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ESTABLISHMENT OF AN AD HOC FORUM FOR THE COMPARISON OF THE TIMES-MARKAL AND LEAP MODEL AS A SUPPORT FOR BELGIAN LONG-TERM ENERGY POLICY

FORUM

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ESTABLISHMENT OF AN AD HOC FORUM FOR THE COMPARISON OF THE TIMES-MARKAL AND LEAP MODEL AS A SUPPORT FOR BELGIAN LONG-TERM ENERGY POLICY
FORUM

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SUMMARY

Policy and scientific context

The growing need for reliable projections of future energy demand, energy technology development, and related emissions and costs is being met by the widespread use of energy models. However, the gap between modellers and potential users of the models remains large. The in-built characteristics of energy models and scenario building exercises (e.g. assumptions made by energy system modellers) often remain hidden for policy makers, conflict with their suppositions, or offer limited information for targeted policy interventions. These observations raise methodological and practical issues regarding the 'interface' between energy system modelling practices and policy making. Even if the models are perceived as "useful" or "usable" by decision-makers, their expectations are often not fulfilled because the model builders are not communicating effectively the insights, structure and understanding available from the model. One of the most important questions in user analysis is determining how the model results have to be presented in the policy context under study. Model builders should keep asking themselves how relevant the results are to the policy-makers. Another question relates to how sensitive a decision may be to a particular variable, the answer providing model users precious insights into the uncertainties involved. The potential value of information also depends on how accurate the information has to be. A deepening of insights can equally be gained from communicating the "pathways" to the results, whereby the modellers try to relay their arguments as clearly as possible to the user community. And finally, important unanswered questions have to be identified, thus defining the modeller's agenda for new research. Academic literature on the use, impacts and effectiveness of the approaches for long-term future analysis in policymaking is still superficial or absent. This project provides an exploratory contribution to this literature in a Belgian energy policy-making context.

Goals

The main goal of the FORUM project was to render more transparent the two energy models or tools presently used by Belgian authorities in their decision-making concerning a transition to a carbon neutral economy. The terms "model" and "tool" refer to a methodology that needs a software application. The aforementioned approaches are the techno-economic, partial equilibrium energy model TIMES as used in the BELSPO-sponsored TUMATIM project (TUMATIM-TIMES), and the energy accounting tool LEAP as applied in the SEPIA project (SEPIA-LEAP).

In doing so the project originally set out to answer the following questions:

- Are the methodologies appropriate to signal to the policy-makers threats, challenges and opportunities concerning sustainable energy systems?
- To what extent to these methodologies take into account the complex (technological, economic and policy-related) interactions within the energy system?
- Can these methodologies aid in making normative policy choices?
- Can these methodologies integrate the experience and know-how of experts and stakeholders, in addition to the existing data-set and given the numerous uncertainties?

The project also developed and tested a questionnaire for evaluating both methodologies from the end user point of view.

Main conclusions

The FORUM members made three major recommendations: to seek synergies between the TIMES-TUMATIM and SEPIA-LEAP approaches; to improve the coherence betweens the scenario results even if they are derived from very different methodologies, and to establish some kind of "platform" where Belgian energy modellers can regularly meet, exchange ideas, results, etc.

- From a policy point of view, both modelling approaches are needed to inform policy makers on the consequences of implementing the various EU roadmaps (low carbon economy, energy & transport) in Belgium. The FORUM therefore suggested that both approaches should be made more relevant to energy and climate change policies by combining them in a more "holistic" approach. Such a merger of could lead to a "win-win" situation. One possibility is to use the TIMES-TUMATIM 'rational actor' approach to derive the energy demand levels for those sectors (such as energy-intensive industries) where the hypothesis of rational economic behaviour is more realistic than for other sectors. SEPIA-LEAP could then explore the 'behavioural variations' or 'lifestyle changes' (driven by other than price policies) in all the other sectors. Alternatively, both approaches could work iteratively. The visions of the Belgian energy system established in SEPIA-LEAP can be used as a starting point for the exogenous demand levels in TIMES-TUMATIM to ascertain the costs of policies leading to those visions. If those costs are considered too high, the initial visions can be adjusted during a second round of the SEPIA-LEAP approach, and run once more in TIMES-TUMATIM, until at some point both approaches converge.

- There are many on-going studies in the EU, Belgium and its regions on what (sustainable) energy systems should look like in 2050. In order to allow more meaningful comparisons of the results of the diverse approaches, a number of questions have to be answered first. First and foremost, what are the explicit assumptions in the scenarios concerning activity levels, "way of life", visions of 2050, etc?. What are the differences between the scenarios in the two approaches, and why do those differences exist in the first place? On a related note, the FORUM members expressed the desire to be given more detailed results of the modelling exercises. For example, concerning the TIMES-TUMATIM output an overview of the investment intensity in the different scenario's was requested. As a result, both VITO and UA made more detailed results of the assimilated scenarios available to the FORUM members.

- The aforementioned problems of lack of synergy and coherence are the reasons why the FORUM proposed that BELSPO should initiate some kind of "platform", where all energy (and climate change) modellers in Belgium could meet every three month or so, and exchange ideas, assumptions, results, ...

During the project, a number of commonalities between the two approaches were identified.

- Costs are an important issue, that cannot be neglected in scenario exercises Both the SEPIA-LEAP and TIMES-TUMATIM approach have to consult the stakeholders to ascertain beforehand which costs should be accounted for in the model. Furthermore, modellers have to confer in advance with the stakeholders and / or scenario builders about the *reliability* and *(un)certainty* of the costs considered in the scenarios. That said, costs may never be the only decisive factor.

- A need for a better understanding of lifestyle change mechanisms is apparent from the comparison of both approaches. The relevant question is to what extent such changes can be induced by price changes and/or voluntary acts, whether those are steered by policy intervention or not. Recent advances in political and social sciences can clarify these enquiries to some extent.

- Both approaches depend on a number of (exogenous) key parameters. The selection of these key parameters should always be subjected to stakeholder review. Candidates for key parameters are e.g. potentials for offshore wind turbines, imports of biomass, the electrification level of transportation means, etc.
- The FORUM project revealed the need for a common "glossary". The same words do not always have the same meaning, either in-between the modellers, between modellers and policy-makers, or both. Examples of terms that may have different meanings are "backstop technologies" or "energy services". A Belgian modelling platform (such as the one mentioned above) could help ironing out small but potentially significant misapprehensions.

Contribution of the project in the context of sustainable development

It is very hard to introduce the long-term perspective in energy and climate change related decision making because policymaking is often short term, compartmentalised and dominated by advocacy. The ultimate goal of using models is not the perfection of the model, but rather its capacity to enhance policy-making capacities to support the transition to a low-carbon society in Belgium. Capacity enhancement can only result from a detailed 'scoping' of policy information needs. Scoping aims at setting the range, nature and importance of the assessment, including its precision, scale, detail of institutional, methodological and practical requirements such as deadlines, data needs, time and budget. A detailed scoping has to answer crucial questions regarding the why?, what?, how? and who? of capacity building for managing the transition to a low carbon economy.

As the project made clear to the FORUM members, SEPIA-LEAP is intended to generate different insights based on *deliberation* between stakeholders and scenario builders concerning plausible paths to a sustainable energy system by 2050 in Belgium. As such, advice on the use of policy instruments is not meant to be a direct output of the SEPIA-LEAP. Rather the tool pictures and streamlines different and sometimes opposing suggestions to reach a particular vision.

The intention of TUMATIM-TIMES is to generate a long-term roadmap to maximize welfare. Keeping this in mind, the most important policy recommendations following the TUMATIM-TIMES scenario runs were:

- Demand reductions are important and necessary. Energy services become more expensive on the average, but less use is made of them. Although the consumer losses are expensive, they are still less expensive than policies that rely exclusively on technological solutions. It is not because demand reductions are expensive that society should abstain from such measures. Policy makers however should be made aware of the consequences on welfare. If not, they might assume that the demand shifts will happen automatically, which is not the case.

- Renewable technologies will be used up to technical potential levels given ambitious climate change policy targets (some technologies even at the EU level).

Although the information provided by the TIMES-TUMATIM and SEPIA-LEAP approach may be scientifically valid, they are of little use if political backing or significant characteristics of the policymaking process are not taken into account.

Key words: energy models, energy system, user analysis, TIMES, LEAP

1. INTRODUCTION

1.1. POLICY CONTEXT

Since the first oil crisis of the 1970s, the need for reliable projections of future energy demand, energy technology development, and related emissions and costs has been met by the widespread use of technology-rich bottom-up energy system models [Götz et al. (2012), Nakata (2004)]. The successful application and interpretation of models in terms of improving policy making by either expanding alternatives, clarifying policy choices or enabling policy makers to achieve desired outcomes depends on an understanding of the assumptions, structural elements, and theoretical and empirical foundations underlying these models [Sanstad & Greening (1998)]. But in spite of efforts to improve the use and usefulness of energy models, with at the forefront the creation of the Energy Modelling Forum (EMF) in 1976 [Sweeney & Weyant (1979)], the gap between modellers and potential users of the models remains large. The in-built characteristics of energy models and scenario-building exercises (e.g. assumptions made by energy system modellers) often remain hidden for policy makers, conflict with their suppositions, or offer limited information for targeted policy interventions [Granger et al. (2008)]. In addition, Volkery and Ribeiro [(2009)] find that scenario techniques are most often used in the early phases of the policy cycle – i.e. for indirect forms of policy support such as awareness-raising and issue-framing. However, their role in the 'harder' parts of policy making – i.e. in processes of policy design, choice and implementation – is limited, partly due to conflicts of perspective between policy makers and scenario planners. These observations raise methodological and practical issues regarding the 'interface' between energy system modelling and scenario-building practices and policy making.

1.2. GOALS

Following McNie [(2007)], 'good' scientific decision support practices should deliver knowledge to policy makers that is *salient*, *credible* as well as *legitimate*. Scenario development in support of public policy is no exception to this rule. More specifically, in the context of the transition to a low-carbon economy, scenarios are called upon for demonstrating how a society could take action in order to reduce greenhouse gas (GHG) emissions by 80% to 95% in 2050 (compared to 1990). If such scenarios are to be 'useful' they must accomplish the following things. They must provide convincing (i.e. technologically, socially and economically feasible) descriptions of low-carbon transition pathways, and clearly identify how these pathways can be brought about by purposeful policy interventions also on the short term [Hughes (2013)] – i.e. they must be *salient*. However, developing such convincing and strategically effective low-carbon scenarios is challenging because of the particular complexity of the decarbonisation problem. This problem calls for the consideration of a broad and technologically complex system, as GHG emissions are generated in a wide range of sectors, driven by the decisions and practices of a huge variety and amount of actors (e.g. large-scale companies, SMEs, governments, households, etc.), each of them functioning according to their own 'decision logic'. The transition scenarios must therefore be able to *credibly* reflect the complexity of this system, including the many uncertainties. Given the number of actors involved in the transition, a scenario planning exercise must clearly also involve an element of consensus-building around values, worldviews and ideologies [Sunderlin (2003)], since the accordance of these values with the values entertained by the actors involved in the transition will determine for a large part the political feasibility of the transition pathway. The scenarios must therefore aim for *substantial legitimacy*. Finally, the notion of involving stakeholders in processes of knowledge production for policy making (i.e. *procedural legitimacy*) is by now becoming recognized as an important step in order to foster 'buy in' of the policies, 'tap into' the knowledge of these stakeholders, and to assure that their values and worldviews are taken into account [Dryzek (1997)].

Pursuing the main lines of the discussion above, the FORUM project set out to answer the following questions:

- Are TUMATIM-TIMES and SEPIA-LEAP appropriate to signal to the potential model users threats, challenges and opportunities w.r.t. policy making in support of the transition to a low-carbon and sustainable energy system? (*salience*);

- To what extent do these approaches take into account the complex (technological, economic and policy-related) interactions within the energy system? (*credibility*);

- Can these models or tools aid in making normative policy choices? (*substantial legitimacy*);

- Can they integrate the experience and know-how of experts and stakeholders, in addition to the existing data-set and given the numerous uncertainties? (*procedural legitimacy*).

Given that "*Models should maintain a high level of transparency in order not to be accused of being an obscure and 'eclectic' methodology*" [Weijermars et al. (2012): p. 10], in the case of modelling exercises transparency can be considered to be an absolute precondition for delivering salient, credible and legitimate knowledge. Therefore, the key 'enabler' of the FORUM project was to render more transparent the two energy models or tools presently used by Belgian authorities in their decision-making concerning a transition to a carbon neutral economy. For the sake of brevity, in the remainder of this report the terms "model" and "tool" will be used as a shorthand for "scenario-building methodologies requiring a software application". TUMATIM-TIMES is a techno-economic, partial equilibrium energy model as employed in the TUMATIM project [Van Regemorter et al. (2008), Benoot et al. (2011)]. SEPIA-LEAP is the energy accounting tool LEAP as applied in the SEPIA project [Heaps (2012), Laes et al. (2011)]. The TUMATIM-TIMES model was developed by the Flemish Institute for Technological Research (VITO) and KU-Leuven; the SEPIA-LEAP tool by the University of Antwerp (UA). Both the TUMATIM and SEPIA projects were sponsored by BELSPO.

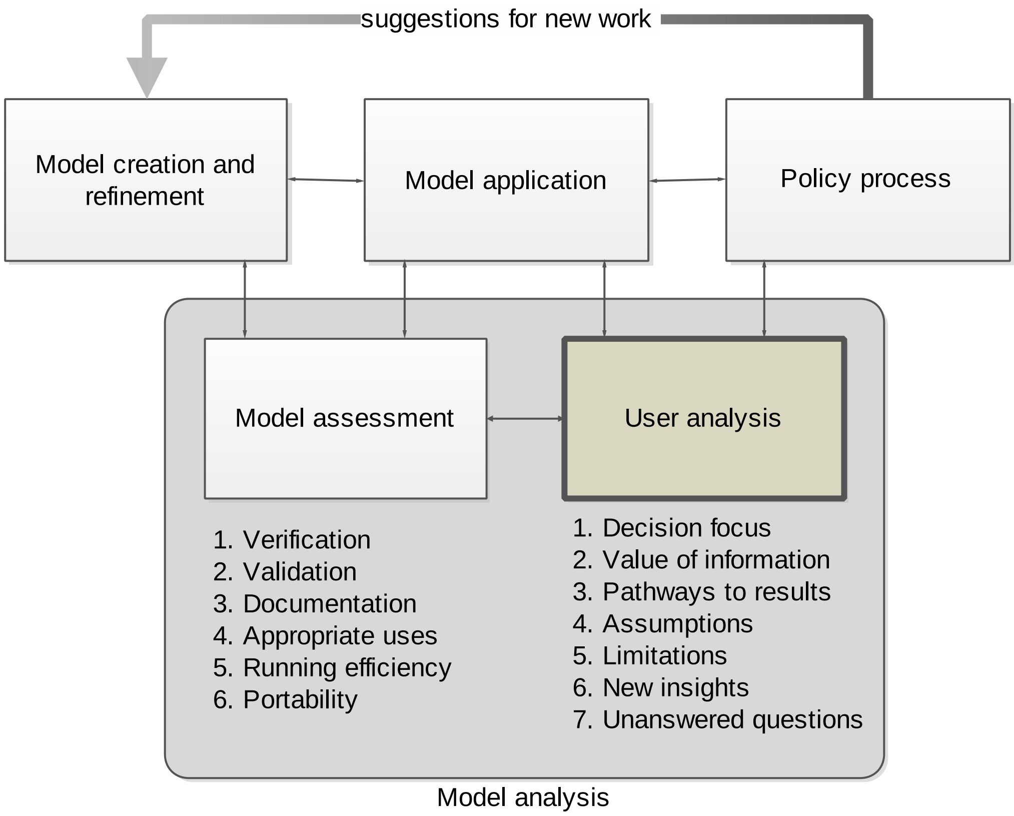
In addition, the FORUM project team developed and tested a preliminary questionnaire for evaluating energy models from the end user point of view.

1.3. SCIENTIFIC CONTEXT

Reviews of energy models have a long tradition in energy literature. For example, in the 1970s a joint project "Comparison of Energy Options: A Methodological Study" of the International Institute for Applied Systems Analysis (IIASA) and the United Nations Environment Programme (UNEP) led to the publication of several energy model reviews, the oldest report dating back to 1974 [Charpentier (1976)]. One of the most recent efforts is the ATEsT "Models Characterization Report" [Amerighi (2010)]. This inventory of existing models is a prerequisite to performing an evaluation of the models and to propose tools and methods to be used for transition planning and systemic energy modelling in the framework of the Strategic Energy Technology Plan (SET-Plan) launched by the European Commission (EC). For Belgium, BELSPO commissioned a similar exercise of inventorying simulation models to support climate change policies [Federaal wetenschapsbeleid (2003)].

Although the project team did make a comparison of both approaches (TIMES-TUMATIM and SEPIA-LEAP) following the ATEsT format, the FORUM project was not about traditional model comparison or even assessment as such but about "user analysis" (fig. 1).

Figure 1: User analysis in the broader context of model analysis



Source: Richels (1981)

Even if the models or tools are perceived as "useful" or "usable" by decision-makers, their expectations are often not fulfilled because the model builders are not communicating effectively the insights, structure and understanding available from the model [Richels (1981), p. 50]. One of the main components of user analysis is determining how the model results have to be presented in the policy context under study. Model builders should keep asking themselves how relevant the results are to the policy-makers. Another question relates to how sensitive a decision may be to a particular variable, the answer providing model users precious insights into the uncertainties involved. The potential value of information also depends on how accurate the information has to be. A deepening of insights can equally be gained from communicating the "pathways" to the results, whereby the modellers try to relay their arguments as transparently as possible to the user community. The final component of user analysis is the identification of important unanswered questions, defining the modeller's agenda for new research [Richels (1981), p. 53].

Whereas the (energy and climate change) problems are long term, complex and uncertain, policymaking is often short term, compartmentalised and dominated by advocacy [EEA (2011), p. 8]. These characteristics make it very hard to introduce the long-term perspective in energy and climate change related decision making. For this reason academia, public and private sectors have become ever more interested in developing approaches for long-term future analysis. But even well-constructed, rigorously analysed scenarios are of little relevance if there is no political backing or if significant characteristics of the policymaking process have not been taken into account [EEA (2011), p. 7]. The information provided by the TIMES-TUMATIM and / or SEPIA-LEAP approach may be scientifically valid, it is of no use if policy makers do not perceive them as needed.

Academic literature on the use, impacts and effectiveness of the approaches for long-term future analysis in policymaking in particular is still superficial or absent [EEA (2009), EEA (2011)]. Our analysis provides an exploratory contribution to this literature in a Belgian energy and climate policy-making context. The purpose of this report is to analyse the practical challenge of reconciling the 'supply and demand' of insights derived from energy scenario modelling between scenario builders and users. Our approach is highly problem oriented (rather than centred on a theoretical inquiry), in the sense that we look at this challenge within a particular context and setting (i.e. policy support for the formulation of long-term energy and climate policy in Belgium) and try to find workable solutions for this setting. In doing so, we recognize the highly contextual and pragmatic nature of reconciling 'supply and demand' of scientific information and that "no single explanation can be expected to cover every case" [Menand (1997): p. 351]. Using a problem-oriented approach requires that we can clarify the current state of affairs and the desired goals (of producing more 'useful' knowledge) and to identify the discrepancies between the two [Clark (2002)].

2. METHODOLOGY

In order to assess the salience, credibility and legitimacy of the results produced by TUMATIM-TIMES and SEPIA-LEAP, the team let itself guide by the 'user analysis' method. The FORUM methodology included the following steps:

- The establishment of an ad hoc "FORUM" for evaluating the two approaches, using the TIMES-TUMATIM and SEPIA-LEAP results of "assimilated scenarios" (see infra) as a point of reference;
- A survey and discussion to gain insight in the expectations of potential model users;
- A technical comparison of the two model approaches and scenarios developed in the framework of the BELSPO sponsored TUMATIM and SEPIA projects;
- The construction of assimilated scenarios. From the above comparison and based on the expectations of potential model users new similar scenarios were derived which were to be run by the two models in parallel;
- A side-by-side comparison of the final results of the assimilated scenarios.

During the project a close eye was kept on the trade-off between model comparisons as such and energy policy analysis for which the different models simply serve as tools. In this respect it is imperative to point out that SEPIA-LEAP only forms part of a broader (i.e. non-modelling) methodology to assess long-term sustainable energy policy in the Belgian context, whereas TIMES-TUMATIM is more of a closed modelling system.

2.1. FORUM MEETINGS

The project team first decided on the qualifications the FORUM members had to answer to. Candidate members first and foremost had to be potential users of the models, and secondly experts who either have built energy models themselves and / or who are very familiar with the usage of such models. It was also agreed – after consultation with BELSPO – that a relatively small group (6 members) would be adequate, albeit evenly divided over both language groups (French and Dutch, using English as working language) and if attainable with at least one representative from each regional level and the federal level. Six partakers may not seem much, but can be justified by the fact that the ideal size of a focus group for non-commercial topics, especially as participants have more expertise of the topic, should not exceed five to six people [Krueger & Casey (2000)].

A short-list of eight potential FORUM members was drafted. Six people eventually agreed to join the FORUM (or to send their representatives), one of whom later declined because of insufficient expertise with this particular kind of energy models. A last member joined the FORUM after the first meeting, thus making sure the predetermined target of six members was met. It was unfortunate however that none of the candidate members belonging to the Walloon or Brussels region (for reasons unknown) were able to participate in the FORUM. For the members' names and affiliations, we refer to the acknowledgements.

The FORUM gathered three times during the project. All FORUM meetings took place at the BELSPO offices in Brussels. For the minutes of the meetings we refer to annex I and the FORUM website.

2.1.1. FORUM 1

The first meeting (FORUM 1) took place on Thursday, 10th of February, 2011. During the first meeting the potential model users were given the opportunity to ask questions about the two approaches, to comment on their perceived expectations and to make critical remarks concerning the proposed assimilated scenarios. The main theme was a discussion of the most salient results of the survey on user expectations (see chapter 3).

Following the first meeting, the project team set out to adjust the scenarios, based on the inputs of the forum members; and to generate preliminary results during a first run of the adjusted or "assimilated" scenarios with the original versions of the TIMES model used in the TUMATIM project and the LEAP tool used for the SEPIA project.

2.1.2. FORUM 2

The second meeting (FORUM 2) took place on Monday, 2nd of May 2011. FORUM 2 intended to find out to what extent the preliminary results of the models satisfy the expectations of the potential users. Due to unforeseen circumstances (the data consistency check took longer than expected), the TIMES-TUMATIM results were not ready in time for the second FORUM meeting. As an alternative, a brief description was given of the methodology used by TIMES-TUMATIM to emulate the SEPIA-LEAP results. The main theme was a thorough discussion on the relative merits of both modelling approaches.

Prior to the third meeting, the initial intent was that the project team would adjust the models, to the extent feasible, to better meet the expectations of the forum members; and to generate final results of the assimilated scenarios with the adjusted models.

Instead, the results of TIMES-TUMATIM were finalized in this stage, and a detailed comparison of the results of both approaches for the benefit of the FORUM members was drawn up.

2.1.3. FORUM 3

The third meeting (FORUM 3) took place on Tuesday, 4th of October 2011. The third meeting was initially aimed at discussing the model adjustments, but was kept limited to a recapitulated albeit this time very meticulous description of how the TIMES-TUMATIM approach attempts to emulate the SEPIA-LEAP scenario results, followed by a side-by-side comparison of the results of both approaches. The main theme consisted of ascertaining in what ways potential model users might have to adjust their expectations concerning the possibilities of policy-supporting models or tools.

All three FORUM discussions form the foundations of the project results, to be discussed in chapter 3.

2.2. PROBING THE EXPECTATIONS OF POTENTIAL MODEL USERS

The first step consisted of creating an a priori listing of expectations potential model users might have regarding the results of energy system models. To this end a preliminary survey concerning expectations was set up [see annex II or the FORUM website]. The goal of the questionnaire was to gain insight in the expectations of potential model users with regard to long-term energy system analysis practices – i.e. the entire process in which data are gathered, assumptions are formulated, models are run, results are validated and fed into the policy process. The point of the questionnaire was therefore not to identify ‘good’ or ‘bad’ models, but rather to identify more or less ‘useful’ modelling approaches in the context of energy system analysis in support of appropriate long-term energy strategic planning for Belgium.

The questionnaire was designed solely for use within the FORUM project. The responses were used as a basis for discussion during the first FORUM workshop, organised in February 2011.

The survey consisted of five parts, enquiring about:

- Energy system analysis in Belgium today and tomorrow;
- Expected outputs;
- Spatial and temporal resolution of analysis results;

- Expertise and role of stakeholders;

- Modelling methodology.

The detailed results are available at the FORUM website: www.ua.ac.be/BELSPO-FORUM.

The first part of the survey was aimed at finding out what the main use has been of energy system analysis results up till now in the long-term energy strategy planning in Belgium. Furthermore, the potential model users were asked which issues or problems should be addressed in energy system analysis as a support for long-term energy strategy planning in Belgium.

A predefined list of eight possible issues was provided, consisting of:

1) effects of market-oriented policies;
2) effects of non-price policies;
3) the rebound effect;
4) the impact of energy innovations on the energy sector;
5) the impact of changes in the energy system on the wider economic system, system reliability and security, greenhouse gas emissions and other environmental issues;
6) distributional issues;
7) externalities;
8) uncertainties and risks.

The potential model users were encouraged to add other problems to this list.

Finally, they were given the opportunity to address the main shortcomings in today's practice with regard to a selection of five issues they considered the most vital.

Given that energy system analysis in support of long-term energy planning cannot generate all outputs to a very high level of detail, part II surveyed what outputs – according to the potential model users – an analysis at the very minimum should generate. For a number of categories, the surveyed were not only asked to rank the outputs in terms of priority, but also to give the amount of detail required in terms of an acceptable margin of error (e.g. 5%, order of magnitude). The preselected categories were 1) resource use, 2) energy demand, 3) technology mix, 4) costs, and 5) greenhouse gas emissions. The surveyed were allowed to specify categories other than those mentioned in the list.

Part III queried the importance of spatial coverage (EU, Europe, world), spatial resolution (from single building or plant to region), time horizon (2030, 2050, 2100 or beyond) and temporal resolution (from daily to 5-year intervals) for five distinct categories: 1) resource use, 2) electricity technology mix and costs, 3) non-electricity technology mix and costs, 4) greenhouse gas emissions, and 5) other environmental damage.

In part IV, the surveyed were asked – given a non-limitative list of groups of stakeholders – to appraise firstly how feasible and desirable it is that each of these groups *acquire a thorough understanding* of how outputs of energy system analysis in support of long-term energy strategy planning in Belgium are attained; and secondly how desirable it is that they *actively participate* in the energy analysis process itself. This part concluded with two open questions, namely 1) how important it would be for the organisation [which] the potential model user represented to gain a profound operational knowledge of the models used in energy system analysis, and 2) whether this organisation would be interested in using energy system models for their own purposes?

The last part queried whether In the context of long-term energy strategy planning in Belgium the potential model users had any preferences (if at all) for certain types of modelling methodology (simulation, optimisation, partial or general economic equilibrium, integrated assessment, energy accounting, …) and / or approach (top-down, bottom-up, hybrid)?

Additionally, the surveyed persons were given the opportunity to make two optional summary statements, namely about the *main benefits* they expect from the use of energy system analysis, and about the major *potential pitfalls* when using energy analysis to support the long-term energy strategy planning process in Belgium.

In a second step, the results of the survey were used to distil "three challenging statements" on the expectations of the potential model user. These statements are:

- Minimisation of total social costs is a good approach for developing sustainable energy pathways on the long term;
- Active participation in energy system analysis is appreciated, but how can this be achieved in practice?;
- Long term energy system analysis has to start from backcasting and narrative scenario building.

The statements were discussed during the first FORUM meeting (see chapter 3 and annex I).

2.3. Comparison of the TIMES-TUMATIM and SEPIA-LEAP approaches

The detailed results of the BELSPO sponsored TIMES-TUMATIM and SEPIA-LEAP projects can be found in the final reports available at the BELSPO website www.belspo.be [Benoot et al. (2011); Laes et al. (2011)]. This sections gives a synopsis of the projects' main goals.

The objectives of the TUMATIM project were twofold. Firstly, a further development of the existing TIMES energy model to improve the integration of uncertainty in the evaluation of policy scenarios, and secondly the analysis of a set of case studies addressing issues important for the development of a sustainable energy system. Uncertainty may cover fluctuating energy prices, future carbon prices and environmental constraints, technology progress and / or security of supply. In addition, there is uncertainty surrounding model parameters such as price elasticities that can also influence the choice or costs of technologies. The policy cases analysed with the TIMES model covered the renewable target for Belgium and the EU proposal of a 30% GHG emissions reduction target in 2030 and 80% in 2050 compared to 1990 emissions for the EU. The Belgian TIMES model explored the choice of technologies and energy system costs, with an emphasis on the availability of nuclear and carbon storage.

The goal of the SEPIA project was to develop and discuss the feasibility of the main components of sustainability assessment in the Belgian energy policy context. The research methodology was interdisciplinary by attempting to integrate insights on energy system dynamics stemming from engineering, economics, policy sciences, sociology and ethics; while at the same time being attentive to the context-dependent nature of such knowledge by trying to incorporate stakeholder insights. Scenario building following the "hybrid backcasting approach" developed in SEPIA takes place starting from a systematic exploration of futures. Future visions are quantitative and qualitative interpretations of a sustainable energy system in 2050. From these visions, SEPIA works backwards to define the pathway that links the energy system 'here and now' to the energy system 'there and then' (i.e. in 2050). Pathways are built with the scenario-building tool LEAP [Heaps (2012)]. A 'scenario' results from each combination of a vision and a pathway.

In a first step detailed characterizations were prepared of TIMES (the techno-economic, partial equilibrium energy model) as employed in the TUMATIM project, and of LEAP (the energy accounting decision support system tool) as utilized in the SEPIA project. The project team early on decided to use the “energy models classification form” provided by ATEsT[1] as a template for these descriptions [Amerighi et al. (2010)]. ATEsT aims to enhance SETIS with tools and methodologies for transition analysis and planning by the joint effort of European research institutes and the JRC (Joint Research Centre). (see also www.atest-project.eu) SETIS is an information system to "map" technologies and provide updated information to support policy making [European Union, 2010]. The above mentioned characterisations of TIMES-TUMATIM and SEPIA-LEAP are available at the BELSPO-FORUM website (www.ua.ac.be/BELSPO-FORUM). A more technical description of SEPIA-LEAP is also available at the BELSPO-FORUM website.

In a second step a brief side-by-side summary of the main characteristics of TUMATIM-TIMES and of SEPIA-LEAP was drawn up (see annex III and the FORUM website). This summary was used at the first FORUM meeting to acquaint the FORUM members with the two energy policy tools.

There are a lot of similarities between TIMES and LEAP. They are both *energy system* models or tools, intended to analyse the evolution of detailed energy flows by combining multiple (energy consuming and producing) sectors and energy carriers, with a focus on competition and complementarities between energy technologies. Both are, what ATEsT calls, “hybrid, bottom-up” models. *Hybrid* refers to models explicitly addressing environmental issues, in the case of TIMES and LEAP all energy related greenhouse gas (GHG) emissions and ambient air pollutants. *Bottom-up* models are defined as technology-oriented models, using highly disaggregated data to describe energy end-uses and technological options in detail, whereas the macro-economic background remains exogenous. They treat energy demand as either given, or as a function of energy prices and national income. In TUMATIM-TIMES, the *reference* energy demand and fuel prices as well as technology data and costs are provided as exogenous inputs to the model. In scenarios (other than the reference) technology choices, energy prices[2] and energy service demand are computed by the model. In SEPIA-LEAP the degree of endogenization is fairly limited. The main macro variables provided as exogenous inputs are population and average household size, total floor area of commercial buildings, outputs of different manufacturing sectors (either physical outputs or indices) and number of passenger-km and freight-km. These activity levels,

[1] ATEsT = Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Energy Technology Information System.
[2] The least-cost solution yields estimates of energy prices (the so-called “dual” solution).

multiplied by energy intensities based on expert judgement, determine the useful and / or final energy demand in LEAP.

To solve the TIMES-TUMATIM model, one has to minimize or maximize an objective function (e.g. costs or consumer and producer surplus) under a number of constraints (e.g. a CO_2 emission reduction target). TIMES-TUMATIM selects among technologies and levels of demand for energy services based on their relative (lifecycle) costs, making it a powerful approach for short-term studies (e.g. what will the costs be of meeting a certain policy target?), especially where many technological options exist. SEPIA-LEAP uses built-in, non-controversial physical (energy) accounting relationships to allow for forecasting as well as backcasting analysis. For demand forecasting, LEAP does not optimize or simulate the market shares of technologies based on prices but simply analyses the implications of possible alternative market shares and / or activity levels. On the supply-side it does not – unlike TIMES – aim to find the least cost solutions, but uses accounting approaches to provide answers to "what-if" type of analysis under different scenarios (e.g. what will be the energy savings and emission reductions if one invests in more energy efficient, renewables based power plants?). This makes LEAP better suited for examining policy options that go beyond technology choices or hard to cost policy options. LEAP as a tool focuses at least as much on decisions support (including data and scenario management, reporting, units conversion, etc.) as is does on the actual modelling of the energy system. For this reason, SEPIA-LEAP is considered more a "tool" than a "model".

On a final note, it is important to realize that LEAP as a tool focuses at least as much on decisions support (including data and scenario management, reporting, units conversion, etc.) as is does on the actual modelling of the energy system.

2.4. CONSTRUCTION OF ASSIMILATED SCENARIOS

For the benefit of the FORUM members it was essential to provide meaningful comparisons between the results one could expect from TIMES-TUMATIM on the one hand and SEPIA-LEAP on the other hand. To achieve this VITO and UA had to run the TIMES model and the LEAP tool once more, but this time based on "similar" scenarios, the so-called "assimilated scenarios". Scenarios were defined as "*self-consistent storylines of how an energy system might evolve over time*" [Raskin (2005), p. 36]. In the TUMATIM project as well as in the SEPIA project a number of scenarios had already been built using either the TIMES model or the LEAP tool. The SEPIA project used a combination of backcasting (from desired future states of the Belgian energy system) and trend exploration (i.e. exploring how the future states could be brought about by strategically interacting with the exogenous long-term trends affecting the evolution of the Belgian energy system). The TUMATIM scenarios were built on the basis of varying the parameters which determine the outcome of the optimizing runs (e.g. discount rate, availability and penetration rate of technologies, etc.). These existing scenarios formed the basis for two "standard" assimilated scenarios.

The project team agreed to use the "scenario axis approach", according to which a set of key driving forces is identified and the driving forces regarded to be most important and most uncertain in their future development form the axis or dimensions of a matrix, determining the overall logic of the scenario storylines [Bishop et al. (2006)]. The three dimensions withheld for the FORUM assimilated scenarios were: 1) behavioural evolution; 2) technological progress (including the role of flow renewables); and 3) the international and economic context. The standard assimilated scenarios can be summarized as follows:

- A behaviour-optimistic / techno-moderate scenario [B++/T+]. This scenario is characterized by 1) a strong and rapid transition to a sustainable (carbon neutral) lifestyle with a high environmental awareness of all actors involved, whereas 2) technological progress (innovation) is gradual and less intensive as compared to the alternative (B0/T++) scenario, with moderate use of domestic flow renewable energy sources (RES) and relatively limited biomass potentials; and 3) geopolitical uncertainties manifesting themselves in the shape of limited imports of 2nd generation biomass and biofuels, combined with a gradual increase to (still) relatively moderate world fossil fuel prices, and high regional carbon taxes;

- A behaviour-neutral / techno-optimistic scenario [B0/T++]. In this scenario there is 1) a rather slow evolution to a relatively low sustainable way of living, but with 2) a rapid and all-encompassing technological progress (accelerated innovation), with a high potential of domestic flow RES; and 3) high international cooperation with few geopolitical tensions, manifesting itself through large imports of 'green power', combined with a gradual increase to high world fossil fuel prices, high carbon value and with a global emission trading system (ETS) in place.

All assimilated scenarios assume a -80% reduction of GHG by 2050. For SEPIA-LEAP this target in both scenarios applies to the Belgian level, whereas in the TIMES-TUMATIM version of B++/T+ the -80% by 2050 in the EU target is interpreted as a –58% target for Belgium, this being the cost efficient reduction when using the Pan European TIMES model. In the Pan European model the energy systems of thirty countries are modelled separately, and then synthesized by allowing trade of energy commodities among the countries [Intelligent Energy for Europe (2009)]. Also, growth of GDP and demographic growth are supposed equal. International shipping and aviation are not taken into account.

Table 1: Overview of the scenarios (bold=mostly used for comparison).(*)

Scenario name		CO_2	Technology	Behaviour
SEPIA-LEAP	**B++/T+**	-80%	Moderate	Optimistic
	B0//T++	-80%	Optimistic	Neutral
TIMES-TUMATIM "pure"	B-/T++ Reference	No limit	Endogenous & Optimistic	GEM-E3 output
	B-/T++_58%	-58%		Endogenous
	B-/T++_70%	-70%		Endogenous
TIMES-TUMATIM "Emulated"	**B0/T++_58%_TAX**	-58%		Final energy like SEPIA via *tax*
	B0/T++_58%_ELA	-58%		Final energy like SEPIA via *more elastic energy services demand*

(*) All scenarios assume no nuclear, and yes carbon capture and storage (CCS), although the latter is limited in SEPIA-LEAP.

It was further agreed that VITO should run two versions of the B0/T++ scenario with the TIMES-TUMATIM model, whereas UA should run only one version of the B0/T++ scenario with the SEPIA-LEAP tool. The B++/T+ scenario should / could only be run with the SEPIA-LEAP tool.

The pure SEPIA-LEAP version of the B++/T0 scenario shows the strengths of LEAP, in particular taking into account behavioural changes (evolution to a more carbon neutral lifestyle). This version strictly adheres to the SEPIA-LEAP methodology, where choices concerning lifestyles and technologies are explicitly made by stakeholders and scenario builders and where LEAP merely serves as a decision support tool. LEAP only quantifies and visualizes choices, and assures that they are consistent (energy accounting).

The pure TIMES version shows the strengths of the TIMES model. These scenarios are called B-/T++ because the energy service demands increase in the time span of the analysis up to 2050. There are three "pure TIMES" scenarios: "B-/T++ Reference", "B-/T++_58%" and "B-/T++_70%" and they are called "pure" because there is no extra mechanism in the model to alter the level of the use of energy service demand. Within the constraints of the assimilated scenario and additional constraints as deemed necessary within the TIMES framework, TIMES uses cost optimisation to determine the technology choices and pathways. The SEPIA-LEAP version of B0/T++, as determined by stakeholder choices and expert knowledge, basically consists of an 'electric economy' by 2050, founded on mostly wind & solar energy. Finally, in the TIMES-TUMATIM emulating the SEPIA-LEAP B0/T++ version, TIMES tries to mimic (emulate) the demand level reductions of the SEPIA-LEAP version, essentially by altering the assumptions regarding either prices or price elasticities. It was deliberated that the levels of energy demand end use had to be 30% below the levels of the TIMES-TUMATM reference scenario in 2050. In the TUMATIM B0/T++_58%_TAX assimilated scenario increased prices for energy services (up to three times higher than the prices in the TIMES Reference scenario) are introduced, as a result of which the end use of energy services sufficiently decreases (given a price elasticity of -0.3). In the TUMATIM B0/T++_58%_ELA assimilated scenario version the price elasticity of energy services demand is assumed much higher than in the standard TUMATIM-TIMES version, namely -1 instead of -0.3 (given the energy prices of the reference scenario). Setting the price elasticity at a value of -1 was necessary to emulate demand reductions similar to those of the SEPIA B0/T++ scenario. Technology choices are endogenous in all TUMATIM scenarios, assuming optimistic technology potentials, although limited to a certain extent.

The modus operandi as described above had two main advantages. It allowed to demonstrate to the FORUM members the strengths of both approaches (cost optimization of technology choices in TIMES, and participative scenario building while emphasizing behavioural changes in LEAP). It was also to be expected beforehand that the results of the (pure) TIMES results of the B0/T++ scenario ("Low Demand" and "High Elastic" versions) would be strikingly different from the (pure) SEPIA-LEAP results for the same scenario, thus further emphasizing the differences between the two approaches. In all instances, one has to keep in mind that these models or tools form part of a broader context (as explained in the final reports of the TUMATIM and SEPIA projects).

2.4.1. THE ASSIMILATED SEPIA-LEAP B++/T+ STORYLINE

In this pure SEPIA-LEAP storyline there are substantial behavioural changes. Demolition and retrofit rates are high, as are compact housing and urban densities by 2050. Local heat and power grids become facts of life. To satisfy their heat demand extreme low energy buildings use a mix of solar thermal energy, electric powered ground heat pumps and in particular biomass based district heating (CHP). Buildings generate electricity from integrated building PV. Awareness limits number and use of electrical appliances. Energy efficiency of appliances is high. There is a significant shift from (energy intensive) industry to a service economy [a lower contribution of energy intensive industries to the economy (GDP) and an increasing share of high-value added services]. Most low process heat in industry is generated by a mix of biomass and natural gas based CHP, used at its highest potential. Urban motorized passenger transport is restricted (with a modal shift to non-motorized transport), and based on a mix of 2nd generation biofuels, hybrid electric vehicles [ICE + EM] [3] and battery EV. Interurban passenger transport shifts significantly to (electric) rail and electric buses. Freight transport growth is limited. There is a significant shift from freight transport to all electric rail transport. Electricity in main power plants is mostly generated from domestic renewable energy sources or RES (mostly wind) and natural gas CCGT in combination with CCS. Nuclear power is phased out as planned and not replaced. Coal is rapidly phased out. Biomass for power generation is limited to local CHP for buildings and industry, although there may be limited use of (small scale ST) biomass power generation in the transition period. Petroleum refineries are gradually being replaced by domestic based (local) bio-refineries.

2.4.1. THE ASSIMILATED PURE TIMES VERSION B-/T++:

After Copenhagen, the EC proposed to reach a 30% reduction of GHG emissions in the EU by 2030. For 2050 an 80% reduction by 2050 is in line with the European commitment to limit global warming to 2°C max. The Belgian TIMES model is used to explore the climate policies required to reach these targets. The differences with SEPIA-LEAP are that 1) in TIMES the outcomes of GEM-E3 from the TUMATIM project are used to determine energy service demand in the reference scenario, and 2) the TIMES model (rather than expert scenario builders as in SEPIA-LEAP) chooses the (cost) optimal set of technologies. In order to correctly estimate the reduction of the use of energy services, TIMES-TUMATIM needs to compare choices and prices with a reference scenario (i.e. a scenario without climate policy). In this reference scenario and given the demand functions for energy services, TIMES optimizes the choice of energy processes, the energy efficiency, the choice of fuel by the energy users as well as the choice of energy production processes by the energy sector. These choices are based on information on the present and future availability of energy technologies, their costs and performance at the level of the energy consumer and at the level of the energy producer. It is clear therefore that the energy path as derived from this optimisation process takes into account all the no-regret options and may therefore slightly underestimate the real growth of the energy demand. Other criteria besides cost minimisation driving consumer behaviour are not reflected in this reference. In the climate policy scenario, TIMES decides how to reach the climate change policy target. The model not only provides the optimal way to reach the GHG reduction target but also their implications

[3] ICE = internal combustion engine; EM = electric motor.

for Belgium in terms of (energy system) costs. The Belgian TIMES model thus explores both the impact *on* the emissions (target) as well as the impact *of* those emissions (in terms of costs).

2.4.2. THE SEPIA-LEAP B0/T++ STORYLINE

In the SEPIA-LEAP version of B0/T++ there is limited change in behaviour. Urban planning and passenger transport as well as activity levels in industry and services follow the "business as usual" (BAU) path. The transition to extreme low energy buildings is gradual rather than rapid. Energy efficiency levels are very high for all technologies, approaching their technical limits. By 2050 the economy is almost completely "electrified" [electric economy], with the exception of high process temperature demand in industry and (part of) heavy freight road transport. Extreme low energy buildings use electric powered heat pumps and solar thermal at the highest potential. Biomass is not used for heat demand in buildings. Buildings (auto) generate electricity by means of building integrated PV. Smart grids are established by 2050. Accelerated technological innovation allows electrical process heating in industry, as a supplement to low process heat generated by CHP. Passenger transport is fairly high but almost completely electrified (battery electric vehicles, with some hybrid EV in the transition period). Automotive batteries add to the power generating capacities. Due to dematerialisation growth in freight transport remains modest. Heavy duty vehicles (HDV) still rely on diesel in high efficient vehicles. Freight rail is completely electrified. Electricity is generated mostly by RES, both domestic and through large scale imports (North-Africa, Middle-East). Natural gas in combination with CCS is used as backup only. Existing nuclear is extended (to allow building the infrastructure needed for the electric economy) but not replaced. Coal is gradually phased out. Large scale energy storage and HVDC transmission lines are in place by 2050. CHP is mostly limited to industry, and based on an even mix of natural gas and biomass. Petroleum refineries main activities shift to production of diesel (freight road transport) and in particular 'feedstocks' for chemical and other industries.

2.4.3. THE ASSIMILATED TUMATIM SCENARIOS B0/T++, EMULATING THE B0/T++ LEAP

Both the vision for 2050 and the transition paths were to be implemented in TIMES. By restricting the model concerning certain energy uses and technology choices, TIMES can in principle simulate the transition paths derived from the SEPIA-LEAP B0/T++ scenario definition. Because the way energy technologies and sectors are represented is not completely similar in the two models (TIMES-TUMATIM and SEPIA-LEAP), the exercise could have focused on bringing in line the transition paths at the level of technology groups. However, it was not considered very interesting to fully calibrate TIMES with the overall scenario assumptions of the SEPIA-LEAP B0/T++ storyline.

Alternatively, it was decided to only calibrate the final energy of TIMES with LEAP. An interesting result of this exercise are the shadow prices of the extra constraints. The model can tell how much (Belgian) society loses in terms of welfare costs by for example restricting the energy service demand. An open question is whether this reduced demand would still be in line with the overall assumption of GDP since end-use demand tends to be correlated with GDP.

2.5. ADJUSTMENTS AND COMPARISON OF THE ASSIMILATED SCENARIO RESULTS

During the FORUM meetings the members were given the opportunity to comment on the assimilated scenarios and on the quantitative results obtained from re-running the TIMES-TUMATIM and SEPIA-LEAP models. Both comments as well as detailed comparisons of the outputs are presented in this chapter.

Before proceeding with the comparison, it should be made very clear that all FORUM members acknowledged that the FORUM cluster project was principally about a user analysis of methodologies, and that the actual results of the scenario analysis should not be considered all that relevant. Furthermore, the FORUM specifically requested to compare the results of both approaches on carefully selected 'key indicators' – e.g. energy demand in different sectors, penetration of different energy supply options, shares of fuels etc. The members also demanded to point out those results that diverge significantly and to explain these divergences.

2.5.1. DRIVING FORCES – MACRO-ECONOMIC ACTIVITY LEVELS

Table 2: TIMES/GEM-E3 macroeconomic projections for Belgium and international energy prices as used in TIMES-TUMATIM.

	Population	GDP	Crude oil	Natural gas	Coal
Year	%/y	%/y	€$_{2005}$/GJ	€$_{2005}$/GJ	€$_{2005}$/GJ
2010			8,84	4,2	2,43
2015	0,7	1,9	9,67	5,09	3,31
2020	0,6	2,3	12,85	6,97	4,3
2025	0,5	2,3	15,06	8,54	4,96
2030	0,5	2,2	16,01	8,94	5,08
2035	0,4	2,1	16,75	9,5	5,11
2040	0,4	2	17,53	10,11	5,14

	Population	GDP	Crude oil	Natural gas	Coal
2045	0,3	1,9	18,34	10,75	5,17
2050	0,3	1,9	19,2	11,43	5,19

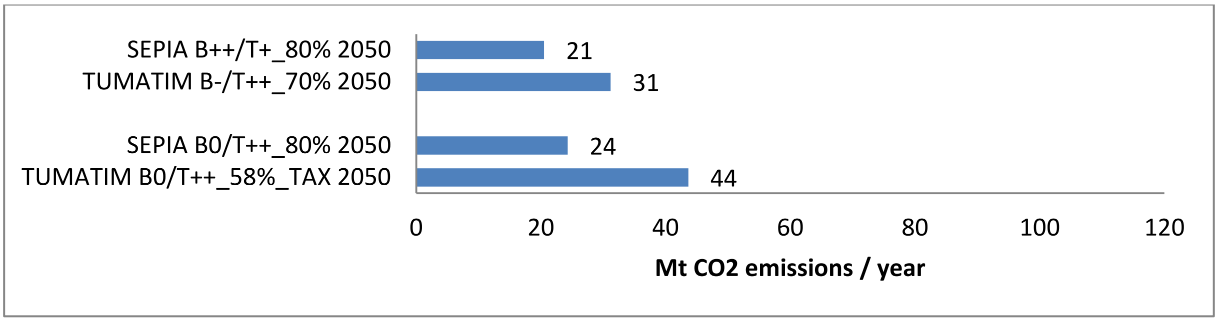
Source: Benoot et al. (2011)

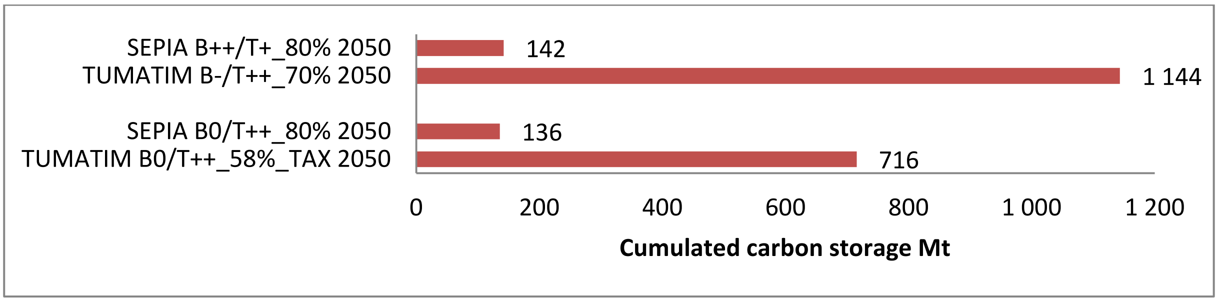
It was agreed beforehand that all runs should use the same assumptions regarding population and GDP growth. UA – lacking a macro-economic component in SEPIA-LEAP – usually refers to preceding exercises performed by other research teams. In the SEPIA-LEAP project a study from KU-Leuven and VITO carried out for BELSPO was used (Van Regemorter et al., 2007). The rationale is that those hypotheses had already been discussed with stakeholders or other relevant actors and are therefore deemed plausible by (most) scenario builders. The FORUM pointed out the possibility of using the projections of either the Federal Planning Bureau (FPB) or of the ones employed by TIMES/GEM-E3. The FBP has projections of the population until 2060, whereas GDP projections go to 2015 after which a certain constant yearly percentage growth is assumed [FPB, 2008; FPB, 2011]. Given that for VITO the TIMES/GEM-E3 assumptions would be ideal and the fact that their application posed no real problem for UA, it was decided to use the TIMES/GEM-E3 projections.

2.5.2. Greenhouse gas emissions

It was confirmed during the first FORUM meeting that the main objective in all scenarios would be to reach a -80% GHG reduction in Belgium in 2050 as compared to 1990 levels. However, in the TIMES-TUMATIM scenarios, with the exception of the "Nuclear No, CCS Yes -70%" scenario, this was interpreted as -80% at the EU level, where the cost efficient allocation of the reduction between the EU countries implies a reduction target of -58% for Belgium in 2050 compared to 2005 levels.

Figure 2: Comparison of CO_2 emissions and cumulated carbon storage [Mt]





Emissions relate to CO_2 only, excluding other GHG. The -80% reduction in SEPIA-LEAP are relative to energy-related CO_2 in 1990 (excluding all other GHG and also excluding non-energy related CO_2 emissions).

The striking difference in cumulated carbon storage is mainly due to the fact that CCS in TIMES-TUMATIM is chosen as cost efficient and in some scenarios is used up to its maximum value of over 1000 Mt cumulative.

2.5.3. Activity levels in the scenarios

The FORUM wondered how – in the SEPIA-LEAP B++/T+ scenario – the assumption that the Belgian economy is evolving towards a service-based economy is modelled precisely? UA replied that this evolution is measured in a semi-qualitative way. It is assumed that the overall level of economic growth (in terms of GDP) is the same in all the scenarios considered. If there is less growth in energy-intensive industries, then there has to be a compensating growth in the overall activity levels of the service sectors. In SEPIA-LEAP, those activity levels are linked to the floor area of commercial buildings. Additional assumptions on building shells, heating and cooling technologies, etc. consequently lead to the final energy demand for the service sectors. Upon which the FORUM expressed the desire to show in the final results just how much lower or higher the activity levels in the services sectors are compared to the B0/T++ scenario. As a result of the FORUM demands, it was decided that future versions of SEPIA-LEAP should aim to improve the consistency and the quantification of the links between activity levels of the subsectors and overall economic growth.

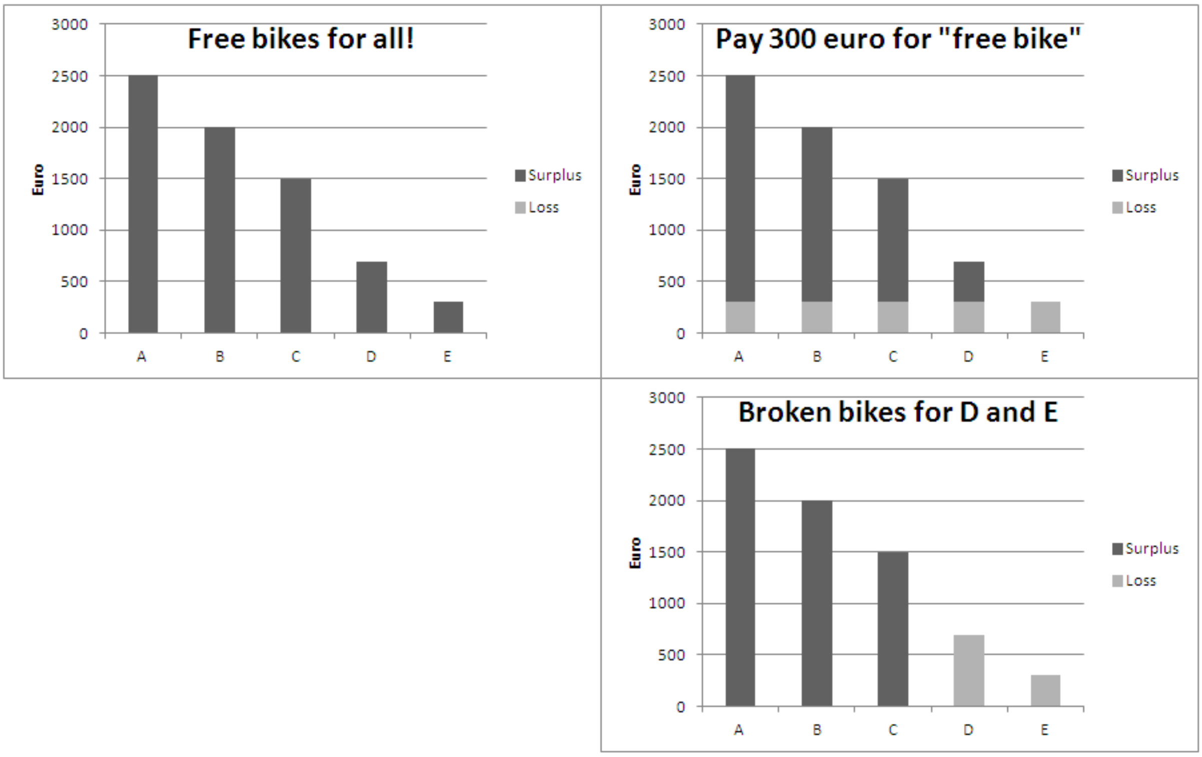
Table 3: Comparison of activity levels in 2050

	Unit	TUMATIM low demand minus 58%	SEPIA B++/T+ minus 80%	TUMATIM no nuclear yes CCS minus 70%	SEPIA B0/T++ minus 80%
Services floor area	[M m²]	...	259,707	..	234,217
Industry Iron and Steel demand	[Mt]	6,740	-	8,473	6,173
Industry Ammonia demand	[Mt]	0,777	0,927	0,977	1,515

Industry Copper demand	[Mt]	0,271	..	0,352	..
Industry Cement & Lime demand	[Mt]	1,938	7,326	12,518	11,834
Industry Glass demand	[Mt]	3,736	1,494	4,541	1,725
Industry Paper demand	[Mt]	1,508	1,771	1,956	2,007
Passenger transport	[M p-km]	131,014	155,781	170,153	265,649
Freight transport	[M t-km]	102,450	83,343	134,215	119,768

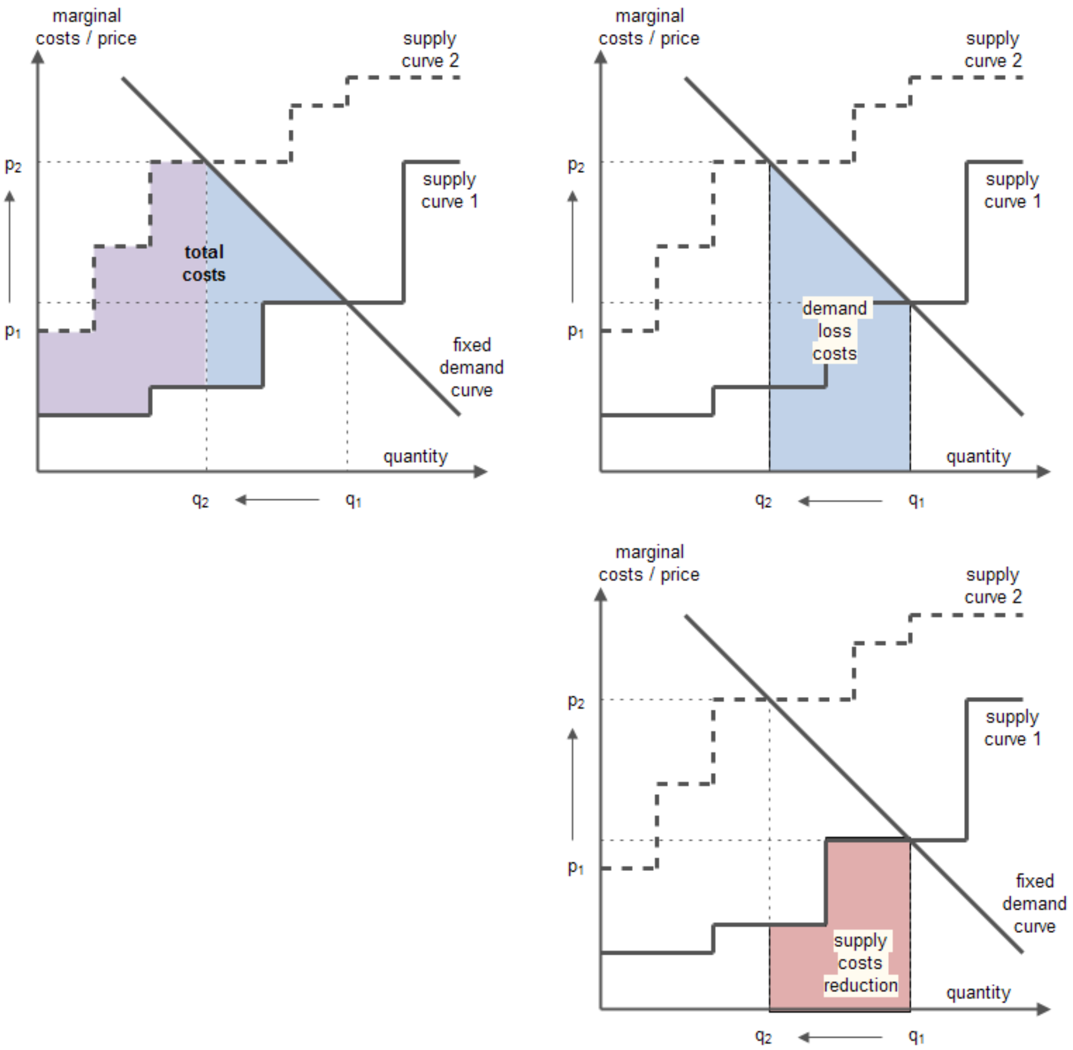
The most controversial theme during all three FORUM meetings however was without any doubt the concept VITO calls "*lost demand cost*" or simply "demand loss". The FORUM is intrigued by the fact that when TIMES-TUMATIM emulates the SEPIA-LEAP results a shift to a service economy or a reduction in activity levels (e.g. mobility in terms of passenger-km) is considered a welfare loss, esp. since the basic assumption is that in none of the assimilated scenarios income per capita changes. Moreover, in studies for the European Commission (EC) decreased demand leads to negative costs (i.e. benefits), e.g. less dependence on fossil fuels, improved health, etc. [European Commission (2009a)]. VITO explained that the concept of 'lost demand cost' as adopted (and for the first time represented in the results in an explicit way) in TUMATIM-TIMES covers only the non-beneficiary aspects of lower energy demand to the economy. They represent the costs of non-fulfilled demand – i.e. they reflect the overall willingness-to-pay of consumers to raise their energy consumption levels back to the level of the TUMATIM reference scenario (sometimes called compensated income methodology).

Figure 3: Illustrating the concept of "demand lost cost" in TIMES-TUMATIM



VITO tries to further elucidate the concept with the use of analogies. Example 1. After having booked a holiday in an exclusive hotel somewhere, tourists are put in another hotel because the original hotel is overbooked. In spite of the fact that it is still the same beach and the same weather and the same holidaymakers on the beach etc., the displaced tourists are not as happy as they would have been because they are disappointed in (some of) their expectations. It is similar with TIMES-TUMATIM, because TIMES-TUMATIM always relates to a certain reference scenario. The concept of (loss of) consumer surplus is not captured in the "income per capita" indicator. Example 2 (figure 3) A manufacturer of electric bikes gauges the "willingness to pay" for such bikes among a number of consumers (say A, B, C, D and E). If at first the producer decides to give the bikes away for free, the "consumer surplus" is given by the sum of the "willingness to pay" by all consumers (or in this particular example 7000 €.) If the producer changes his mind and decides to fix a price of 300 € per bike, the consumer surplus is reduced (to 5500 €), and there is a loss of consumer surplus (equal to 1500 €). Finally, if consumer D and E are somehow prevented from using the electric bike (e.g. because their bikes got broken in a crash), the "demand loss" is defined as the sum of the willingness to pay by consumers D and E (or in this case, 1000 €).

Figure 4: Costs in TIMES-TUMATIM



In TIMES the costs (and benefits) calculations in a particular (climate policy) scenario are always relative to another scenario (in principle the "reference scenario"). The Implementation of climate change policies results in the "forced" use of more expensive energy production technologies. This leads to higher energy prices. Given a fixed demand curve, increasing energy prices in a climate policy scenario relative to the reference scenario imply a reduction in demand, and thus "lost demand costs" (as defined above – the "willingness to pay" for the lost demand). The total (extra) increase in energy production costs is partly compensated by a reduction in production costs (of the reference scenario) ,i.e. costs of energy production no longer needed because of the reduction in demand (in the climate policy scenario). The latter have to be subtracted *from the demand lost costs*. Costs in TIMES-TUMATIM are thus the sum of demand loss (as defined above), production costs increase and (negative) production costs no longer needed because of demand reduction.

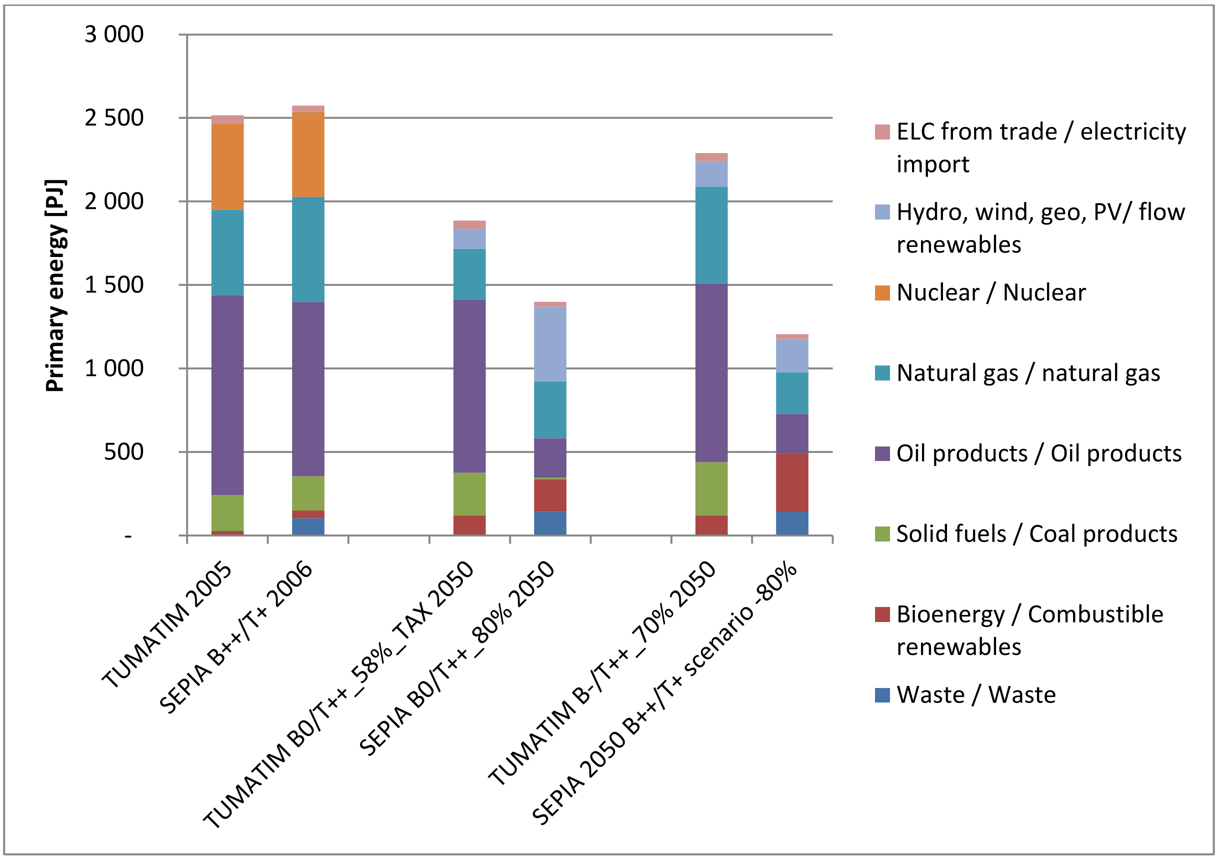
The FORUM responds that this kind of reasoning or assessment of people's expectations makes sense in a behaviour-neutral or “B0” scenario, but not scenarios where behaviour (and possibly also people's expectations) can and will change.

2.5.4. TOTAL PRIMARY ENERGY SUPPLY (TPES)

In terms of potentials (of e.g. flow renewables or biomass) the FORUM stressed the need to clearly distinguish between physical and technical potentials on the one hand, and social-political-institutional potentials on the other hand. For example, in the case of biomass, if all (even only currently known) sustainability criteria are taken into account, the social-institutional potential is markedly lower than the technical one. The project team agreed and stated that as far as technical (maximum) potentials are concerned, both UA and VITO would use the same upper limits (based on the opinions of experts), but that as a matter of fact – depending on the methodology used – the 'sustainable' potentials may be substantially lower. As a result, the original scenarios of the SEPIA-LEAP project, in which biomass played a very prominent role, were adjusted (less prominence of biomass) to better meet the terms of the FORUM members.

At least one FORUM member showed deep concerns regarding the large imports of “green electricity” in the B0/T++ scenario. He insisted that energy security is a vital component of energy policy. Moreover, in terms of policies, it is essential to know what Belgium or its regions are capable of accomplishing. A policy where most electricity is imported is therefore not very useful. In reply, other FORUM members pointed at the limited potentials (of renewables) in Belgium, and at the relevance of the international offshore electricity 'Supergrid' project [OffshoreGrid (2011)]. The FORUM furthermore suggested that in terms of imports, technical limits, both for electricity and gas, had to be taken into account. Another suggestion was that it might be useful to make a distinction between imports from within and outside the EU. The project team responded that – given limited time and budget – the purpose of re-running TIMES-TUMATIM and SEPIA-LEAP in the FORUM project was not presenting the scenario results by themselves, but rather showing the FORUM members the differences and the weaknesses and strengths of two entirely different approaches (see also chapter 3). But as a result of the FORUM demands, SEPIA-LEAP was adjusted to pay more attention to energy imports.

Figure 5: Comparison of primary energy supply in Belgium in 2050



Firstly, one should note that TIMES-TUMATIM uses 2005 as base year, compared to 2006 in SEPIA-LEAP. Secondly, in SEPIA-LEAP, the energy consumption and production levels in the base year are determined by breaking down the IEA energy balance for Belgium in that particular year. This top-down approach ensures that the reconstruction of the energy balance in the base year exactly matches the actual energy balance. TIMES-TUMATIM however has to reconstruct the energy balance from a bottom-up approach, making it very difficult to exactly replicate the given energy balance in a certain year. Thirdly, SEPIA-LEAP uses the IEA energy balance for Belgium as a starting point, TIMES-TUMATIM uses Eurostat and national data. And lastly, definitions of energy flows and products are different in both approaches. “Industrial waste” in the IEA energy balance and therefore also in SEPIA-LEAP includes very specific energetic “waste flows” (co- products) in chemical and petrochemical industries, which are probably considered “oil products” in TIMES-TUMATIM. The use of natural gas seems underestimated in TIMES-TUMATIM, because even in the base year, energy use is determined endogenously by the model.

In the SEPIA-LEAP scenarios the primary supply of combustible renewables, most notably in B++/T+, seems overly optimistic (in spite of slight adjustments of the original SEPIA-LEAP scenarios). This was already a point of contention in the final evaluation of the SEPIA project. In that respect, the level of bioenergy supply in TIMES-TUMATIM looks far less controversial.

As compared to SEPIA-LEAP, the supply of fossil fuels, in particular oil products and especially coal, are relatively high in 2050 in the TIMES-TUMATIM scenarios. In fact, coal consumption even increases in TIMES-TUMATIM. The choice for coal, by explicit assumption almost entirely excluded in SEPIA-LEAP, is inspired by its relatively low costs compared to the alternative electricity production technologies in TIMES-TUMATIM. However, looking at figure 5, it would not be correct to state that biomass in SEPIA-LEAP has the same role as coal in TIMES-TUMATIM, because combustible renewables in SEPIA-LEAP are mainly used in local CHP for both industry and buildings, and not so much for the main production of electricity. The high prevalence of oil products in TIMES-TUMATIM is related to the relatively low shares of biofuels as well as electric vehicles in transportation vis-à-vis the SEPIA-LEAP scenarios, although there is a relatively high rate of electrification in passenger mobility. Finally, in the "B0/T++" scenarios, supply of natural gas is very similar, whereas in the "B-/T++_70%" scenario its share far exceeds the one in B++/T+. One reason for this may be the replacement of (some) gas fuelled CCGT by biomass powered CHP in B++/T+, although one should also keep in mind that total TPES is significantly lower in the SEPIA-LEAP scenarios.

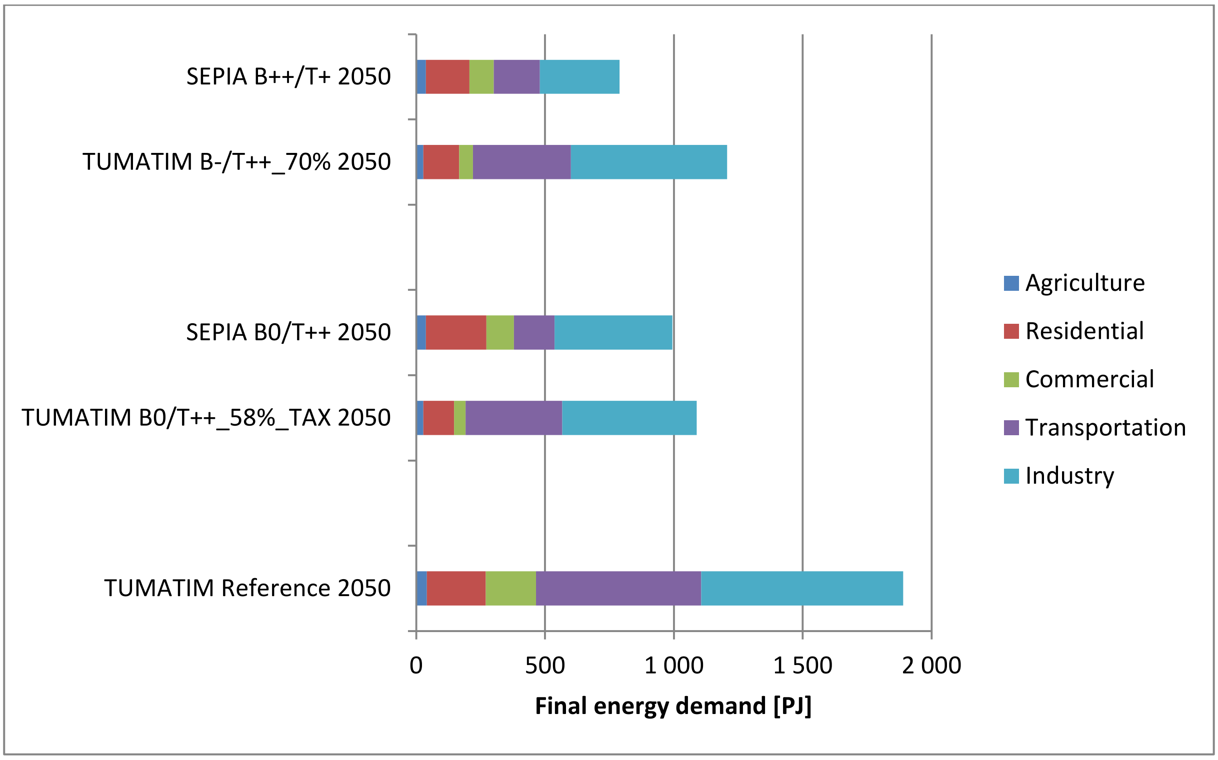
As for flow renewables, all scenarios are more or less in agreement, with the one exception of B++/T+, in which SEPIA-LEAP assumes that fast and drastic technological breakthroughs will rapidly lead to a flow renewables based electric economy. Such a scenario is excluded in the corresponding TIMES-TUMATIM scenario, where CCS plays an important role, the import of biomass is limited and the potential of offshore wind capacity is only 3 GW_e compared to 17 GW_e in LEAP.

2.5.5. ENERGY SERVICES DEMAND AND FINAL ENERGY CONSUMPTION

The FORUM members were particularly interested in the specification of *price elasticities* of energy demand in the TIMES model. In the partial equilibrium model TIMES price elasticities link the energy system to all actions outside the energy system (including changes in lifestyle, urban planning, voluntary actions in industry, etc.). In reply to where these elasticities originate from, VITO clarified that they are based on an analysis of historic data within the TUMATIM project and other projects (the TUMATIM final report gives an overview of the literature for transportation price elasticities). VITO also agreed with a suggestion made by a FORUM member that it would be interesting to calculate price elasticities based on the output of a macro-economic model such as GEM-E3 (co-developed by KU-Leuven). and added that given the existing collaboration between VITO and KU-Leuven within the TUMATIM project it should not prove difficult to follow up on this. VITO promised to check the usefulness of this suggestion. Two other questions were: "Is the price elasticity of energy demand constant over the entire modelling horizon in the TIMES model runs?" and "Are different elasticities used for different energy demand sectors"? VITO answered that in principle different price elasticities could be used for different time horizons, but that VITO would not be doing so in this particular project. VITO confirmed that elasticities are different for different energy demand sectors, but claimed that historic data show that demand in all sectors is quite inelastic (elasticities of about -0.3 are quite common).

Another topic the FORUM gave a great deal of attention was the role of *shadow prices* in the TIMES model. Answering the question whether one will see the shadow prices of reduced energy service levels in the TIMES model runs, VITO explained that when emulating the SEPIA-LEAP B++/T+ assimilated scenario, a lot of additional constraints have to be built into the TIMES model. Some of those constraints are put on technological developments, others on energy service demand levels. The comparison to the reference TIMES model run and the shadow prices of the additional demand constraints should hopefully give a better view on the magnitude of "welfare loss" belonging to the different changes. Referring to the no regret options, the FORUM wanted to know if it is conceivable to have negative shadow prices in the TIMES model runs? The answer by VITO was: no, not in principle. A negative shadow price would indicate that this option should have been chosen by TIMES as part of the cost-optimal solution. Negative shadow prices can only result from constraints put in by the user in order to make the model results more realistic (e.g. in reality additional insulation in existing houses can only be installed gradually, whereas the 'unconstrained' TIMES model might conceivably decide to install additional insulation in all existing houses in just one single year). The fact that the no-regret options in the TIMES model do not appear to be no-regret options in the real world can be explained by 1) costs that were not included in the model; or 2) higher discount rates in sectors that are less cost driven, like households and services. The second problem can be solved within the TIMES model by including a higher sector specific discount rate.

Figure 6: Comparison of final energy demand in Belgium in 2050



First and foremost, in terms of overall final energy demand, all scenarios seem to agree on the feasibility of fairly large reductions by 2050.

In the TIMES-TUMATIM scenarios, and especially in "B0/T++_58%", final energy demand in the residential sector in 2050 is markedly lower than in the SEPIA-LEAP scenario. This would indicate that the penetration of extreme low energy dwellings by 2050 is deemed not only feasible but also very cost-effective in TIMES. For commercial buildings the higher energy consumption in SEPIA relative to TUMATIM, and particularly in B0/T++, is not only related to less optimistic assumptions regarding a rapid adoption of extreme low energy dwellings, but also and predominantly to an assumed structural shift from an energy-intensive industrial economy to a more services-based economy.

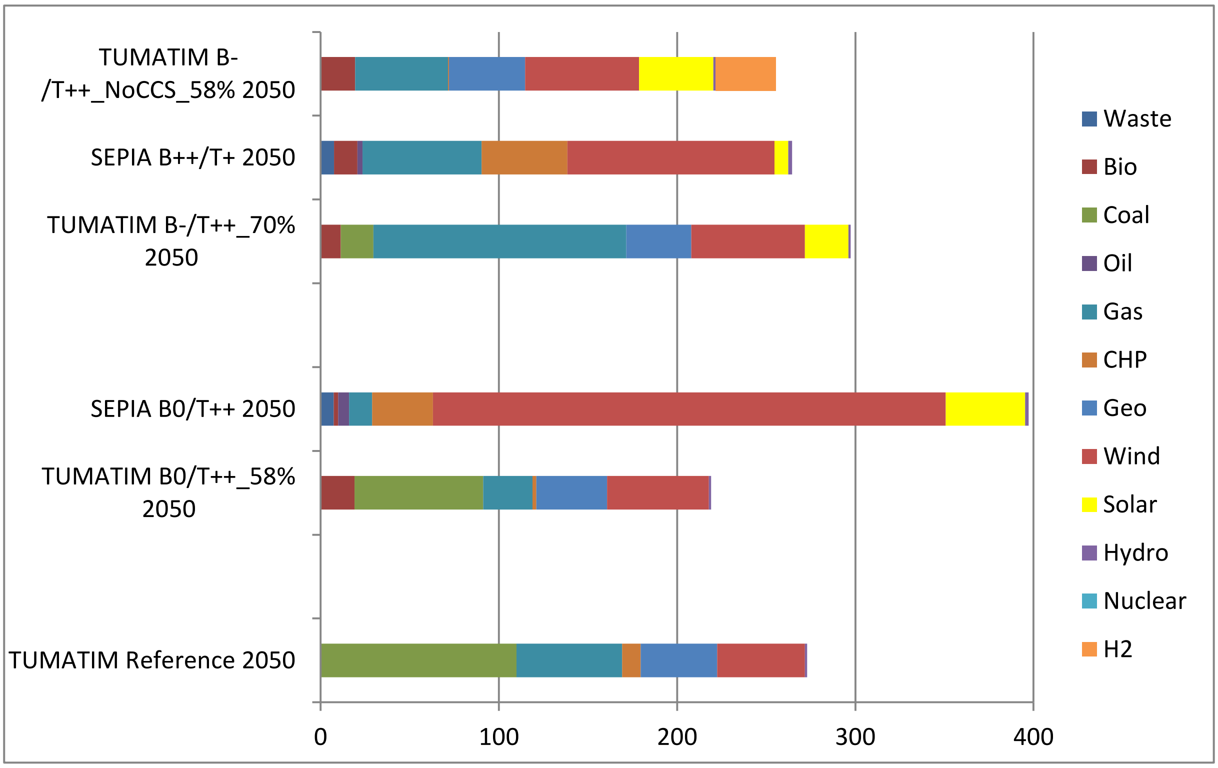
The main differences in final demand between TIMES-TUMATIM and SEPIA-LEAP stem from transportation. In SEPIA B0+/T++ the whole economy, including and perhaps even predominantly the transportation sector, becomes electrified. In SEPIA-LEAP B++/T+ behavioural changes and a shift to a more "local economy" in combination with a mix of biofuels and electric vehicles is responsible for a notable decrease in energy demand. Electric vehicles in particular are assumed to be very energy efficient compared to conventional internal combustion engines (ICE). This is in sharp contrast with TIMES-TUMATIM, where the freight transport is not electrified.

The TUMATIM "B0/T++" scenarios are very similar as far as industrial final energy demand is concerned. In SEPIA "B++/T+", the shift to services sectors in combination with closing down some very energy-intensive industries (in particular steel), leads to a drastic reduction of industrial final energy demand. Those assumptions were not replicated in the "B-/T++_70%" scenario.

2.5.6. Technology paths: electricity production

A suggestion was made by a FORUM member to seek inspiration in the (recent) EU technology roadmaps [European Commission (2009b)]. The usefulness of this idea was put somewhat in perspective by another member, stating that those roadmaps still rely predominantly if not almost exclusively on a techno-economic approach.

Figure 7: Comparison of electricity production in Belgium in 2050.



Total electricity production by 2050 in the different scenarios does not vary that much from the TUMATIM reference scenario, except for the SEPIA B0/T++ scenario, which explicitly assumes the evolution towards an all-out "electric economy".

At first sight the predominance of combustible renewables in SEPIA-LEAP compared to TIMES-TUMATIM does not seem to be reflected in the energy carrier shares of electricity production, where in fact the TUMATIM "Low Demand -58%" scenario seems to use more biomass than the corresponding SEPIA B0/T++ scenario. This is not entirely true however, because both SEPIA-LEAP scenarios rely heavily on CHP, based on a mix of natural gas and biofuels.

Already mentioned is the dominant role of coal in the TUMATIM "B0/T++_58%" scenario, whereas coal is totally absent in the SEPIA scenarios. It is true however that coal in the TUMATIM climate change policy scenarios, and "B-/T++_70%" in particular, is distinctly lower than in the TUMATIM reference scenario.

For natural gas a similar remark applies as for combustible renewables. Although natural gas use appears much lower in the SEPIA scenarios, part of it is contained in the CHP contribution in the SEPIA scenarios.

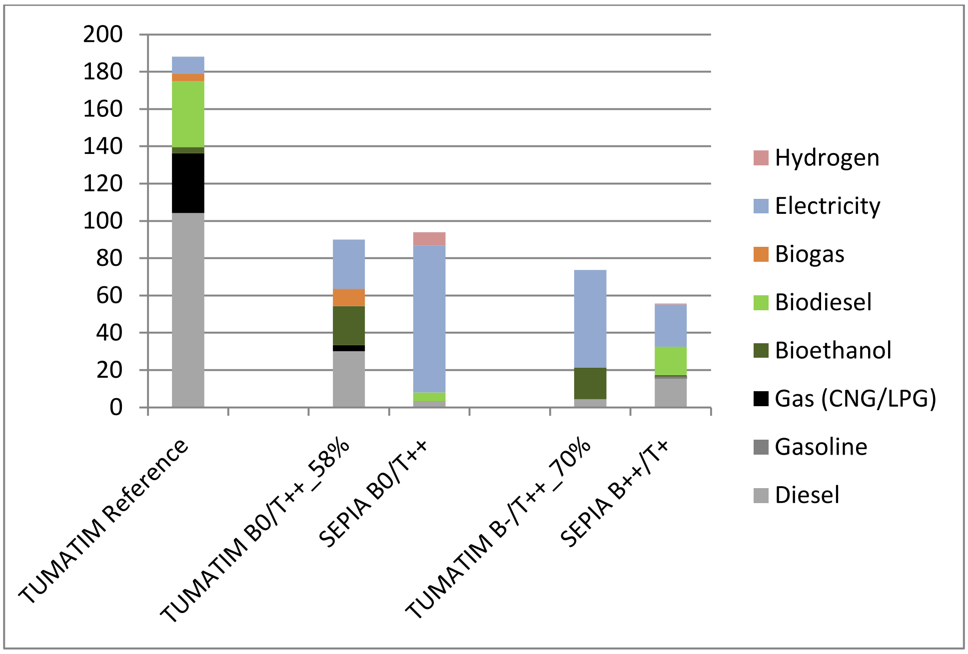
The biggest differences can be seen in flow renewables. Geothermal plays an important role in the TUMATIM scenarios. In SEPIA that specific technology was not considered (by the experts) as a viable option. The SEPIA scenarios are much more optimistic concerning the potentials of wind and solar energy, even in the less technology oriented B++/T+ scenario. It would seem that the experts consulted in the TUMATIM and SEPIA approaches had widely different opinions concerning those potentials. On the other hand, the choices from the TIMES model with regard to renewable energy depend largely on the assumptions on CCS, as can be seen in the "NoCCS" scenario on top of Figure 7.

2.5.7. TECHNOLOGY PATHS: PASSENGER TRANSPORTATION

In 2030 there is a fairly similar use of fossil energy in the sector of passenger transportation.

In 2050, the total energy inputs for passenger transportation is similar in both the "B0/T++" scenarios. The "TUMATIM B0/T++" and "SEPIA B++/T+" scenarios have a similar level of electrification. There is also a similar use of biofuels, although the commodity is bio-ethanol in TIMES whereas it is biodiesel in SEPIA. The electrification level of passenger mobility is strikingly high in the SEPIA B0/T++ scenario, even well above the level in TUMATIM B-/T++-70%.

Figure 8: Comparison of energy consumption for passenger mobility in Belgium in 2050



3. RESULTS

We discuss in depth the strengths and weaknesses of both approaches affecting the salience, credibility and legitimacy of the model results, as perceived by the FORUM members. The results, following the minutes of the meetings, are reported along the following lines. Firstly, what were the a priori expectations of the FORUM members regarding the use of models or tools? Secondly, how and to what extent did or rather can TIMES-TUMATIM and SEPIA-LEAP fulfil those expectations? And thirdly, how and to what extent can both approaches be improved to better meet the expectations; or alternatively, do policy makers have to adjust their expectations regarding what energy system models can and perhaps more importantly cannot do? We conclude with some additional observations concerning TIMES-TUMATIM not explicitly discussed during these meetings.

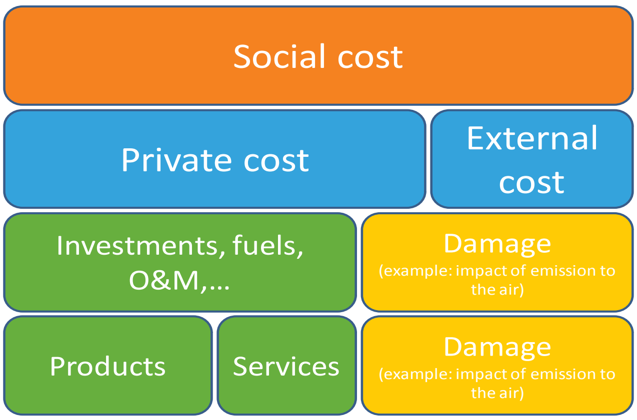
3.1. WHAT ARE THE A PRIORI EXPECTATIONS OF POTENTIAL MODEL USERS?

During the first FORUM meeting the members were confronted with three challenging statements, extracted from the survey on user expectations.

3.1.1. CONCERNING THE MINIMIZATION OF TOTAL SOCIAL COSTS

The first challenging statement laid before the FORUM members was whether: “Minimisation of total social costs is a good approach for developing sustainable energy pathways on the long term.”

Figure 9: the concept of social cost in the TUMATIM project



The project team first clarifies the concept of total social costs (TSC) as used in the TUMATIM project to determine the best technology mix from the perspective of society. The social cost is defined as the sum of both the private and the external costs (sometimes called total costs). External costs are per definition costs that are not borne by society although they have negative (sometimes positive) effects on society (like for example the impact of air pollutants). The more the damage costs enter the private costs, the smaller will be the external costs (see figure 9).

On the positive side, the FORUM members agree that minimization of total social costs (TSC) "can be used as a guiding principle", that it is "a beautiful idea and a precious indicator", and that it is "an important element that can give a reliable indication of how the energy system should evolve" and hence "can play a supporting role".

However, on the negative side, the FORUM members warn against a number of caveats. They point out that the statement is built exclusively on an economic premise, i.e. the economic valuation / estimation of external impacts. This raises two important issues.

A first issue concerns the difficulty or even impossibility of using this indicator in practice. There are other factors and impacts like impacts on poverty, on the fragmentation of territory[4] or on biodiversity whose economic valuation is very difficult or even impossible. Basing decisions on cost minimisation makes use of economic criteria in policy decisions exclusively. But there are other criteria, which cannot be represented by purely economic figures, that must also be utilized, including social aspects, equity, environmental impacts, public health, etc. You can take them into account, but there are high uncertainties involved, spanning many orders of magnitude. These orders of magnitude may make even general assertions such as "It is better to have a particular figure than no figure at all, because numbers can put things in perspective" very risky. In addition, one FORUM member warns against the ambition of modellers, claiming that TSC can never be the only element in the discussion, hereby referring to a recent incident where even the claimed (magnitude of) private costs of a certain stakeholder became the subject of heated discussions.

A second issue relates to the system boundaries. There are many different actors with different interests in and perspectives on the energy system. Whether as a stakeholder you are looking at the system from the outside or from the inside determines what costs are either social or private costs. Looking from the outside you can minimize total social costs. Looking from the inside, it is the interaction among stakeholders that determines which and to what extent social costs need to be minimized. This remark is illustrated by an example taken form the SEPIA project, where the requirement to realize

[4] division of spatial entities into smaller or less coherent pieces.

substantial GHG emission reductions put absolute limitations on what the energy system would have to look like. One can put limits on certain emissions, but e.g. industry (as an important group of stakeholders) could claim that they have already achieved substantial emission reductions. Where does that leave one with the results of a merely cost-based model? Also, some actors are not affected by total social costs. For example, minimizing TSC does not take into account access to basic energy services for the lower income groups, but this so-called "energy poverty" is an important issue for policy makers.

3.1.2. CONCERNING ACTIVE PARTICIPATION IN ENERGY SYSTEM ANALYSIS

The subsequent question was put forward to the FORUM members: "Active participation in energy system analysis is appreciated, but how can this be achieved in practice?"

The debate revolved mainly around the "tensions" between stakeholders and modellers. On the one hand, active participation needs a lot of work of the scientific team involved, preparing all the information with which the stakeholders have to be fed. On the other hand, it is claimed that existing groups representing stakeholders already have the necessary competences . Examples given are the CFDD / FRDD or the CCE / CRB[5]. But this argument is somewhat undermined by the fact that it is always the same people who get invited. It is difficult enough to get them engaged initially. To keep them engaged is even more difficult, because they are overburdened with requests. Also, the remark is made that representatives of organisms like CFDD/FRDO are usually called in after all the calculations have been done. Early involvement may improve the participation process. This is counteracted by the fact that CFDD/FRDO not only advises the federal authorities at the federal government's and parliament's request, but on its own initiative as well. A remark that it is very difficult to find a group of people with a deep understanding of the complete energy system is countered by giving the example of a recent CFDD/FRDO advice on bio-energy/-fuels. In spite of the obvious and huge complexity of the subject matter, a group of people were capable of producing an extremely valuable document, covering and reflecting on all the critical dimensions of the sustainability of implementing bio-energy/-fuels, and of relating which aspects are relevant to which types of actors.

[5] CFDD = Conseil fédéral du Développement durable; FRDO = Federale Raad voor Duurzame Ontwikkeling; CCE = Conseil central de l'Economie; CRB = Centrale Raad voor het Bedrijfsleven.

Some suggestions were made to resolve the problem. A reference was given to the 'Science-Policy link' consultation group within "De Lente van het Leefmilieu / Le Printemps de l'Environnement", where the suggestion was made that each government department may want to have (at least) one 'scientific officer', to bridge the gap between scientists and policy makers. Unfortunately, this never got beyond the stage of an idea. Another reference is "NL Agency", the Dutch contact point for businesses, knowledge institutions and government bodies, focusing on sustainability, innovation, international business and cooperation.

In conclusion, one has to find a balance between on the one hand active participation of the stakeholders (who per definition have their own specific and partial perspective on parts and aspects of the energy system), and on the other hand the scenario builders with greater expertise in understanding the energy system as a whole. In an abstract way scientists already recognize the large number and diversity of actors in the energy system, and how they relate to each other on economic and other dimensions. One has to take these ideas as a starting point in participation exercises and take them further to look at the implications.

3.1.3. CONCERNING BACKCASTING AND NARRATIVE SCENARIO BUILDING

The third and last challenging statement was formulated as: "Long term energy system analysis has to start from backcasting and narrative scenario building."

The project team first clarified that TIMES, in spite of sporadic claims to the contrary, can and occasionally does perform backcasting at a limited level, although not related to behavioural aspects. In reply to the question whether backcasting according to TIMES implies fixing the future values of certain variables, e.g. fixing the share of renewables in the long term future, it is confirmed that TIMES can indeed fix the values of future long term objectives.

It is agreed that long term objectives are important and necessary, and both narratives and backcasting can have great value in creating better insights into how society may transition to a (desired) future state, as long as the degree of internal logic is very high.

However, it may be difficult to put quantified long term policy objectives on everything, hereby referring to e.g. the Treaty of Lisbon or the Maastricht Treaty. The intriguing question is: "If 5 years ago modellers made a certain prognosis / forecast with regard to certain objectives, then how come their assessments haven't materialized?" To answer that question one requires knowledge of more than just the economic aspects. For scientists it is important to increase their body of knowledge to understand where those differences come from and thus enabling them to produce better models of reality. Socio-technical scenarios (STS) reflecting the high complexity of energy systems (composition and dynamics) can thus prove to be very useful.

3.1.4. Conclusions concerning user expectations

The three main conclusions drawn from the first FORUM discussion are:

- Minimization of total social costs are a valuable piece of information, but certainly not the only one, and uncertainties should always be clearly indicated;

- Active participation of stakeholders is difficult to achieve, but necessary;

- Long term objectives are important, and backcasting is an important tool but it should not be the only tool.

In the second FORUM meeting the members were asked to evaluate the TIMES-TUMATIM and SEPIA-LEAP approaches, based on the first results of the assimilated scenarios, and using the above mentioned conclusions as a reference.

3.2. Strength and weaknesses of both approaches

During the second FORUM meeting, the merits and limitations of both methodologies were thoroughly discussed.

3.2.1. The strengths of TIMES-TUMATIM

One of the core strengths of TUMATIM-TIMES is that it provides information on the costs of the energy transition for different demand sectors. Without information on costs, the likelihood that policymakers will actually implement the results of the modelling exercise are very slim. Because of the significance of cost information, the model users have to be very precise and meticulous in their communication on costs. One question to be addressed concerns the type of costs that are being calculated. Possible types include investments costs, overall system costs, shadow costs, macro-economic costs – being often much smaller (see e.g. study European Commission, etc.) Another questions is related to what constitutes an adequate base for comparison (e.g. reference scenario, compared to overall GDP, etc.) Moreover, it is important that the model users make sure that *all* costs are included. The FORUM refers to the principle of full social costing, with the inclusion of environmental and health effects.

Another strength of TUMATIM-TIMES is its ability to model the effects of price policies (e.g. subsidies, taxes, tradable green certificates, etc.), as well as the effects of standards and the implementation of targets.

Lastly, TUMATIM-TIMES models energy system development in an internally consistent way. Both energy demand and supply sectors are submitted to the same law of rational behaviour and hence adapt to each other in accordance with this law.

3.2.2. The weaknesses of TIMES-TUMATIM

The costs for new technologies up to 2050 are very uncertain. Because transition paths calculated by TIMES are entirely cost dependent, this observation adds to the uncertainty of these calculated transition paths. However, a new TIMES feature gives information on the 'distance' between the cost-optimal transition path and the technologies that were not chosen in this path. Owing to this new feature the model users are able to identify technologies that were only slightly too costly to be included in the cost-optimal transition path. Given the uncertainty on future costs, this information may indicate possible alternative transition paths.

TIMES can only model the effects of price policies, standards and the implementation of targets, whereas other types of policy could be equally important (e.g. spatial planning, organisation of public transportation, etc.). Furthermore, TIMES does not allow policy inferences on social impact and land use.

TIMES assumes integral comparisons and full liquidity of funds whereas studies show [e.g. Allacker et al. (2009)] that decision making is not in all cases based on the "overall costs". In some instances – for example in the case of housing – investment costs can and will play a more prominent role in decision making. At a minimum these model outcomes show room for improvement as far as the decision making process is concerned.

Because price elasticities of energy demand depend on the alternatives available to energy consumers (which in turn depend on the type of public policies in place – e.g. the availability of public transportation determines the price elasticity of the demand for private transportation), historic values of price elasticities might be a bad predictor of future elasticities. In this sense, the TUMATIM-TIMES approach is inherently 'conservative'. This weakness can be mitigated to some extent by allowing for a range of values for price elasticities.

3.2.3. THE STRENGTHS OF SEPIA-LEAP

The main advantage of SEPIA-LEAP is that this approach allows model users to quantify alternative visions identified in an interactive stakeholder exercise. Related to this is the possibility to model various scenario ‘narratives’ taking into account interactions between energy supply and demand going beyond responses to price stimuli. Subsequently, SEPIA-LEAP as a tool gives the opportunity to initiate discussions on a wide range of public policy instruments (beyond price instruments) and approaches (e.g. coordination between public policy actors) needed to bring about the transition paths in accordance with the different visions (cf. Dutch energy transition platforms).

3.2.4. THE WEAKNESSES OF SEPIA-LEAP

In LEAP the computation of investment costs or social costs and benefits ensuing from the choices made concerning activity levels and technologies is purely optional, and LEAP at the time of the FORUM project did not use cost-optimization as a driver, which may be relevant for a number of sectors where costs are an important incentive. In the SEPIA project it was decided not to calculate costs, mainly because the project did not allow enough time to build a comprehensive database on technologies including costs data. Using the data of TUMATIM-TIMES was not a valid option either, because at the time these figures were not yet publicly available. Since policy makers noticeably prefer scenarios in which economic costs are quantified, costs have since been incorporated in the SEPIA-LEAP tool, but not in time to be relevant for the FORUM project. The FORUM members once more underlined the importance of elucidating in a simple and understandable way the very large uncertainties that accompany long-term cost estimates and which are often overlooked..

3.3. SUGGESTIONS BY MODEL USERS TO IMPROVE THE MODELLING APPROACHES

3.3.1. BEHAVIOURAL CHANGES VERSUS TECHNOLOGICAL CHANGES

The SEPIA-LEAP assimilated scenarios in the FORUM project showed a strong dichotomy between behaviour-oriented (demand pull) policies on the one hand and technology inspired (supply push) strategies on the other hand. The FORUM pleaded for a more balanced ‘mixed’ approach.

In the SEPIA-LEAP “behaviour-optimistic / technology-moderate” (B++/T+) scenario changes in behaviour are perceived as far-fetched and utopian. In the “behaviour-neutral / technology-optimistic” (B0/T++) scenario it is assumed that as long as society keeps introducing new promising technologies to replace the existing technology stock, drastic

CO_2 reductions can and will be met. In reality, technology (efficiency) improvements only manage to reduce GHG emissions in relative but not in absolute terms. As a matter of fact, absolute CO_2 emissions worldwide are still on the increase! Measures to mitigate climate change are therefore not a matter of either / or. Smart combinations of technology and behaviour can in some instances induce behavioural changes and vice versa. This transition path may be the most promising way forward, and should as such be reflected in the narratives or scenarios.

3.3.2. ON THE LINK BETWEEN ENERGY EFFICIENCY AND CARBON PRICES

The modelling approaches, and in particular SEPIA-LEAP, should dedicate more effort to exploring the links between energy efficiency improvements, GHG emission reductions and carbon prices .

The FORUM drew attention to the so-called "rebound effect", where absolute increases in CO_2 emissions may actually be caused by increases in energy efficiency. Improving energy efficiency results in downward pressure on costs (prices) of energy services, in turn leading to higher consumption of energy. For this reason, governments need to put a price on carbon. Or they have to put a ceiling or 'maximum budget' of carbon emissions – e.g. not only limiting CO_2 emissions at the EU level, but also at the level of individuals or households. Conversely, one FORUM member called attention to a discussion a propos the implementation of the EU 20-20-20 package, where it was argued that a full adoption of the non-binding target of 20% efficiency by 2020 would lead to a 25% fall in GHG emissions in the EU in 2020. Such a causal relationship would almost certainly have an impact on the CO_2 price. For policy makers it would therefore be interesting to know how these two (efficiency measures and carbon prices) interact, and if as a consequence they may be obliged to take allowances off the market?

3.3.3. ON MODELLING BEHAVIOURAL CHANGES

In TIMES-TUMATIM the problem of consumer behaviour is approached solely via (carbon / energy) prices. It might be useful to investigate complementary approaches.

Modelling consumer behaviour based on prices implies working with price elasticities. But even if carbon prices are high, this approach would only be relevant if price elasticities are sufficiently high. If energy services have low price elasticities, then even high prices would have limited influence. To have a more adequate picture of consumer behaviour, it is important to know what the 'motivational factors' are in order to qualitatively identify the changes in behaviour or lifestyle. Environmental concerns are generally placed low on the list of motivations. Prices or other aspects are generally more important, but this should be investigated for specific cases. Research on (social) behaviour is a topic in itself. Behaviour is very difficult to model quantitatively, but qualitative research on the behaviour of all main societal actors or decision-makers is gradually becoming more established.

3.3.4. ON THE USE OF BACKSTOP TECHNOLOGIES

TIMES-TUMATIM makes use of so-called "backstop technologies". Backstop technology is the concept that a technology to solve the problem will automatically be developed and become affordable as a result of increasing scarcity [Nordhaus (1973), Liski & Murto (2007)]. These technologies are triggered only if no CCS is available. Therefore, in the TIMES-TUMATIM scenario where nuclear is not allowed but CCS is (NoNuc-GoCCS) backstop is not an issue. The preferred backstop technology is capturing the exhaust gases of fossil fuel power plants and transforming them to synthetic fuel. This option is triggered starting from carbon prices of about 600 €/ton CO_2. Other backstop technology options are included in the model but not selected in the scenario runs. Backstop as implemented in TIMES-TUMATIM invoked a number of critical remarks from the FORUM.

The EC low carbon roadmap (a combination of PRIMES, GEM-E3, amongst others) [European Commission (2011)] is founded on four pillars: energy efficiency, renewables, CCS and nuclear. The EC however does not pronounce an opinion on the required shares of CCS and nuclear in individual Member States. From the EU perspective only existing technologies, including CCS and nuclear, are considered. In the low carbon roadmap CCS is (already) triggered at a price of 30 €/ton CO_2. For the EC backstop technologies do not appear to be necessary. VITO concedes that similar results (where no backstop technologies are chosen) can be replicated with the EU TIMES model. Given a target of -80% at the EU level, the CO_2 price is lower. However, CO_2 prices are higher in the situation with a target of -70% at the Belgian level.

The FORUM suggested that instead of initiating backstop technologies once carbon prices start escalating in economic optimization models, it would be more interesting to explore and 'fine-tune' the constraints one puts in the model. Prices of 600 €/ton are completely unrealistic (incidentally, this was also the case in some of the scenarios run for the CE2030 project) [D'haeseleer et al., (2007)]. In such cases, modellers or scenario builders should identify the constraints in the model that are causing the high carbon prices, and consider what indications they provide for policy-making and whether these constraints should be relaxed or not. Such an analysis gives more interesting information to policy makers than simply assuming that a backstop technology will become available. VITO promises that in future TIMES-TUMATIM will do so for biomass and wind potentials. Nevertheless, policy makers should remain aware that the Belgian TIMES model would still prefer the backstop technology to the photovoltaics (PV) technology. This is mainly because of the difficulties to lower the emissions in the transportation sector.

The FORUM also warned that one should be very reluctant to use the concept of backstop technologies, because of the high uncertainties involved (costs, technological feasibility, etc.). Policy makers have to remain realistic about all technologies. Usually, expectations surrounding new technologies are very high at the start, but when they are actually realised expectations have to be revised in a downward sense (e.g. biofuels).

Finally, a few minor remarks were made by the FORUM. One has to be aware that not everyone uses the same definition of backstop technology {referring to the definition given during the last FORUM meeting[6]} For example, Verbruggen (2008) defined backstop as a "supply technology that can deliver an unlimited amount of energy at a given (high or very high) cost." The FORUM also indicated that CCS is still not a proven technology.

3.3.5. CONCERNING "LOST DEMAND COST" IN TUMATIM-TIMES

In spite of repeated efforts of VITO to explain the use of 'lost demand cost' in TUMATIM-TIMES, this concept kept raising many questions among the FORUM members. A number of suggestions were made to improve the communication on this topic.

The way VITO presented 'lost demand cost' in its PowerPoint presentation during the third FORUM meeting (i.e. by a high red bar in the bar graph) seemed to imply that it represents a degree of popular resistance to low-carbon futures. One can only imagine how such a representation would be interpreted by e.g. the council of ministers. Additionally, the FORUM referred to an IPCC report [Watson et al., (1996)] describing how technologies can realize a -50% reduction globally, while still allowing good enough standards of living. These options require changes in lifestyles (e.g. smaller houses or passive houses), but not loss of comfort. It is dangerous to put costs of lost

[6] During FORUM 3, backstop technology was defined as "a set of processes that (a) is capable of meeting the demand requirements and (b) has a virtually infinite resource base". [Nordhaus (1973)]

demand next to investment costs (as VITO did in its presentation), and not next to benefits. The FORUM therefore proposed to represent the "lost demand cost" in a different way, and to at least also include beneficial effects on health, ecosystems, etc. when reporting on the TIMES model results.

In TUMATIM-TIMES welfare costs are limited to the energy system. There is indeed demand for energy services, but they represent only 10% of total market costs. Welfare can also be obtained in other ways. For that reason, total welfare costs can only be calculated correctly if one has a link to a macro-economic model. This explains why a macro-economic loop is important. At the FPB/BFP, there have been studies coupling PRIMES with HERMES, a macro-economic model for Belgium.

The transition to a low-carbon future implies that demand for energy services will be met in a structurally different way. Transition implies that we change our behaviour, whereas TUMATIM-TIMES modelling implies that behaviour is (relatively) fixed: people do not change their willingness-to-pay for certain energy services. It is important to highlight the consequences of this assumption.

3.3.6. Concerning large structural changes

If prices increase, there will be structural changes in technologies and behaviour, which one cannot reproduce in models such as TIMES. This is illustrated by the example of public transport. In future, public transport may improve in many ways, allowing a much swifter transition from private to public transport. But say (e.g.) large investments in public transportation do not come out of TIMES. VITO admits this, since TIMES does not utilize cross-price elasticities.

The FORUM observes that TIMES can only model marginal changes, but not the big changes. A structural change in society implies that behaviour would be completely different, but then the model would require a significantly different demand curve. However, the demand curve in a model such as TIMES is fixed. This particular problem applies to all economic models. In LEAP you can make assumptions on such deep structural changes and calculate through their consequences. Therefore LEAP is not so much a model as it is a decision tool.

The question is: How do politicians initiate structural change? What helps politicians to concretize low-carbon future objectives? Here one has to fall back on political science, or the more narrative scenario methods used in transition management literature [see e.g. EEA (2009)]. In the EC Roadmaps there is also an interesting combination of visions embodying structural changes (e.g. the assumption that only public transport is allowed in European cities in 2050) and economic optimization models.

3.4. Additional remarks concerning TUMATIM-TIMES not mentioned during the FORUM meetings

VITO insists on making two additional observations concerning the TUMATIM-TIMES scenarios, although they were not discussed during the FORUM meetings, and therefore do not represent the views of the FORUM members.

3.4.1. Trade-off between demand loss and lowering the carbon intensity following TIMES

The TIMES assimilated scenario B0/T++_58% is an exact copy of the B-/T++_58% scenario, except for one thing. The model was forced to attain levels of energy end-use demand in all sectors that are about 30% below the demand of the reference scenario in 2050, with a gradual shift. This change resulted in prices of energy end-use that are higher than in the standard climate scenario. Compared to the reference scenario, prices can be three times higher[7]. Another difference is that in this B0/T++_58% scenario, the reduction of energy end-use is similar for all sectors. As was discussed in the previous chapter, this is not the case in the cost efficient climate scenario. Differences in the demand reduction exist mainly depending on the share of the energy cost in the total cost of end use.

The results for the B0/T++_58% scenario show that the sum of all fixed, investment and variable annual costs decrease on average with 15 B€$_{2005}$. This decrease is much stronger than in the standard climate scenario.

Table 4: Annual increase of costs and expenditures, compared to the reference scenario (B€2005)

	Total welfare cost	Energy production cost	Energy expenditure
B-/T++_58%	2.6	-0.2	6.5
B0/T++_58%	10.8	-15.3	60.1

[7] One can calculate that increasing the price level from 100 to 300 decreases the demand level with about 30 %, according to the formula $Q_1/Q_0 = \exp[-0.3.\mathrm{Ln}(3)] = 72\%$

On the other hand, the total welfare cost has increased by a factor 4, mainly because the reduced demand generates losses for the energy user. The energy expenditures of this consumer will go to a smaller quantity of energy services and this shift is important in terms of welfare loss. Another conclusion is that, although the expenditures go to fewer energy services, the level of expenditures increase with about 60% when averaged over the total time horizon. This number can be compared to a maximum increase of the energy expenditures of 10% in the cost efficient climate scenario without the option for nuclear and carbon storage. This scenario is in a certain way an extreme scenario since a very high price increase is assumed to cause the demand drop. However, it demonstrates that an extra policy of demand reduction being imposed on top of a climate policy can lower the increase of the CO_2 price (Table 5). As the technology choices are driven by costs including this CO_2 price, one can expect that some low-carbon technologies are not cost efficient.

Table 5: CO_2 price in the B0/T++_58% scenario, in comparison to the standard climate scenario

	2020	2030	2040	2050
B-/T++_58%	19	103	262	472
B0/T++_58%	19	30	143	206

Another way of explaining is that regarding technology choices, the average emission intensity is higher in the scenario B0/T++_58% because both scenarios have the same CO_2 emissions level. This is reflected in higher levels of oil consumption and lower levels of the use of renewable energy.

Given the assumption regarding low and fixed price elasticities, these results indicate that there are reasons to believe that a policy primarily oriented towards deep or uniform demand reduction is questionable for efficiently tackling CO_2 emissions. Instead, a climate policy directly oriented to the reduction of CO_2 emissions induces only modest relative reductions of energy services, but it will be more cost efficient and it will induce more technology development.

3.4.2. ABOUT USING FIXED LONG TERM PRICE ELASTICITIES

An alternative approach to decrease the demands would be to lower the demand price elasticities. This has an opposite effect in a certain way because the total welfare cost will go down. It is also counter-intuitive that the cost of demand loss increases, whereas one could expect a lower cost because the demand is more elastic.

4. SUGGESTIONS TO IMPROVE THE MODELLING APPROACHES

First we provide a guide for improved policy-making capacities based on the project team's experiences, followed by recommendations made by the FORUM members during the meetings, and concluding with lessons the model / tool builders themselves learnt during the FORUM project.

4.1. A GUIDE FOR IMPROVED POLICY-MAKING CAPACITIES

One should not forget that the ultimate goal of building models or tools is not the perfection of the model / tool itself, but rather its capacity to enhance policy-making capacities to support the transition to a low-carbon society in Belgium. Capacity enhancement can only result from a detailed 'scoping' of policy information needs. Scoping aims at setting the range, nature and importance of the assessment, including its precision, scale, detail of institutional, methodological and practical requirements such as deadlines, data needs, time and budget. A detailed scoping has to answer crucial questions regarding the why?, what?, how? and who? of capacity building for managing the transition to a low carbon economy.

4.1.1. WHY?

The first question addresses vision building – what will the transition management initiative set out to achieve and by when? Vision building implies a clear specification of the objectives and principles of sustainable energy provision that will be aimed for by a certain end date.

4.1.2. WHAT?

Topics to be dealt with during capacity building should at the very least include coverage, orientation and time:

- Coverage. What sectors / issues / problems will the transition management initiative seek to cover? It is usually necessary to select the sectors / issues / problems to be covered by foresight, mostly because of resource constraints and the need to organise exercises of manageable proportions;
- Orientation. Specifying that transition management activities are oriented towards energy system dynamics in the Belgian context, one can of course not omit taking into account that these dynamics are closely related to European and even global developments. The scoping exercise has to specify how these dynamics will be

taken into account (e.g. using a European model as part of the exercise or using outcomes of other exercises as exogenous inputs);

- Time. Time horizons have to be related to the transition management initiative's objectives and orientation. In our case (and in many similar exercises), a time horizon of 2050 seems to be appropriate.

4.1.3. HOW?

The way capacity building is to take place requires answering questions related to methods, transparent dissemination, implementation and continuous improvement:

- Methods. What methods are to be used at the various stages of an exercise? The scoping document needs to include at least a brief (and non-academic) description of the main methods used, including a candid discussion of their advantages and drawbacks;

- Transparent dissemination. How are the results of the transition management initiative to be diffused beyond those immediate actors who took part in the exercise? After all, it is usually impossible to intimately involve everyone who is expected to act on its results;

- Implementation. How are the results of the transition management initiative to be followed up with action? Simply 'getting the process right‟ can indeed increase the chances of successful follow-up action, but political awareness of the possibilities for follow-up action should ideally be considered from the outset. Successful implementation could for instance involve follow-up actions by actors who have been directly involved in an exercise. This in turn points out the need for a careful selection of participants;

- Continuous improvement. How can the process and outcomes of the transition management initiative in turn be assessed? Arrangements should be put in place to obtain some measure of whether the exercise has met its objectives. One could envisage developing questionnaires (e.g. based on the questionnaire developed for FORUM) to be filled out by participants in the initiative;

4.1.4. WHO?

A number of actors are involved in capacity building, and matters to be taken in hand encompass organisation, management and financing, participation and consultation:

- Organisation, management and financing. How and by whom is the transition management initiative organised and managed? Here, one needs to explain the role of the steering committee and the internal functioning of the initiative. Managing a sustainability assessment process, in terms of personnel and knowledge management, is a creative process, but some lessons can probably be learnt from other experiences (cf. experience of FPB-TFDO);

- Participation. What should be the breadth of actor engagement in the transition management initiative? Who participates in the assessment is a central concern, not least because of a need to produce results that are widely considered to be legitimate, robust, and transparent. Who participates also depends upon other elements of the scope, including objectives;

- Consultation. What should be the depth of actor engagement in the transition management initiative? As is evident from the responses to our questionnaire, the FORUM did not arrive at a clear consensus on this issue. Nevertheless, answering the question on consultation is crucial for ensuring the success of a transition management initiative.

4.2. RECOMMENDATIONS MADE BY THE FORUM MEMBERS

In a (partial) response to the research questions set out at the beginning of this report, the FORUM members made a number of recommendations, namely:

1) to improve the coherence between the scenario results even if they are derived from very different methodologies (*salience*);

2) to seek synergies between the TIMES-TUMATIM and SEPIA-LEAP approaches (*salience and credibility*);

3) to establish some kind of "platform" where Belgian energy modellers can regularly meet, exchange ideas, results, etc. (*credibility*).

We will now explore these recommendations in more detail.

4.2.1. IMPROVE THE COHERENCE BETWEEN THE DIFFERENT APPROACHES

There are many on-going studies in the EU, Belgium and its regions on what (sustainable) energy systems should look like in 2050. Discussions as the ones carried out in the FORUM project are essential to gain a clearer understanding of the differences between the results of the diverse approaches. This in turn may lead the way to more coherent scenario results in future.

In order to allow more meaningful comparisons, a number of questions have to be answered first. What is implied (i.e. what are the assumptions) in the scenarios concerning activity levels, "way of life", visions of 2050, etc.?. What are the differences between the scenarios in the two approaches, and why do those differences exist in the first place? In other words, the modellers have to make their comparisons much more explicit still.

Although the FORUM concedes that plurality is better, it is always interesting to be able to compare on the same basis, even if the models are not linked directly in a specific project.

Somewhat related to the above, the FORUM expressed the need to be given more detailed results of the modelling exercises. For example, concerning the TIMES-TUMATIM output an overview of the investment intensity in the different scenario's was requested. As a result, both VITO and UA agreed that more detailed results of the assimilated scenarios would be made available to the FORUM members (in Excel spreadsheet). VITO also promised to make the results more transparent, esp. concerning the so-called "front-end data".

4.2.2. SEEKING SYNERGY BETWEEN THE TWO APPROACHES

The FORUM observed that both approaches (TIMES-TUMATIM and SEPIA-LEAP) are substantially different. From a policy point of view, it would be interesting to see how both modelling approaches could be combined in order to inform policy makers on the consequences of implementing the various EU roadmaps (low carbon economy, energy & transport) in Belgium.

It was therefore proposed that both approaches should be made more relevant to energy and climate change policies by seeking "synergies" or by combining them in a more "holistic" approach. In future exercises a merger of both approaches could thus lead to a "win-win" situation.

One possibility is to use the TIMES-TUMATIM 'rational actor' approach to derive the energy demand levels for those sectors (such as energy-intensive industries) where the hypothesis of rational economic behaviour is more realistic than for other sectors. SEPIA-LEAP could then explore the 'behavioural variations' or 'lifestyle changes' (driven by other than price policies) in all the other sectors.

Another prospect is to work iteratively. The visions established in SEPIA-LEAP can be used as a starting point for the exogenous demand levels in TIMES-TUMATIM to ascertain the costs of policies leading to those visions. If those costs are deemed too high, the initial visions can be adjusted during a second round of the SEPIA-LEAP approach, and run once more in TIMES-TUMATIM, until some point of (policy) convergence is reached.

4.2.3. A BELGIAN ENERGY MODELLING PLATFORM (BEMP)

In the eyes of the FORUM members the FORUM project did not satisfactorily answer the question: "What did SEPIA learn from TUMATIM, and vice versa?"

This, together with the above mentioned problems of lack of synergy and coherence, is one of the reasons why the FORUM proposed that BELSPO should initiate some kind of "platform", where all energy (and climate change) modellers in Belgium could meet every 3 month or so, and exchange ideas, assumptions, results, etc.

4.3. LESSONS LEARNT FROM FORUM BY THE MODELLERS

4.3.1. DIFFERENCES BETWEEN TUMATIM AND SEPIA

Before embarking on a search of the commonalities of TUMATIM-TMES and SEPIA-LEAP, it is necessary to point out the fundamental differences between the aspirations of the two BELSPO projects.

SEPIA-LEAP was intended to generate different insights based on *deliberation* between stakeholders and scenario builders concerning plausible paths to a sustainable energy system by 2050 in Belgium. As such, advice on the use of policy instruments is not meant to be a direct output of the SEPIA-LEAP decision support tool. Rather the tool pictures and streamlines different and sometimes opposing suggestions to reach a particular vision.

The intention of TUMATIM-TIMES was to generate a long-term roadmap to maximize welfare. Keeping this in mind, the most important policy recommendations following the TUMATIM-TIMES scenario runs were:

- Demand reductions are important and necessary. Energy services become more expensive on the average, but less use is made of them. Although the consumer losses are expensive, they are still less expensive than policies that rely exclusively on technological solutions. It is not because demand reductions are expensive that society should abstain from such measures. Policy makers however should be made aware of the consequences on welfare. If not, they might assume that the demand shifts will happen automatically, which is not the case.

- Renewable technologies will be used up to technical potential levels given ambitious climate change policy targets (some technologies even at the EU level).

Completing the response to the research questions explicated in chapter 1.2, we next discuss commonalities between the two approaches concerning:

- Welfare costs (*salience*);
- Behavioural changes (*substantial legitimacy*);
- The role of exogenous variables (*procedural legitimacy*).

On a side note, we express the need for a common glossary among modellers and model users.

4.3.2. COMMON GROUND CONCERNING WELFARE COSTS

The FORUM members made very clear that (welfare) costs are an important issue, that cannot or should not be neglected in scenario exercises.

Although SEPIA-LEAP did point out some interesting pathways to reach the -80% GHG emission reductions by 2050 in Belgium, the tool at the time of the FORUM project did not give an in indication of what it would cost society to realize them.

In TIMES-TUMATM on the other hand welfare costs play a very prominent role, but the results depend heavily on certain basic assumptions, predominantly the reference case.

Therefore, both the SEPIA-LEAP and TIMES-TUMATIM approach have to consult the stakeholders to ascertain beforehand which costs should be accounted for in the model or tool. Expenses that definitely have to be incorporated are the less controversial investment costs of (new) technologies. To aid the stakeholders they must be given the opportunity to discuss all relevant costs, if possible chosen from a ready-made list of technology costs options.

Furthermore, the modellers or tool builders of both approaches have to confer in advance with the stakeholders and / or scenario builders about the *reliability* and *(un)certainty* of the costs considered in the scenarios.

That said, there is general agreement that costs may never be the only decisive factor [Verbruggen, (2011)].

4.3.3. COMMON GROUND CONCERNING BEHAVIOURAL CHANGES

The FORUM underscored the importance of changes in lifestyles or demand reductions, next to and together / in conjunction with technological innovations, as a vital means of reaching the energy and climate change policy targets, i.e. both are required.

The SEPIA-LEAP tool calculates the effects of "voluntary" reductions in activity levels on energy consumption, where the rationale for such reductions is explicitly justified by the value judgements of stakeholders and / or scenario builders. It simply assumes that such behavioural changes occur, but does not specify the causal mechanisms behind these changes. It demonstrates to policy makers that radical lifestyle adjustments can make a significant contribution to the reduction of GHG emissions in Belgium.

On the other hand, TIMES-TUMATIM models energy service demand levels are based primarily on a single determining factor, i.e. price elasticities. The basic assumption here is that patterns observed in the past will still be valid in the far future. In other words, preferences for energy services will not change, and therefore any reduction in energy service levels will be considered as a loss of welfare. The scientific validity of extrapolating trends into the future is a matter of opinion, not scientific fact. There is a danger that policy makers accept what comes out of the model as irrefutable scientific evidence, and not as a matter of collective choice.

A need for a better understanding of lifestyle change mechanisms is apparent from the comparison of both approaches. The relevant question is to what extent such changes can be induced by price changes and/or voluntary acts, whether those are steered by policy intervention or not. Recent advances in political and social sciences can clarify these enquiries to some extent.

4.3.4. COMMON GROUND FOR THE ROLE OF EXOGENOUS VARIABLES

SEPIA-LEAP depends heavily on the explicit inputs of stakeholders and scenario builders. Apart from checks and balances concerning the energy flows in the Belgian energy system, most measures are a direct translation of inputs made by the (expert) scenario builders. Because of the sheer number of choices involved they can never be the subject of a full stakeholder review.

TIMES-TUMATIM on the other hand is perfectly suited for the typical desk research approach. In principle, no stakeholder interaction is required, as the expert modeller can derive all the exogenous inputs needed from literature. Although not required, stakeholders can nevertheless assist in specifying and/or validating assumptions on exogenous parameters (e.g. GDP growth, population, technological constraints, etc.).

The selection of a limited number of key parameters in both approaches should always be subjected to stakeholder review. Candidates for key parameters are e.g. potentials for offshore wind turbines, imports of biomass, the electrification level of transportation means, etc. The stakeholder review should be integrated in the capacity building effort.

4.3.5. COMMON TERMINOLOGY

The FORUM project revealed the need for a common "glossary". The same words do not always have the same meaning, either in-between the modellers, between modellers and policy-makers, or both.

For example, during the third FORUM meeting UA used the Nordhaus (1973) definition of "backstop technology", where both VITO and some FORUM members pointed out that this wasn't the only definition of "backstop", and that they themselves used (slightly) different definitions.

Another example concerns the different interpretations of "energy services". In TIMES-TUMATIM "mobility by car" is considered an energy service, whereas in SEPIA-LEAP a similar energy service would be the rather broader concept of "mobility" in general, which can be satisfied by many different transport modes (from private to public transport, or from non-motorized to motorized).

Alternatively, different terms may essentially mean the same thing. For example, what TIMES-TUMATIM calls "front-end data", is more or less the same what SEPIA-LEAP means by "macro-economic drivers". A Belgian modelling platform (such as BEMP, see above) could help ironing out these small but potentially significant misapprehensions.

4.3.6. CONCLUSIONS

In sum, we can conclude that the use of energy system modelling for policy support in the transition towards a low-carbon economy represents a clear trade-off. On the one hand, such models allow for the systematic and consistent inclusion of a variety of dynamic factors such as the demographic composition of the population, macro-economic evolutions, the availability of primary energy supplies, etc. On the other hand, such models may obscure the crucial role of subjective judgments made by the modellers in choosing a particular models structure and parameters. For instance, the typical TIMES model treats the evolution of technologies and demand response to energy prices in a very simple and deterministic way (compared to the 'real world'). Furthermore, the further we look into the future, the less we know with certainty. In the case of policy support for the low-carbon transition models and scenarios should therefore reflect this 'fact of life' and become simpler as they are projected further into the future. On the timescales typical for this type of exercise (i.e. 2050-2100), formal energy system models are probably best used as inputs to a broader stakeholder process that weighs multiple sources of evidence. This may include sensitivity studies of the values of uncertain parameters as well as using a number of structurally different energy models (as suggested by the FORUM intermediaries), but should also include a variety of qualitative considerations that are typically captured inadequately in formal models (e.g. the dynamics of technological innovations, drivers of energy-related behaviour, etc.). Perhaps the most important lesson to be learnt from the FORUM experience is that different modelling teams are bound to come up with different policy recommendations based on the particularities of their modelling approaches and inevitably subjective assessments. Approaches such as FORUM precisely aim to more clearly explain and justify the sources of those differences to intermediaries and possibly even policy makers. The outcome of such processes injects a much necessary dose of healthy scepticism with regard to the policy goal of finding 'the best solution' to the transition challenge. Because of the political sensitivities involved in such 'debunking', it might be difficult to implement such FORUM-like exercises as part of official governmental assessment processes. However, when carried out as a carefully thought-out and peer-reviewed independent assessment, the results of such exercises could prove to be very valuable in a more indirect way to the many analysts involved in energy transition policy support activities.

5. DISSEMINATION AND VALORISATION

- A scientific paper in the A1 journal FUTURES on "lessons learned from the FORUM project".
- Presentations, including a description of the FORUM results, at the Workshop "Transition to a low carbon economy: status of the long run scientific modelling in Belgium", FPS Health, Food Chain Safety and Environment, Brussels, 22 March 2012.

6. PUBLICATIONS

Journal articles:

- Laes E. and Couder J. (2014), Probing the Usefulness of Technology-Rich Bottom-Up Models in Energy and Climate Policies: Lessons Learned from the FORUM project, in: FUTURES (forthcoming).

A number of documents have been prepared or are in preparation:

- Questionnaire of user expectations (form). This form could in future be used for similar exercises, or to survey a larger sample of policy makers, perhaps even in a EU context. http://www.ua.ac.be/main.aspx?c=.BELSPO-FORUM&n=103833
- Descriptions of TIMES-TUMATIM and SEPIA-LEAP following the ATEsT format http://www.ua.ac.be/main.aspx?c=.BELSPO-FORUM&n=103834
- Couder J. and Verbruggen A. (2011): Modelling the Belgian energy system with SEPIA-LEAP, BELSPO intermediary report, Brussels, 2011. http://www.ua.ac.be/main.aspx?c=.BELSPO-FORUM&n=103834
- Detailed results of the scenario runs during the FORUM exercise http://www.ua.ac.be/main.aspx?c=.BELSPO-FORUM&n=103835

All these publications are available from the FORUM website: www.ua.ac.be/BELSPO-FORUM

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ANNEX I: MINUTES OF THE FORUM MEETINGS

Meeting Report FORUM I (BELSPO, Brussels, February 10th, 2011)

Present: Igor Struyf [IS] (BELSPO), Catherine Stuyckens [CS] [SPF Economie, PME, Classes moyennes et Energie], Johan Brouwers [JB] (VMM-MIRA), Alain Henry [AH] (Bureau fédéral du Plan]), Mohamed Al Marchohi [MAM] (SERV, replacing Peter Van Humbeeck), Wouter Nijs [WN] (Vito, project team), Erik Laes [EL] (Vito, project team), Johan Couder [JC](UA, project team, reporting on the meeting)

Excused with notification: Aviel Verbruggen (UA, project team), Fre Maes (FOD Volksgezondheid, veiligheid van de Voedselketen en Leefmilieu), Sara Ochelen (LNE)

Absent: Bart Naessens (LNE), Wim Buelens (VEA)

PART 1: description of TIMES-TUMATIM and discussion of most salient survey results

[WN] & [JC] present the TIMES-TUMATIM and SEPIA-LEAP approach. (See slides in attachment)

[EL] puts forward three challenging statements, based on a recent survey (December 2010 – January 2011) among FORUM members. The statements are discussed one by one.

Statement 1: Minimisation of total social costs is a good approach for developing sustainable energy pathways on the long term.

[IS] states that 1) you can use total social costs as a guiding principle, 2) there are different kinds of social costs, and 3) the statement is built exclusively on an economic premise: i.e. the economic valuation/estimation of external impacts. The system boundaries and whether you look at (parts of) the system from the inside or the outside determine what costs are social costs and what costs are private costs for certain stakeholders/energy system actors. Looking from the outside you can minimize total social costs. Looking from the inside, it is the interaction among stakeholders that determines which and to what extent [social] costs need to be/are minimized. For example, in the SEPIA project, the requirement to realize substantial GHG emission reductions puts absolute limitations on what the energy system will have to look like. You can put limits on certain emissions, but e.g. industry (as an important (group of) stakeholders/energy system actors) will/could claim that they have already achieved substantial emission reductions. Where does that leave you with the results of a [merely cost-based] model?

[WN] first clarifies the assumed definition of social cost for this project that could be used for determining the best technology mix from the perspective of the society. The social cost is defined as the sum of both the private and the external costs (sometimes called total costs). External costs are per definition costs that are not borne although they have a negative (sometimes positive) effect on the society like for example the impact of emissions to the air. The more the damage costs get into the private costs, the smaller will be the external costs (see figure). He says that models allow you to sometimes quantitatively justify the reduction of emissions. It is better to have a particular figure than no figure at all, because numbers can put things in perspective. For instance, the costs of reducing emissions may be two to three times lower than the avoided damage costs! By trying to estimate damage costs of for example GHG emissions, the impacts become part of the debate much easier and the impacts get more specific. This is necessary to get a good balance between the precautionary principle and the principle of the existence of an "optimal level of pollution". The borders of the system you envisage should be taken as large as possible and indeed the real world only captures smaller parts of the system (EU, sector specific, human impact...). However, this is not a reason why in the future the system can not be taken larger and more international. Costs play an important role in technology choice so he thinks it can be an efficient way to reduce for example pollution if costs get more and more a social dimension.

[IS] responds that the orders of magnitude relative to the involved uncertainties may make even this type of general assertions very risky.

According to [AH] the minimization of total social costs (TSC) is a beautiful idea and a precious indicator, but impossible in practice. There are other factors and impacts like impacts on poverty, on the fragmentation of territory (division of spatial entities into smaller or less coherent pieces) or on biodiversity whose economic valuation is very difficult or even impossible. Basing decision on cost minimisation makes only use of en economic criteria in policy decision, while other criteria, which cannot be represented by purely economic figures, must also be used: social aspects, equity, environmental impacts, public health, etc. You can take them into account, but there are high uncertainties involved, spanning many orders of magnitude. Also according to [IS], there are many different actors with different interests in and perspectives on the energy system. These actors will 'play games', focussing on their own role and position in the system, and some actors do not always care about total social costs (TSC). For example, minimizing TSC does not take into account access to [basic] energy services for the lower income groups, but this [energy poverty] is an important issue to policy makers!

[JB] sees social costs minimization as an important element that can give a reliable indication of how the energy system should evolve, but he warns against the ambition of modellers. TSC can have a supporting role but they can never be the only element in the discussion. He refers to a recent incident, where even the claimed (magnitude of) private costs of a certain stakeholder were the subject of heated discussions.

[EL] concludes that (minimization of) total social costs are a valuable piece of information, but not the only one, and uncertainties should always be clearly indicated.

Statement 2: Active participation of stakeholders in energy system analysis is appreciated. But how can this be achieved in practice?

[AH] says that this needs a lot of work of the scientific team involved, preparing all the information with which the stakeholders have to be fed.

[CS] refers to existing groups that already have the necessary competences and who represent the stakeholders (e.g. the Conseil fédéral du Développement durable / Federale Raad voor Duurzame Ontwikkeling or the Conseil central de l'Economie / Centrale Raad voor het Bedrijfsleven). To this [JB] replies that it is always the same people who get invited. It is difficult enough to get them engaged initially; to keep them engaged is even more difficult, because they are overburdened with requests. [IS] refers to the 'Science-Policy link' concertation group within “De Lente van het Leefmilieu / Le Printemps de l’Environnement”, where the suggestion was made that each government department may want to have (at least) one 'scientific officer', to bridge the gap between scientists and policy makers. Unfortunately, this never got beyond the stage of an idea. [JC] refers to SenterNovem [now called NL Agency], the Dutch contact point for businesses, knowledge institutions and government bodies, focussing on sustainability, innovation, international business and cooperation.

[IS] also says that in an abstract way scientists already recognize the large number and diversity of actors in the energy system, and how they relate to each other on economic and other dimensions. One has to take these ideas as a starting point in participation exercises and take them further to look at the implications.

[WN] wants to know if there are alternative methods other than bringing stakeholders together round a table. [EL] remarks that representatives of organisms like CFDD/FRDO are usually called in after all the calculations have been done. Early involvement may improve the participation process. [AH] retorts that CFDD/FRDO not only advises the federal authorities at the federal government's and parliament's request, but as well on its own initiative.

[IS] says that one has to find a balance between active participation of the stakeholders on the one hand (which per definition have their own specific and partial perspective on (parts and aspects of) 'the energy system') and the scenario builders with greater expertise in understanding the energy system as a whole on the other hand. [JC] replies that the SEPIA project experience learned that it is very difficult to find a group of people with a deep understanding of the complete energy system. [IS] counters this by giving the example of a recent CFDD/FRDO advice on bio-energy/-fuels. In spite of the obvious and gigantic complexity of the subject matter, a group of people were capable of producing an extremely valuable document, covering and reflecting on all the critical dimensions of (sustainability of) implementing bio-energy/-fuels, and relating which aspects are relevant to which types of (societal/energy system) actors.

[EL] concludes that it is difficult, but necessary.

Statement 3: Long term energy system analysis has to start from backcasting and narrative scenario-building.

[IS] As [long as] the degree of internal logic is very high narratives can have great value.

Backcasting obviously also has great value in working out (creating greater insight into) how (we may) get to a future state.

[WN] says that backcasting is used for many different purposes, e.g. limiting GHG emissions or for visionary futures. He complains that people often ask why MARKAL doesn’t do backcasting, but MARKAL (on some occasions) does, e.g. by manually inputting certain constraints. To [WN], that is an enrichment [of the MARKAL approach].

[IS] wonders what [WN] exactly does understand by backcasting. Does that mean fixing the future values of certain variables, e.g. fixing the share of renewables in the long term future (2050)? [WN] confirms that MARKAL does do backcasting at a limited level, by fixing the values of future long term objectives, although not related to behavioural aspects. [AH] agrees that long term objectives are both important and necessary.

[IS] responds that it is difficult to put quantified LT (policy) objectives on everything, hereby referring to e.g. the Treaty of Lisbon or the Maastricht Treaty. He is intrigued by the question: if 5 years ago modellers made a certain prognosis/forecast with regard to certain objectives, then how come their assessments haven't materialized? To answer that question one requires knowledge of more than just the economic aspects. For scientists it is important to increase their body of knowledge to understand where those differences come from and thus enabling them to produce better models of reality. [JC] points out that there is an important difference between forecasts (prediction) and scenario's (possible but not necessarily realistic futures). Scenarios may also warn policymakers, if we don't stop doing this of start doing that, the future consequences might be dire. According to [IS] policy makers among others don't always understand the difference between forecasts and scenarios. Socio-technical scenarios (STSs) reflecting the high complexity of energy systems (composition and dynamics) can be very useful.

[WN] muses about what will make changes happen? What influences people's behaviour? The distinction between what is long term objective and what is assumption is not always clear. An objective as such (or a transition path to desirable future) does not influence all people's behaviour and so will not be sufficient.

[EL] concludes that long term objectives are important, and that backcasting is an important tool but should not be the only tool.

PART 2: presentation of the assimilated scenarios and FORUM discussion

[JC] and [WN] present the assimilated scenarios. (See slides in attachment).

There are 2 basic scenarios: a behavioural neutral [B0] / technology optimistic [T++] one; and a behavioural optimistic [B++] / technology moderate one [T+]. Vito will run the B0/T++ using the pure TIMES-TUMATIM approach, UA using the pure SEPIA-LEAP approach, after which Vito will try to emulate the results of the SEPIA-LEAP exercise with TIMES. Only UA will run the B++/T+ scenario, using the SEPIA-LEAP method.

[AH] wants to know what assumptions will be used for GDP and population. [JC] says that the most important thing is that all runs use the same assumptions regarding GDP & POP, and that UA – lacking a macro-economic component in LEAP – usually refers to previous exercises done by others (likes the one KUL & VITO have done for BELSPO) because those have already been discussed through and are therefore deemed plausible by (most) scenario builders. [AH] points out the possibility of using the projections of the Federal Planning Bureau (FPB) or of the ones used by TIMES/GEM-E3, as long as all scenarios and models use the same assumptions. The FBP has projections of the population until 2060, whereas GDP projections go to 2015 after which a certain constant yearly percentage growth is assumed. For [WN] the TIMES/GEM-E3 assumptions would be ideal. [JC] has no problem applying those to SEPIA-LEAP.

[IS] is intrigued why in TIMES-TUMATIM emulating the SEPIA-LEAP results a shift to a service economy or a reduction in activity levels (e.g. mobility in terms of passenger-km) is considered a welfare loss, esp. since the basic assumption is that in none of the scenarios income per capita changes. [WN] tries to explain that using an analogy. When people have booked a holiday in an exclusive hotel somewhere, and they are put in another hotel because the original hotel is overbooked, it still is the same beach and the same weather and the same people on the beach etc, but they are not as happy as they would have been because they are disappointed in (some of) their expectations. It is similar with TIMES-TUMATIM, because TIMES-TUMATIM always relates to a certain reference [scenario]. The concept of (loss of) consumer surplus is not captured in the indicator "income". (WN promises after the meeting to give a better explanation on consumer preferences and eventual welfare losses in the next meeting).

[IS] responds that this kind of assumption/assessment of people's expectations is logic in a 'B0' scenario, but not in a scenario where behaviour (and possibly also people's expectations) change.

In terms of potentials (of e.g. flow renewables or biomass) [IS] stresses the need to clearly distinguish between physical and technical potentials on the one hand, and social-political-institutional potentials on the other hand. For example, in the case of biomass, if all (even only currently known) sustainability criteria are taken into account, the social-institutional potential is markedly lower than the technical one. [JC] agrees, and says that as far as technical (maximum) potentials are concerned, both UA and VITO will use the same upper limits (based on the opinions of experts), but that indeed – depending on the methodology used – the 'sustainable' potentials may be substantially lower.

A suggestion to seek inspiration in the (recent) EU technology roadmaps is put in perspective by [IS], since those still rely predominantly/almost exclusively on a techno-economic approach.

It is confirmed that the main objective in all scenarios is to reach a -80% GHG reduction in 2050 as compared to 1990 levels.

[JB] shows concerns regarding the large imports of green electricity in the B0/T++ scenario. He re-iterates that energy security is important. Also, regarding policies, it is important to know what we (Belgium or its regions) can do. A policy where most electricity is imported is not very useful. [CS] points at the limited possibilities in Belgium, and at the relevance of the international offshore electricity 'Supergrid' project. It is remarked that in terms of imports, technical limits, both for electricity and gas, have to be taken into account. [MAM] suggests that it might be useful to make a distinction between imports from within EU and outside the EU. [JC] says that – given limited time and budget – the purpose of this exercise is not the scenarios as such, but rather showing the FORUM members the differences and weaknesses & strengths of two entirely different approaches.

CONCLUSIONS: It is agreed that the next FORUM meeting will take place after the Easter holidays (last week of April, first week of May). By then all 4 runs should be ready, and sent to all FORUM members one week beforehand. At the request of [CS], all FORUM members will shortly receive additional documentation on TIMES-TUMATIM and SEPIA-LEAP (manuals, reports of projects).

Meeting Report FORUM II (BELSPO, Brussels, 02-05-2011)

Present. Panel members: Mohamed Al Marchohi (SERV); Catherine Stuyckens (FPS Economy); Vincent Van Steenberghe (FPS Environment); Fre Maes (FPS Environment); Johan Brouwers (MIRA); Alain Henry (FPB); Igor Struyf (BELSPO). Project team: Johan Couder (UA); Wouter Nijs (VITO); Erik Laes (VITO), reporting on the meeting.

Informative Q&A after presentation of SEPIA-LEAP and TUMATIM-TIMES scenario runs

Q1: In the SEPIA-LEAP B++/T+ scenario, the assumption is that the Belgian economy is evolving towards a service-based economy. How is this modelled precisely?

The evolution towards a service-based economy is modelled in a qualitative way. A common assumption for all scenarios is the overall level of economic growth. If there is less growth in energy-intensive industries, then there has to be a compensating growth in the overall activity levels of the service sectors. These activity levels are linked to the floor area of commercial buildings in LEAP. Additional assumptions on building shells, heating and cooling technologies, etc. then lead to final energy demand for the service sector.

OK. It would be interesting to see in a subsequent presentation of the results the quantitative part belonging to the low-high assumed service-based economy: how much lower/higher was assumed exactly for the energy service of the sectors ?

Q2: Will you see the shadow price of reduced energy service levels in the TIMES model runs?

Yes. When emulating the SEPIA-LEAP B++/T+ scenario, a lot of additional constraints will have to be built into the TIMES model; some will be put on technological developments, others on energy service demand levels. The comparison to the reference TIMES model run and the shadow prices of the additional demand constraints will hopefully give a better view on the magnitude of "welfare loss" belonging to the different changes.

Q3: Is it possible to have negative shadow prices in the TIMES model runs (referring to no regret options) ?

In principle not – a negative shadow price indicates that this option should have been chosen by TIMES as part of the cost-optimal solution. Negative shadow prices can only result from constraints put in by the user in order to make the model results more realistic (e.g. additional insulation in existing houses can only be installed gradually, whereas the 'unconstrained' TIMES model might conceivably decide to install additional insulation in all existing houses in one year). The fact that no-regret options in the TIMES model do not appear to be no-regret options in the real world can be explained by 1) costs that we do not include in the model 2) a higher discount rate in sectors that are less cost driven, like households and services (can be solved within the model by including a higher sector specific discount rate).

Q4: Where do the assumed price elasticities of energy demand come from in the TIMES model runs?

They are based on an analysis of historic data within the TUMATIM project and other projects (the report of TUMATIM gives an overview of the literature for transportation price elasticities).

Q5: It would be interesting to calculate price elasticities based on the output of a macro-economic model such as GEM-E3.

Agree, since there is collaboration with KU-Leuven within TUMATIM, it can be suggested. At least we will check the usefulness.

Q6: Is the price elasticity of energy demand constant over the entire modelling horizon in the TIMES model runs? Is it different for different energy demand sectors?

In principle different price elasticities could be used for different time horizons, but this will not be done for this exercise. Elasticities are different for different energy demand sectors, but historic data show that demand in all sectors is quite inelastic (elasticity of about -0.3 is quite common).

Q7: Are the ETS and non-ETS sectors modelled differently in the TIMES model runs?

No; this option is used in other TIMES applications; if time is there, it will be implemented also in the new Belgian TIMES model.

Discussion on the relative merits of both modelling approaches

(comments are arranged thematically)

Strengths/Weaknesses of TUMATIM-TIMES

Strengths:

- TUMATIM-TIMES gives information on the costs of the energy transition for different demand sectors. Without information on costs, chances are very small that results of a modelling exercise will actually be implemented by policy makers. Because of the importance of cost information, one has to communicate in a very precise way about costs – e.g. what type of cost is calculated (investments costs, overall system costs, shadow costs, macro-economic costs – being often much smaller (see e.g. study European Commission, etc.), what is an adequate base for comparison (e.g. reference scenario, compared to overall GDP, etc.)?

- BUT: one has to make sure that all costs are included (principle of full social costing, including environmental and health effects).

- TUMATIM-TIMES is able to model the effects of price policies (e.g. subsidies, taxes, tradable green certificates, etc.), the effects of standards and the implementation of targets.

- TUMATIM-TIMES models energy system development in an internally consistent way (both energy demand and supply sectors are submitted to the same law of rational behaviour and hence adapt to each other in accordance with this law).

Weaknesses:

- Costs for new technologies up to 2050 are very uncertain. Because transition paths calculated by TIMES are entirely cost dependent, this observation adds to the uncertainty of these calculated transition paths. However, a new TIMES feature gives information on the 'distance' between the cost-optimal transition path and the technologies that were not chosen in this path. Thanks to this new feature one is able to identify technologies that were only slightly too costly to be included in the cost-optimal transition path. Given the uncertainty on future costs, this information indicates possible alternative transition paths.

- TIMES can only model the effects of price policies, standards and the implementation of targets, whereas other types of policy could be equally important (e.g. spatial planning, organisation of public transportation, etc.). Also is cannot conclude on social impact and land use.

- TIMES assumes integral comparisons and full liquidity of funds whereas for example studies show (BELSPO study) that the decision making is not solely based on this "overall cost" but -for example in the case of houses- based more on the investment cost. At least these model outcomes show room to improve the decision making.

- Because price elasticities of energy demand depend on the alternatives available to energy consumers (which in turn depend on the type of public policies in place – e.g. the availability of public transportation determines the price elasticity of the demand for private transportation), historic values of price elasticities might be a bad predictor of future elasticities. In this sense, the TUMATIM-TIMES approach is inherently 'conservative'. This weakness can be mitigated to some extent by allowing for a range of values for price elasticities.

Strengths/Weaknesses of SEPIA-LEAP

Strengths:

- Possibility to model alternative visions identified in an interactive stakeholder exercise.

- Possibility to model various scenario 'narratives' taking into account interactions between energy supply and demand going beyond responses to price stimuli.

- Possibility to initiate discussion on a wide range of public policy instruments (beyond price instruments) and approaches (e.g. coordination between public policy actors) needed to bring about the transition paths in accordance with the different visions (cf. Dutch energy transition platforms).

Weaknesses:

- LEAP-modelling is less adapted to calculate economic and other costs of the choices made and it does not use cost-optimisation in as a driver, which is relevant for those sectors in which this is a important driver.

- Policy makers seem to prefer scenarios in which economic costs are made quantitative, but one should underline the importance to present in a simple and understandable way the very large uncertainties that go along these long-term cost estimates and which are often overlooked.

Looking for a synergy between both approaches

- There is an agreement that the FORUM cluster project is principally concerned with a comparison of methodologies; actual results are not that important.

- Compare both approaches on carefully selected 'key indicators' – e.g. energy demand in different sectors, penetration of different energy supply options, shares of fuels etc. Indicate significantly divergent results and explain this divergence.

- In particular: indicate where the 'rational actor' approach deviates from the 'lifestyle changes' assumed in SEPIA-LEAP.

- Try to get an overview of the investment intensity in the different scenario's (TIMES output).

- Try to emulate the SEPIA scenario storylines by changing TUMATIM-TIMES input parameters (e.g. energy service demand etc.). In particular, it is interesting to see how the storylines on international developments could be 'translated' into the different modelling approaches.

- Look for 'win-win' options: e.g. for some sectors (such as energy-intensive industries), the assumption of rational economic behaviour is more realistic than for others (e.g. households). Information on energy demand levels for those sectors could then be derived from TUMATIM-TIMES, while 'behavioural variations' (driven by other than price policies) in the other sectors could be explored with LEAP.

- A combined approach could be to work iteratively: LEAP and visions – TIMES and costs (partial policies) – redo the LEAP based on input from TIMES
- The output of the TIMES B0 T++ scenario will be used to redraft an adapted B0 T++ LEAP scenario as an example for such iterative work and how both models can work mutually reinforcing.
- For a possible future exercise, it would be interesting to see how both modelling approaches could be combined in order to inform policy makers on the consequences of implementing the various EU roadmaps (low carbon economy, energy & transport) in Belgium.

CONCLUSIONS. Organisation of next FORUM: end of Sept. 2011. In the 3rd (and final) FORUM meeting results on the four proposed scenarios will be presented according to the guidelines received in this meeting (e.g. selection of key indicators for making comparisons, highlighting and explaining divergent results).

Meeting Report FORUM III (BELSPO, Brussels, 04-10-2011)

Present. Panel members: Mohamed Al Marchohi (SERV); Catherine Stuyckens (FPS Economy); Fre Maes (FPS Environment); Johan Brouwers (MIRA); Alain Henry (FPB); Igor Struyf (BELSPO). Project team: Erik Laes (VITO), reporting on the meeting; Johan Couder (UA), reporting on the meeting; Wouter Nijs (VITO).

Excused: Vincent Van Steenberghe (FPS Environment); Aviel Verbruggen (UA)

Notice: remarks in *italic* were made after the meeting by Wouter Nijs, in reaction to comments of the FORUM members on a draft version of this report. They were not discussed during the meeting.

Discussion – thematic reporting

[On backstop technologies]

What are examples of backstop technologies in TUMATIM-TIMES? At what level of carbon prices is their use triggered by the model?

Backstop technologies are triggered only if no CCS is available. In NoNuc-GoCCS backstop is not an issue. The preferred backstop technology is capturing exhaust gases of fossil fuel power plants and transforming it to synthetic fuel. This option is triggered starting from carbon prices of about 600 €/ton CO_2. Other backstop technology options are included in the model but not chosen in the scenario runs.

Comment:

- In the EC low carbon roadmap (= combination of PRIMES, GEM-E3, etc.), CCS is (already) triggered at a price of 30 €/ton CO2. From EU perspective only existing technologies, including CCS and nuclear, are considered. The low carbon roadmap rests on 4 pillars: energy efficiency, renewables, CCS and nuclear (but the EC does not pronounce an opinion on the necessary shares of CCS and nuclear in individual Member States). For the EC backstop technologies do not appear to be necessary. [WN: OK, we have similar results with the EU TIMES model (where no backstop technologies are chosen). The CO2 price is lower in the case you have a target of -80% at the EU level. However, CO2 prices are higher in the situation with a target of -70% at the Belgian level].

- Not everyone uses the same definition of backstop technology {see definition given on slide}. One should be very reluctant to use that concept, because of the high uncertainties involved (cost, technological feasibility, etc.). We have to be realistic about all technologies. Usually, expectations about technology are very high in the beginning, but when they are actually realised expectations have to be revised in a downward sense (e.g. biofuels).

- CCS is also still not a proven technology.

[On lost demand cost]

The concept of a 'lost demand cost' is strange. In EC decreased demand leads to negative costs (i.e. benefits), e.g. less dependence on fossil fuels, improved health, etc.

The concept of 'lost demand cost' as adopted (for the first time represented in the results in an explicit way) in TUMATIM-TIMES covers only the non-beneficiary aspects of lower energy demand to the economy. They represent the costs of non-fulfilled demand – i.e. they reflect the overall willingness-to-pay of consumers to raise their energy consumption levels back to the level of the TUMATIM reference scenario. How (else) do you explain historic evolution, the growth of the demand for energy services (ES)? If there is a growth in demand for ES, this means a high level of ES demand has an economic value for consumers. Can we say that limiting the ES of others (BRIC countries?) do not change their future welfare?.

Comments:

- The way this 'lost demand cost' is represented (i.e. by a high red bar) seems to suggest that it represents the degree of popular resistance to low-carbon futures. Imagine how such a representation would be interpreted by e.g. the council of ministers... Represent it in a different way, e.g. at least including also beneficial effects on health, ecosystems, etc.

- There is demand for energy services, but you can have welfare in other ways. Total welfare costs can only be calculated correctly if you have a link to a macro-economic model. At the FPB, there have been studies coupling PRIMES with HERMES, a macro-economic model for Belgium. In TUMATIM-TIMES welfare costs are only limited to the energy system. These represent only 10% of total market costs. [WN: a macro-economic model that is calibrated with TIMES will have a loss of welfare that is rather similar, except for the second order effects of income loss. WN will include this discussion in the report later.]

- The transition to a low-carbon future implies that demand for energy services will be met in a structurally different way. Transition implies that we change our behaviour, whereas TUMATIM-TIMES modelling implies that behaviour is (relatively) fixed: people do not change their willingness-to-pay for certain energy services. It is important to highlight the consequences of this assumption.

- In the IPCC report, we have the technologies to reach -50% globally, while allowing good enough standard of living; that require changes in lifestyle (e.g. smaller houses or passive houses) but not loss of comfort. It is dangerous to put costs of lost demand next to investment costs, and not next to benefits. That is why a macro-economic loop is important.

[On changes in lifestyle]

Comments:

- In SEPIA B++/T+ changes in behaviour are portrayed as far-fetched and utopian. In B0/T++ it is assumed that as long as we can add up new promising technologies, drastic CO_2 reduction will be met. In reality, technology (efficiency) improvements only manage to reduce relative GHG emissions, but not in absolute terms. As a matter of fact absolute CO2 emissions are still on the increase. It is not either/or. Research on (social) behaviour is a topic on itself. Behaviour is very difficult to model quantitatively, but (there is increase) in research on qualitative studies of behaviour of all main societal actors or decision-makers. Smart combinations of technology and behaviour can in some instances induce behavioural changes and vice versa. This may be the most promising way forward.

- Absolute increase in CO_2 emissions is caused by increased efficiency, because that puts downward pressure on costs (prices) of Energy Services [ES], which leads to higher consumption of energy (i.e. the rebound effect). So governments need to put a price on carbon. Or put a ceiling or 'maximum budget' of carbon emissions – e.g. not only limiting CO2 emissions at the EU level, but also at the level of individuals or households.

- Discussion around the implementation of the EU 20-20-20 package have shown the relation between efficiency and GHG emissions. Full adoption of the non-binding target of 20% efficiency by 2020 shows that GHG emissions in the EU would fall by 25% in 2020. This of course has an impact on the CO2 price. For policy makers it is interesting to know i) how do these two (efficiency measures and carbon prices) interact?, and ii) do we have to take allowances of the market?

[On carbon prices]

Comments:

- Instead of starting backstop technologies once carbon prices get (very) high in economic optimization models, (it would be) more interesting to explore and 'play with' the constraints you put in the model. Prices of 600 €/ton are completely unrealistic (this was also the case in some of the scenarios run for the CE2030). In such cases, you have to look for the constraints in the model which are causing the high carbon prices, and consider which indications they give for policy-making and whether they should be relaxed or not. Such an analysis gives more interesting information to policy makers than simply assuming that a backstop technology will become available. [WN: correct, thanks for the advice. This will happen in the future for biomass and wind potentials. However, be aware that the Belgian TIMES model prefers the backstop technology to the PV technology. This is mainly because of the difficulties to lower emissions in the transportation sector.]

- Approaching the problem of consumer behaviour only via carbon prices assumes you have to work with price elasticities. Even if carbon prices are high, this is only relevant if price elasticity is high enough. If Energy Services (ES) have low price elasticities, then even high prices would have limited influence. To have a more adequate picture of consumer behaviour, it is important to know what the 'motivational factors' are to qualitatively identify the changes in behaviour (or) lifestyle. Environmental properties are generally placed low on the list of motivations. Prices or other aspects are generally more important, but this should be investigated for specific cases.

[On big structural changes]

If prices increase, there will be structural changes in technologies and behaviour, which you cannot reproduce in models such as TIMES. Say (e.g.) large investments in public transportation, does that come out of TIMES?

No, there is no cross-price elasticity.

Comment:

- In future, public transport (may) be better in many ways, (and) then substitution will go faster. But the demand curve in a model such as TIMES is fixed. A structural change in society implies behaviour would be completely different, but then you require another demand curve.

- TIMES can only model marginal changes, but not the big changes. That applies to all economic models. Deep structural changes cannot be simulated with MARKAL. In LEAP you can make assumptions on such deep structural changes and calculate through their consequences. Therefore LEAP is not so much a model as it is a decision support tool.

- The question is: How do politicians initiate structural change? What helps politicians to concretize low-carbon future objectives? Here you have to go to political science, or the more narrative scenario methods used in transition management literature. In the EC Roadmaps there is also an interesting combination of visions embodying structural changes (e.g. assumption that only public transport is allowed in European cities in 2050) and economic optimization models.

Rounding up

- There are (many) "2050 studies" coming up. These discussions are fundamental, to make the different models more coherent; to make (more) meaningful comparisons. What is implied (what are assumptions) in the scenarios concerning activity levels / way of life; visions of 2050?

- Missing from the results is: What did SEPIA learn from TUMATIM, and vice versa? [interaction between models – see also FORUM meeting 2]

- Make more explicit comparisons, what are the differences between the scenarios in the two approaches, and why are the differences there? Action: more detailed results of assimilated scenarios will be made available to the FORUM members (in Excel spreadsheet), both for TUMATIM and SEPIA. VITO will try to make results more transparent, esp. concerning the so-called "front-end data".

- BELSPO should initiate some kind of platform, where all modellers in Belgium could meet every 3 month or so, and exchange ideas, assumptions, results, …

- Both approaches [TUMATIM versus SEPIA] are completely different. Approaches should be made more "synergetic" / "holistic". Plurality is better, but it is always interesting to be able to compare on the same basis; and even if models are not linked directly in a specific project, models should be made more relevant to policies.

CONCLUSIONS. - JC as usual will send draft of FORUM III meeting to all members for revisions. FORUM team will have internal meeting to discuss blueprint of final report, article etc. Draft final report has to be ready beginning December, and will be mailed to all FORUM members for comments. Detailed results will be made available in spreadsheet format. End of project January 2012 – details of how final results will be presented to be discussed with BELSPO (Igor).

ANNEX II: QUESTIONNAIRE

Dear member of the FORUM model user group,

We kindly invite you to fill in the following questionnaire. The goal of this questionnaire is to gain insight in your expectations with regard to long-term **energy system analysis practices** – i.e. the entire process in which data are gathered, assumptions are formulated, models are run, results are validated and fed into the policy process. The point of the questionnaire is therefore not to identify 'good' or 'bad' models, but rather to identify more or less 'useful' modelling approaches in the context of **energy system analysis** in support of appropriate **long-term energy strategic planning for Belgium**.

The questionnaire is designed solely for use within the FORUM project and responses will be treated anonymously. Responses will be used as a basis for discussion during the first FORUM workshop, to be organised in January 2011.

The questionnaire takes about one hour max. to complete. The working language of the FORUM project and of the related documents and mailings is English by default, but feel free to use your own language when responding to this questionnaire. We sincerely thank you for your time and effort !

The FORUM research group.

ENERGY SYSTEM ANALYSIS TODAY AND TOMORROW

How are energy system analysis results up till now mainly used in long-term energy strategy planning in Belgium?

(more than one answer is possible)

- ☐ Substantively, influencing contents of a policy proposal or implementation
- ☐ Opportunistically, in support of policy preferences
- ☐ Primarily for scientific research
- ☐ Model results have only a marginal influence on policy outcomes
- ☐ Other. Please describe.

[insert text here]

If you wish, you can add further comments or examples.

[insert text here]

Which issues/problems should be addressed in energy system analysis as a support for long-term energy strategy planning in Belgium, and what are the main shortcomings in today's practice?

(please select max. 5 issues/problems from the following list)

☐ Effects of market-oriented policies (e.g. taxes, subsidies, emission charges, tradable permits, etc.) on the energy sector

☐ Effects of non-price policies (e.g. eco-labelling, voluntary agreements, norms, standards, etc.) on the energy sector

☐ The rebound effect, i.e. the effect where behavioural responses to energy efficiency improvements lead to less energy savings than expected from a pure engineering view

Impact of energy innovations (e.g. new technologies, technological learning) and innovation policy on the energy sector

- ☐ renewables
- ☐ fossil-fuel
- ☐ nuclear
- ☐ energy efficiency

Impact of change in the energy sector

- ☐ on the wider economic system (e.g. creation/loss of jobs, shifts in volumes of international trade, etc.)
- ☐ on system reliability and energy security
- ☐ on greenhouse gas emissions
- ☐ on environmental parameters

☐ Distributional issues (inter- and intragenerational equity)

☐ Externalities (i.e. monetary evaluation of direct/indirect impacts)

☐ Uncertainties and risks (e.g. uncertainties related to technology development, risks of oil price shocks, etc.)

☐ Other (please specify)

[insert text here]

According to you, what are the main shortcomings in today's practice w.r.t. the 5 selected issues/problems?

[insert text here]

EXPECTED OUTPUTS

Realistically speaking, while carrying out energy system analyses choices have to be made w.r.t. the type of outputs resulting from the analysis and the expected level of precision. Given that energy system analysis in support of long-term energy planning cannot generate all outputs to a very high level of detail, what outputs – according to you – should an analysis at the very minimum generate in the following categories in order to be useful?

Please rank outputs in terms of priority (highest priority score 5; lowest priority score 1), and if possible give amount of detail required in terms of an acceptable margin of error (e.g. 1%, 5%, order of magnitude).

Resource use

Priority score: 1☐ 2☐ 3☐ 4☐ 5☐

Acceptable margin of error:

Energy demand

Priority score: 1☐ 2☐ 3☐ 4☐ 5☐

Acceptable margin of error:

Technology mix (both on supply and demand side)

Priority score: 1☐ 2☐ 3☐ 4☐ 5☐

Acceptable margin of error:

Costs

Priority score: 1☐ 2☐ 3☐ 4☐ 5☐

Acceptable margin of error:

Greenhouse Gas Emissions

Priority score: 1☐ 2☐ 3☐ 4☐ 5☐

Acceptable margin of error:

Other (please specify, e.g. environmental damage)

[insert text here]

SPATIAL AND TEMPORAL RESOLUTION

In order to provide meaningful results in the context of long-term energy strategic planning for Belgium, how important is the resolution for modelling following categories:

Please indicate the relevant checkboxes

	Resource use	Electricity Technology Mix and Costs	Non-electricity Technology mix and Costs	Greenhousegas emissions	Other environmental damage
Spatial coverage of the energy system analysis includes (besides the national level)					
EU	☐	☐	☐	☐	☐
Europe	☐	☐	☐	☐	☐
World	☐	☐	☐	☐	☐
Spatial resolution of energy system analysis includes					
Single building or industrial plant	☐	☐	☐	☐	☐
Neighbourhood or production site	☐	☐	☐	☐	☐
Municipality	☐	☐	☐	☐	☐
Provinces	☐	☐	☐	☐	☐
Regions	☐	☐	☐	☐	☐
Time horizon of energy system analysis includes the period up to					
2030	☐	☐	☐	☐	☐
2050	☐	☐	☐	☐	☐
2100	☐	☐	☐	☐	☐
Beyond 2100	☐	☐	☐	☐	☐
Temporal resolution of energy system analysis includes					
Daily intervals	☐	☐	☐	☐	☐
Monthly intervals	☐	☐	☐	☐	☐
Yearly intervals	☐	☐	☐	☐	☐
5-yearly intervals	☐	☐	☐	☐	☐

If you wish, you can add further comments or examples.

[insert text here]

EXPERTISE AND ROLE OF STAKEHOLDERS

According to you, how feasible and desirable is it that the following groups of stakeholders acquire a thorough understanding of how outputs of energy system analysis in support of long-term energy strategy planning in Belgium were reached?

(lowest feasibility/desirability score 1; highest feasibility/desirability score 5)

	Feasibility					Desirability				
	1	2	3	4	5	1	2	3	4	5
Energy suppliers	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Grid operators	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Regulators	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Environmental NGOs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Consumer organisations	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Journalists	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Labour unions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Employers' organisations	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Industrial associations	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
General public	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Policy advisors	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other (please specify) [insert text here]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

According to you, how desirable is it that the following groups of stakeholders actively participate in the energy analysis process itself?

(lowest desirability score 1; highest desirability score 5)

	Desirability				
	1	2	3	4	5
Energy suppliers	☐	☐	☐	☐	☐
Grid operators	☐	☐	☐	☐	☐
Regulators	☐	☐	☐	☐	☐
Environmental NGOs	☐	☐	☐	☐	☐
Consumer organisations	☐	☐	☐	☐	☐
Journalists	☐	☐	☐	☐	☐
Labour unions	☐	☐	☐	☐	☐
Employers' organisations	☐	☐	☐	☐	☐
Industrial associations	☐	☐	☐	☐	☐
General public	☐	☐	☐	☐	☐
Policy advisors	☐	☐	☐	☐	☐
Other (please specify) [insert text here]	☐	☐	☐	☐	☐

How important is it to your organisation to gain a profound operational knowledge of the models used in energy system analysis? Please explain.

[insert text here]

Would your organisation be interested in using energy system models (e.g. enabling you to model new scenarios, alternative assumptions, etc.)? Please explain.

[insert text here]

METHODOLOGY / APPROACH

In the context of long-term energy strategy planning in Belgium, do you have any preferences (if any) for certain types of modelling methodology and/or approach?

(more than one answer is possible as more than one model can be used in energy system analysis)

METHODOLOGY

- ☐ Simulation
- ☐ Optimisation
- ☐ Partial economic equilibrium
- ☐ General economic equilibrium (CGE or macro-econometric)
- ☐ Integrated assessment
- ☐ Energy accounting
- ☐ Other (specify)

[insert text here]

APPROACH

- ☐ Top down
- ☐ Bottom up
- ☐ Hybrid

If you wish, you can add further comments or examples.

[insert text here]

OPTIONAL SUMMARY STATEMENTS

According to you, what main benefits do you expect from the use of energy system analysis to support the long-term energy strategy planning process in Belgium? [insert text here]

According to you, what are the major potential pitfalls when using energy system analysis to support the long-term energy strategy planning process in Belgium? [insert text here]

ANNEX III: COMPARISON TUMATIM-TIMES / SEPIA-LEAP

TUMATIM -TIMES	
Model focus	Belgian climate policy, energy consumption and production, local air pollution.
Model output	Technology choices, primary and final energy consumption and emissions across sectors, energy carriers, years and scenarios. Costs of energy system.
Capability to model energy policies	Price policies (taxes, subsidies, certificates) and non-price policies (emission ceilings, targets).
Capability to model economic and social effects	Energy system costs and damage costs: YES; Labour: only when coupled with a macro-economic model like GEM-E3.
Capability to model uncertainty and to assess risk.	Sensitivity analysis, trade-off analysis to include distribution of expected costs, hedging strategies to include temporary uncertainty around a technology or an environmental policy.
Model scope	Belgium (country)
Time horizon & transition path	Medium to long term (20 to 100 years), variable time-steps
System boundaries	Residential & Commercial, Industry (energy intensive & non-intensive sectors), Transportation, Agriculture. Transformation: Power sector, Refineries. Imports determined by the European model.
Energy commodities	All energy carriers.
Emissions	All GHG included in the Kyoto Protocol and local pollutants (NOx, SO_2, VOC, PM)
Technology representation	Explicit technological data.
Technology competition	Conversion technologies are described in detail, leading to competition between conversion technologies.
Analytical approach	Bottom-up, perfect foresight, lowest (social) costs, behavior calibrated on the basis of willingness to pay.
Model type	Optimization with elastic demand. Back-casting. Simulation possible for visionary scenarios
Degree of endogenization.	Reference energy service demand, fuel prices, technology information and costs are provided as exogenous input to the model. Endogenous prices, technology choices and scenario energy service demand.
Technological progress characterization	Technological progress is time-dependent. Only exogenous learning in the Belgian TIMES model.

SEPIA-LEAP (Long-Range Energy Alternatives Planning system	
Model focus	Tracking energy consumption, production and resource extraction in all sectors of the Belgian economy + tracking all related GHG emissions.
Model output	Energy consumption across branches (sectors / subsectors), energy carriers, years and scenarios. Energy conversion, transmission/distribution, imports/export and primary resource requirements. All energy-related GHG emissions.
Capability to model energy policies	Non-price policies only.
Capability to model economic and social effects	No.
Capability to model uncertainty and to assess risk.	Deterministic model, but with extensive possibilities for sensitivity analysis.
Model scope	Belgium (country)
Time horizon & transition path	Medium to long term (20 to 50 years), annual time-steps
System boundaries	Demand: buildings (dwellings & commercial buildings), industry (energy intensive & non-intensive sectors), transportation, agriculture. Supply: main power, CHP, petroleum refineries, bio-fuel plants and hydrogen plants. Domestic primary energy production + all imports.
Energy commodities	All energy carriers.
Emissions	All GHGs (included in the Kyoto Protocol).
Technology representation	Technology cards with explicit technological data.
Technology competition	Conversion technologies are described in detail, leading to competition between conversion technologies.
Analytical approach	Bottom-up, with basic relationships based on non-controversial physical (energy) accounting.
Model type	Forecasting / Back-casting / Scenario analysis
Degree of endogenization.	Very limited. Data are provided as an exogenous input to the model.
Technological progress characterization	Technological progress is time-dependent. Different technologies with higher efficiencies enter the market in different years.