows. These arrows simply set out the **linkages** between the variables; they show what influences what. The arrows describe what we think the causal relationships are within the system; notice that the arrows have a direction to express this idea of causality.

In Figure 1 each of the nodes are shown as being able to take various states. Thus yield can be ‘good’ or ‘poor’, or soil type can be ‘sandy’ or ‘clay’. In the diagram, the nodes are represented by a special type of box, called a ‘belief bar’, which we can use to express the probability that the variable (node) is in a particular state, and how this might influence the other nodes to which it is linked. At the moment no real probabilities have been assigned, and all the nodes show a 50:50 chance of being in a particular state. What the BN allows us to do is to assign probabilities to the states for the different nodes to describe how we think the world actually works. The way we do this is to build **Conditional Probability Tables (CPT)** for each node.

Table 1: CPT for the Crop water Application Node

Irrigation_applicati...	Soil_Type	Enough	Not enough
High	Sandy	70.000	30.000
High	Clay	80.000	20.000
Low	Sandy	10.000	90.000
Low	Clay	20.000	80.000

Table 1 shows the CPT for the node 'Crop Water Application' that is part of the network described in Figure 1. Technically CPT is the contingency table of conditional probabilities³ stored at each node, containing the probabilities of the node given each configuration of parent values. Clearly when building a BN we do not have to confine ourselves to variables that have only two states. The software can handle a number of discrete states or even continuous values.

³ The conditional probability of an event is the probability of the event occurring under certain given conditions.

10.2. Alternative scenarios

Table 1: Alternative Sustainability Scenarios

Alternative scenario	Improving energy, material and water, efficiencies	Reduced pollution loads	Expansion of renewable energy sources	Reduced pressure from urban sprawl, intensive agriculture and transport infrastructure	Improving status of terrestrial and aquatic semi-natural habitats	Improved planning and decision making	Shift to precaution and prevention, and internalisation of damage costs	Localisation of markets	Shift from paid employment to alternatives
<p>AS1, Commitment to change: Under this scenario there is clear commitment to the goals of sustainability. There are marked improvements in the efficiencies of using energy, materials and water, and there is expansion in renewable energy production. The rate of change is moderate to high and significant improvements have mostly been achieved by 2030. The rate of investment in R & D has been over 3%. Greenhouse gas emissions have reduced significantly by 2030 and there is reducing pressure from the expansion of urban land and intensive agriculture from 2030. Regulation measures, including strong cross-compliance have been implemented, and farming and forestry management practices are predominantly green as early as 2020.</p>	<p>Significant improvements in the efficiency of material use and waste minimisation. Water abstraction rates are stable or declining. GHS reduction targets for 2020 and 2050 met.</p>	<p>High rates of investment in R&D (>3%) means that increase in nutrient transfer efficiencies are good so that there has been improvement in water quality.</p>	<p>No marked expansion of renewable energy sources and reduced pressure on area of land devoted to food crops from biofuels.</p>	<p>Rate of urban expansion and growth in area of intensive agriculture slackens by 2030. Improvements in production of fuel crops means that area for food crops is adequate and that EU consumption does not lead to pressure at Global scales.</p>	<p>Habitat and WFD goals only achieved by 2025.</p>	<p>Strong soil framework directive implemented by 2025.</p>	<p>Green management practices in forestry and agriculture widespread.</p>	<p>Diversity of agricultural production is high and from 2030, and there is the EU approach to self-sufficiency in most key food and energy products.</p>	<p>Demand for consumer goods has increased at 2000 rates until 2025, but returns to 2000 levels by 2050.</p>

<h2>Alternative scenario</h2> <th data-bbox="268 1487 592 1659"> <p>Improving energy, material and water, efficiencies</p> </th> <th data-bbox="268 1323 592 1487"> <p>Reduced pollution loads</p> </th> <th data-bbox="268 1151 592 1323"> <p>Expansion of renewable energy sources</p> </th> <th data-bbox="268 978 592 1151"> <p>Reduced pressure from urban sprawl, intensive agriculture and expansion of transport infrastructure</p> </th> <th data-bbox="268 815 592 978"> <p>Improving status of terrestrial and aquatic semi-natural habitats</p> </th> <th data-bbox="268 651 592 815"> <p>Improved planning and decision making</p> </th> <th data-bbox="268 488 592 651"> <p>Shift to precaution and prevention, and internalisation of damage costs</p> </th> <th data-bbox="268 324 592 488"> <p>Localisation of markets</p> </th> <th data-bbox="268 194 592 324"> <p>Shift from paid employment to alternatives</p> </th>	<p>Improving energy, material and water, efficiencies</p>	<p>Reduced pollution loads</p>	<p>Expansion of renewable energy sources</p>	<p>Reduced pressure from urban sprawl, intensive agriculture and expansion of transport infrastructure</p>	<p>Improving status of terrestrial and aquatic semi-natural habitats</p>	<p>Improved planning and decision making</p>	<p>Shift to precaution and prevention, and internalisation of damage costs</p>	<p>Localisation of markets</p>	<p>Shift from paid employment to alternatives</p>
<p>AS2, Muddling through: Under this scenario some of the sustainability goals identified are achieved in the medium term, but success is patchy and modest. In contrast to AS1, there have been improvements in the efficiencies of using energy materials and water are made, and there is expansion in renewable energy production. The rate of change is moderate and significant improvements have been achieved by 2030. The rate of investment in R& D has been between 2-3%. However, greenhouse gas emissions have continued to increase slowly and there is still pressure from the expansion of urban land and intensive agriculture. On the positive side regulation measures, including strong cross-compliance have been implemented, and farming and forestry management practices are mostly green.</p>	<p>Moderate improvement in the efficiency of material use and waste minimisation. Water abstraction rates are stable. GHS reduction targets for 2020 and 2050 not fully met.</p>	<p>Moderate rates of investment in R&D means that increase in nutrient transfer efficiencies are good so that there has been some improvement in water quality.</p>	<p>Marked expansion in area of land devoted to bio-fuels.</p>	<p>Rate of urban expansion and growth in area of intensive agriculture slackens by 2030. Expansion of non-food crop area means that EU need for food cops leads to some pressure at Global scales.</p>	<p>Habitat and WFD goals only achieved by 2025.</p>	<p>Strong soil framework directive implemented by 2025.</p>	<p>Green management practices in forestry and agriculture widespread.</p>	<p>Intensive agriculture and specialisation is still widespread, but diversity of agriculture increases after 2030, and there is greater EU self sufficiency in food and energy production.</p>	<p>Demand for consumer goods has continued to grow at 2000 rates, but slackens by 2040.</p>

<h2>Alternative scenario</h2> <th data-bbox="268 1485 592 1659">Improving energy, material and water efficiencies</th> <th data-bbox="268 1323 592 1485">Reduced pollution loads</th> <th data-bbox="268 1149 592 1323">Expansion of renewable energy sources</th> <th data-bbox="268 981 592 1149">Reduced pressure from urban sprawl, intensive agriculture and expansion of transport infrastructure</th> <th data-bbox="268 824 592 981">Improving status of terrestrial and aquatic semi-natural habitats</th> <th data-bbox="268 678 592 824">Improved planning and decision making</th> <th data-bbox="268 488 592 678">Shift to precaution and prevention, and internalisation of damage costs</th> <th data-bbox="268 338 592 488">Localisation of markets</th> <th data-bbox="268 194 592 338">Shift from paid employment to alternatives</th>	Improving energy, material and water efficiencies	Reduced pollution loads	Expansion of renewable energy sources	Reduced pressure from urban sprawl, intensive agriculture and expansion of transport infrastructure	Improving status of terrestrial and aquatic semi-natural habitats	Improved planning and decision making	Shift to precaution and prevention, and internalisation of damage costs	Localisation of markets	Shift from paid employment to alternatives
<p>AS3, Failing to deliver: Under this scenario the transition to sustainability has been unsuccessful or weak. Increased consumption of resource intensive goods has meant that there has been less progress towards higher energy and resource efficiency. There is some expansion in renewable energy production, but the rate of change is slow and significant improvements are not achieved until 2050. The rate of investment in R& D has been no more than 2%. Greenhouse gas emissions have increased and there is still pressure from the expansion of urban land and intensive agriculture. On the positive side regulation measures, including strong cross-compliance have been implemented, and farming and forestry management practices are mostly green, but these are token gestures.</p>	<p>Modest improvement in the efficiency of material use and waste minimisation. Water abstraction is increasing or stable at best compared to 2000 levels. Significant reductions in GHG emissions not achieved.</p>	<p>Low rates of investment in R&D means that increase in nutrient transfer efficiencies are modest, meaning that improvements in water quality are slow.</p>	<p>Marked expansion in area of land devoted to bio-fuels.</p>	<p>Rate of urban expansion and growth in area of intensive agriculture does not slacken. Lack of improvements in efficiency of production of fuel crops means that area for food crops is insufficient and that EU consumption exerts pressure on land at Global scales.</p>	<p>Habitat and WFD goals only achieved by 2050.</p>	<p>Strong soil framework directive only implemented by 2050.</p>	<p>Green management practices in forestry and agriculture widespread.</p>	<p>Intensive agriculture and specialisation is still widespread and there is some tendency to shift problems outside EU in order to remedy detrimental environmental effects 'at home'.</p>	<p>Demand for consumer goods has continued to grow at 2000 rates.</p>