Modelling the energy use of products

A review of approaches from practice

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Abstract
This report describes the 'Strategic modelling approach review' project conducted by ECN for AEA Technology from the United Kingdom (acting on behalf of the Defra department). Defra runs the Market Transformation policy programme (MTP) to develop and implement policy on sustainable energy using products. AEA supports this programme with the MTP modelling approach. The research objective was to identify potential options for AEA to improve the cost effectiveness of the MTP modelling approach. From an overview of comparable modelling approaches from countries across the world and from other research findings, key areas are identified for which options are evaluated. The key areas include the focus of modelling efforts in scope and detail, the evidence data analyses and calculations, output possibilities, validation and verification, and the evidence data used and data collection methods.

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Summary

This report describes the ‘Strategic modelling approach review’ research project conducted by ECN for AEA Technology from the United Kingdom, which is acting on behalf of the Defra government department.

AEA operates the MTP modelling approach. This approach is used to support the Market Transformation Programme, a policy programme run by Defra, which aims to develop and implement government policy on sustainable energy using products.

The MTP approach is a bottom-up, technology-based modelling approach that uses an accounting technique as the main calculation method for managing data and results. The MTP approach includes a calculation model and an evidence base to support the approach. A typical characteristic of a bottom-up approach is the detailed information and data that are included, which generally requires substantial modelling efforts. An important aspect of the MTP modelling approach is that a large part of the calculations done are not performed by the calculation model, but outside the calculation model.

AEA wanted to commission a study to identify opportunities to increase efficiency of the MTP approach while maintaining or improving its quality. The objective of this study therefore was ‘to qualitatively identify the potential options for AEA to cost effectively improve the MTP modelling approach’. An overview was made of comparable modelling approaches from other countries across the world. Based on these and other research findings potential options for AEA are suggested.

The project comprised a webinar, a literature study, a questionnaire and a workshop. The webinar, an online, live meeting in which the MTP calculation model was demonstrated, was the starting point. The literature study provided theoretical findings on the modelling approaches that are subject of the study. A workshop was held to consult experts about their modelling approaches and modelling experience. The search and selection of experts was part of the research. The experts were sent a questionnaire, including the literature study to provide background information and guidance, to collect information serving as input for the workshop.

The overview of modelling approaches shows that the approaches reviewed are very similar to the MTP approach. Almost every approach is characterised as a technology-based and bottom-up model. They are either stand-alone models, or modules being part of a larger (energy system) modelling approach. There are various modelling techniques applied, although the accounting technique is most commonly used. A non exhaustive overview is provided of several other characteristics, such as inputs and model results, evidence data collection methods, validations methods, and important challenges and improvements to the approaches.

Potential options to increase quality and efficiency of modelling are identified for the MTP approach. This is done for key modelling areas. The recommended options for AEA imply a shift, change or expansion of activities and model features. Due to the limited scope of this study the recommendations are rather general. They do not describe detailed actions for direct implementation in the MTP modelling approach.

The key areas and options evaluated are listed here:

Focus in scope and detail: focus modelling efforts by choosing the extent to which energy using products (scope) and which parameters (amount of detail of inputs) are modelled.

Options:
- Focus on relevant energy using products: for example choose only the products that represent the largest share of energy consumption or have the largest savings impact from policy supported by the MTP approach.
- Focus on relevant model parameters: for example choose per energy using product whether or to which extent parameters such as product ownership, usage and efficiency need to be modelled by considering their impact on modelling results.
- Model the choice of focus and detail: create for example a dashboard within the model.

Evidence data calculations and analyses: include in the calculation model or expand the modelling approach with those analyses, assumptions and calculations on the collected evidence data that are currently conducted outside the model.

Options:
- Model behavioural influences: for example create cost-benefit curves in the model that take into account the influence of (economic) behaviour.
- Model the 'average unit energy consumption' calculation: standardise this calculation by including it in the model itself, as the calculation currently requires significant efforts on the part of AEA outside the calculation model.

Output possibilities: include in the calculation model or expand the modelling approach with (additional) output calculations.

Options:
- Include an 'energy use decomposition method': this implies modelling separately, and in this way making transparent, the impact on energy use of developments in ownership, usage and efficiency over time.
- Model savings calculations: create specific savings calculations within the calculation model.

Validation and verification: include in the calculation model or expand the modelling approach with validation and verification methods.

Options:
- Model calculation checks: for example create checksums within the calculation model.
- Model output and input validity checks: for example create a check of historical data, previous model results, or results from other approaches within the model.
- Model sensitivity analysis: create such an analysis within the model.
- Model uncertainty analysis: create such an analysis within the model.
- Model a calibration method: create such a method to act on the findings from sensitivity and uncertainty analysis within the model.

Evidence data used and data collection methods: change the way in which evidence data is collected and which evidence data to use as input.

Options:
- Change or expand evidence data collection methods: for example use survey data.
- Standardise data collection that is outsourced to external consultants: standardise the way in which data is requested from external consultants and the way in which external consultants are required to deliver data.

General and specific advantages and disadvantages are indicated for the options. The main advantage is that modelling efforts can be reduced. Other advantages are standardization and self documentation of modelling activities. These increase transparency of the modelling approach, which results in improved insight in the model inputs and results and facilitates model audits.

The main disadvantage is that the options require short-term investments. However, these can lead to lower modelling operation and maintenance efforts in the long term. Another disadvantage is that the options imply some loss of flexibility of the approach, as parts of the approach will no longer be tailor-made.

1. Introduction

The Energy research Centre of the Netherlands (ECN) conducted the 'Strategic modelling approach review' project for AEA Technology (AEA) from the United Kingdom, which is acting on behalf of the Department for Environment, Food and Rural Affairs (Defra).

Defra is responsible for the Market Transformation Programme (MTP), a policy programme that aims to develop and implement UK and EU government policy on sustainable energy using products (EuP). The primary focus is on products that consume electricity and are used in the built environment.

The programme is supported by AEA's MTP modelling approach, which is used to analyse and support the actual and potential impacts of policy on energy using products. This approach comprises a calculation model and an evidence (data and knowledge) base supporting the approach, respectively referred to as the calculation model and the evidence base. AEA develops, maintains and operates the modelling approach, including the evidence base. Besides the primary objective, which is to conduct policy analyses for Defra, the modelling approach is also used for other national and international clients.

The MTP modelling approach is technology based and bottom-up. This implies that it contains a high level of detail in terms of energy using products and parameters modelled. Therefore, the approach offers detailed insight in the environmental performance of individual EuPs and impact of policies. However, this bottom-up approach is very intensive in terms of evidence data requirements. Modelling efforts, especially for evidence data collection and analyses conducted to obtain direct input data, are perceived to be relatively large. This could render the approach less efficient than other suitable modelling approaches.

Defra is in search of opportunities to increase the efficiency of the modelling of energy using products. This lead AEA to commission a research study on options to increase efficiency for the MTP modelling approach, without reducing the quality of the outputs, whilst looking at ways to improve them.

For this study the complete MTP modelling approach, the calculation model and evidence base, were benchmarked against alternative modelling approaches applied in countries across the world. AEA provided ECN with a list of research questions to be addressed, including priorities.

The research objective of this study is summarised as follows: *to qualitatively identify the potential options for AEA to cost-effectively improve the MTP modelling approach***.**

ECN addressed the research objective in a number of steps:
- A literature study, including a study on the MTP calculation model.
- An inventory and selection of alternative modelling approaches applied across the world, and selection of international experts involved in these approaches.
- A questionnaire to the experts involved in selected alternative modelling approaches.
- A workshop with the experts.

This report summarises the findings of the research study. Chapter 2 provides the background of the Market Transformation Programme, the MTP modelling approach, the key research questions and briefly explains the research approach applied. Chapter 3 gives an overview of the modelling approaches reviewed. Chapter 4 evaluates the potential cost-effective options for the MTP approach. Chapter 5 presents a discussion on the findings and limitations of the study and provides suggestions for further research. Appendixes A and B provide overviews of concepts and definitions used, and details of the selected alternative modelling approaches .

2. Background

2.1 The Market Transformation Programme (MTP) modelling approach

The UK Government's sustainable development policy to reduce carbon dioxide (CO_2) emissions includes policy to reduce energy consumption in demand sectors. One of the focus areas is energy using products, particularly those used in buildings and dwellings (the built environment).

The trends of a rising energy consumption have led the government to establish the Market Transformation Programme (MTP), for which Defra is responsible. The MTP implements energy saving policies that target energy (mainly electricity) using products. Under the MTP, Defra is responsible for creating, evaluating and developing specific policies focusing on specific EuPs.

The MTP leads to several questions for Defra regarding the impacts of existing and potential policies on energy using products. AEA is responsible for providing answers and information for these questions, by delivering studies and by offering an hoc enquiry service. The main information source AEA uses for this is the MTP modelling approach.

The MTP modelling approach has to be adequate to support the following activities of Defra:

- Development, assessment (including Impact Assessment) and agreement of policies on standards (e.g. labelling, minimum and/or incentivising standards) for energy using products, both nationally as well as at European and/or international level.
- Development, assessment (including Impact Assessment) and agreement of other policies that affect the performance and sustainability of energy using products (e.g. behavioural policies, public procurements, etc).
- Assessment of policy costs and benefits, in terms of moving from current or baseline scenarios to policy scenarios.
- Feeding into the wider UK Government evidence or target setting programmes, including monitoring progress against target set (such as those models underpinning the setting of Carbon Budget targets for the UK).
- Engagement with industry, retailers and other interested parties so that a common understanding is reached on how environmental impacts from these products can be mitigated (such as action plans that are agreed and measures implemented).

The current MTP approach is viewed as providing the best way to offer answers to the detailed, EuP specific policy questions of Defra. General policy questions that need to be answered are how energy consumption by EuPs will develop in the future and what the impacts of policies in terms of savings are or could be. AEA is capable to support Defra on this. With the MTP approach AEA can analyse the developments of energy consumption and savings of individual products and impacts of specific products policies.

The current MTP modelling approach can be characterised as an technology based, bottom up type, stock model. The main characteristic of such an approach is high detailedness, meaning that model results can be delivered and inputs are required on a detailed level. Inputs and outputs are modelled in the MTP approach for a large number of individual energy using products (technologies). For each individual product, parameters as ownership, usage and specific energy consumption (power) are modelled as input data, whereas energy consumption, savings and costs and benefits are model results. The MTP calculation model therefore is impressive in terms of details modelled, but it is clearly structured. The MTP approach also is a stock model. It calculates the stock of individual energy using products, often based on input data on sales and replacement (lifespan of products). The model can further be regarded as an accounting model. This means the approach mainly aims to manage data and results (Mundaca et al., 2010). Underlying assumptions and (intelligent) analyses conducted to arrive at direct input data, are not performed within (or by) the MTP calculation model but are performed outside it.

2.2 Subject, scope and terminology

The subject of this research are modelling approaches. We explicitly define the boundaries of this subject as not only a calculation model to support policy analysis, but also the knowledge or evidence base that supports the model in particular and the MTP in general. The recommendations of this research regard both aspects of the modelling approach.

The scope of this research follows the scope of MTP modelling approach, which are the technologies, sectors and policies that are modelled. This research focuses on policies that impact the energy consumption of products used in buildings and dwellings. These are denoted as energy using products, of which electricity using products are a subcategory. Such products are specific technologies like appliances (e.g. 'white goods' like refrigerators, dryers, audio-video/IT/TV), lighting, and installations (e.g. for heating, hot water, cooling, aircon, pumps). The main policies affecting these technologies are minimum efficiency requirements (such as the EU Eco-design) and labelling policies (such as the UK Eco-label), although a variety of other policies are modelled or might need to be in the future. Sectors addressed by the policies are residential dwellings, non residential buildings and industry. The focus is not on energy related products, as these do also not currently have the focus in the MTP approach.

The terminology and definitions used in the report are clarified in Appendix A, to ensure a common understanding of concepts used in this study.

2.3 Key research questions and deliverables

The research questions, clustered and prioritised (questions with priority are in bold), are listed below.

Context of policy modelling:
- **What are the main outputs obtained by each approach, and how frequently are the outputs delivered? What are the main outputs used for in various countries?**
- What are the drivers for products policy modelling in the respective countries, and how is this reflected in the level of effort expended and the choice of modelling approach?
- What is driving the trends identified for novel market transformation models? Are those trends local, national or international?

Approaches for policy modelling:
- **What modelling and wider evidence base management approaches are applied in each one of the chosen countries? (i.e. top-down/bottom-up methodology or a mixture of both)**
- What are the main strengths and weaknesses related to each approach?
- What is the scope; which industries and products are considered in each programme?
- What has been the biggest challenge to each approach and what steps are being / were taken to overcome it?
- Which assumptions are significantly different between each approach?
- How user-friendly is each model?

Data and calibration:
- **How do other programmes obtain evidence data to feed into their models?**

- **How the results from the modelling are validated and verified?**

Costs and complexity:
- **In general, model complexity involves a trade-off between simplicity and accuracy of the model. Considering their predictive power, how complex is each model?**
- **What is the cost to set up, run, maintain/update and validate each approach?**

Evaluating policy modelling:
- **What are the risks to the UK for adopting an alternative approach?**
- How satisfied are the participants with each approach?
- How does the UK approach compare with the approaches reviewed?
- Not addresses separately, but underlying all other issues (questions)

ECN chose to focus the research on the key objective formulated. This report will not in a structured way describe the answers to the key research questions, but instead reports directly on the potential options. The key questions of AEA are still addressed in this report, although many indirectly.

The basis for the recommendations from this research are findings from theory and practice. To provide a theoretical background, a literature study was conducted and a webinar was held in which AEA demonstrated the MTP calculation model. For findings from practice a workshop and questionnaire were conducted, to collect information and opinions from experts involved in other modelling approaches. In the workshop experts were consulted on their approaches, to learn from the experience in different countries. Modelling approaches from the following countries were represented: Australia, United States, Canada, Belgium, Denmark, Germany, Finland, and the Netherlands. A filled-in input document about a modelling approach applied in Japan is included as separate deliverable, but was not available to ECN in time to be considered for the report. Prior to the workshop, an input document was sent to experts which included the literature study and the questionnaire. Experts were also asked to complete and present on the workshop a standard presentation based on their questionnaire answers. Finally, it is explicitly noted that the information from the experts represent their personal views.

A major part of work for the project involved finding and selecting experts for the workshop. Around 25 to 30 experts were found, that are familiar with approaches similar in objective to the MTP approach and were suitable for and interested in the workshop. AEA selected eleven experts based on suggestions of ECN to invite to the workshop, of which ten were able to attend the workshop. Including the approach of ECN but considering two experts representing the same model, also eleven different modelling approaches are the basis of this research.

The original input document is part of this publication, as separate document. Other findings from theory and practice used for this report are delivered as separate attachments to the publication: all filled-in input documents, the presentations of the experts, an ECN workshop presentation, and the webinar minutes. Detailed information about each modelling approach is therefore available separately.

3. Overview of modelling approaches

This chapter provides an overview of the modelling approaches that have been subject in the study. After an overview in the next section of general characteristics of the selected modelling approaches, several other characteristics are illustrated in the following sections: inputs and model results, evidence data collection methods, validations methods, and important challenges and improvements to the approaches. This chapter is not intended to provide an exhaustive overview.

3.1 General characteristics of modelling approaches reviewed

Table 3.1 presents general characteristics of the approaches reviewed. This has the aim of 'positioning' the approaches, rather than labelling them.

Table 3.1 *Overview of modelling approaches reviewed*

Modelling approach	Country	Basis structure	Stand alone/ Energy system model module	Main modelling techniques	Main policy types analysed
MTP	GB	Technology, bottom up	Stand alone	Accounting	Existing, Future
EVA	NL	Technology, bottom up	Stand alone	Accounting	Past, Existing, Future
EES	AU	Technology, bottom up	Stand alone	Accounting, various	Past, Existing, Future
ELMODEL	DK	Technology, bottom up	Stand alone	Simulation	Past, Existing, Future
DEESY	DE	Technology, bottom up	Module of energy system model	Accounting	Past, Existing, Future
ECM	BE	Technology, bottom up	Module of energy system model	Optimisation	Existing, Future
TIMES	DE	Technology, bottom up	Module of energy system model	Optimisation	Existing, Future
Kotitalouksien	FI	Statistical analysis	Stand alone	Statistical	Past, Existing
CIMS	CA	Technology, bottom up	Module of energy system model	Simulation	Existing, Future
NEMS - RDM and CDM	US	Technology, bottom up	Module of energy system model	Simulation, Econometric	Existing, Future
NEMS - LCC and NIA	US	Technology, bottom up/ Top down	Module of energy system model	Accounting, Statistical	Existing, Future

This information is based on information provided by experts in the questionnaire and at the workshop. These provided better insight in the general characteristics of the modelling approaches, allowing to make a general overview of similarities and differences. Included in Appendix B are the 'fingerprints' of the models as presented at the workshop, based on the questionnaire, which are more elaborate.

The overview shows that according to their basic structure, all modelling approaches except for the statistical approach are technology-based, bottom up models. They are either stand alone approaches or modules of larger energy system modelling approaches. Techniques applied vary, as models primarily based on accounting, simulation, optimisation (e.g. linear programming in

ECM, partial equilibrium in TIMES) and/or econometric analyses are all present. The accounting technique is most common, which seem usually the basis for stand-alone approaches. Except for the statistical approach, all modelling approaches can perform projection. Furthermore, not all approaches are able to do an ex post evaluation of impacts from policies in the past.

Each expert also provided information on the modelling approaches background, including the drivers for energy using products policy modelling (who is the model owner, who are clients, geographical scope, time frame of the model results). This information is not summarised here, but was taken into account for the selection and elaboration of the potential options.

Several other characteristics of the approaches are illustrated in the following sections.

3.2 Inputs and model results

The level of inputs and model results for most modelling approaches are individual energy using products. Regarding input data and model results several different types are found, which are summarised below.

Types of input data:

- The main input data explicitly fed into the modelling approaches, either endogenously or exogenously determined, are ownership data (stock, sales, market shares, life spans) and characteristics of energy techniques (e.g. specific consumption/power and usage hours/cycles etc). This is mainly the case for the accounting approaches.
- Other input data found that is explicitly, or also endogenously determined are: load curves to reflect energy usage (e.g. TIMES), efficiency factors or learning effect (e.g. CIMS), energy prices or CO_2 prices (e.g. DEESY, ECM, TIMES, CIMS, NEMS), elasticities (e.g. NEMS), investments, O&M costs, energy system costs, fuel prices (e.g. TIMES), discount rates possibly varied to reflect economic behaviour (e.g. ECM, TIMES), behaviour hurdle rate (e.g. ECM), macro economic data (income, productivity) (e.g. NEMS, TIMES), non economic behaviour (e.g. Kotitalouksien, CIMS, NEMS) and energy savings in %, implementation degree and application degree (e.g. ECM)[1].

Types of model results:

- As expected, all model approaches except for the Kotitalouksien statistical analysis, deliver energy (mostly electricity) consumption/demand and energy savings of appliances. Although not all approaches do this within the model itself (e.g. for ELMODEL savings are calculated outside the model, for DEESY savings are calculated in energy system model). The Kotitalouksien approach delivers the distribution of consumption over categories, like per reference household or housing type. Another specific feature of one of the models (EVA) is decomposition of electricity use in volume, structure and efficiency effects over time.
- Emissions (GHG, other) are delivered by a number of modelling approaches, although a significant number do not deliver these by the model itself (e.g. not by EVA, ELMODEL, ECM).
- Most approaches can also deliver results for different energy carriers.
- Some approaches, mainly the energy system model modules, incorporate economic aspects such as investment and operation & maintenance (O&M) costs (e.g. DEESY), electricity and CO_2 prices (e.g. Times), or societal costs and benefits (e.g. TIMES, EES, ECM, NEMS). Least-life cycle cost impacts from policy per appliance type or group for example are modelled by NEMS-LCC.
- Some modelling approaches deliver results in other categories: examples are other air pollutants (e.g. TIMES) and health effects (e.g. CIMS).

[1] Some of the data mentioned may actually (partly) represent intermediate model results instead of input data, if there have been model calculations involved to create them.

3.3 Evidence data collection methods

The main evidence data collection methods or data sources are government statistics (total energy/electricity consumptions, number of households, ownership of appliances), external expert judgement and literature (e.g. Eco-design preparatory studies, forecast studies).

Other examples are surveys or questionnaires (e.g. EES, ECM, ELMODEL), billing data from energy companies (e.g. ECM, NEMS), actual metering (e.g. EES), and results from other modelling approaches (e.g. TIMES).

3.4 Validation and verification methods

Included in many approaches models are general updates, consistency checks, and calibration to act on (correct for) deviations that are encountered.

Also other validation and calibration methods of the approaches reviewed have been mentioned. These are either performed outside the model, or by the model itself. Examples are scenario or sensitivity analysis (e.g. ECM, TIMES, DEESY), metered consumption in situ (e.g. EES), parametric programming techniques (e.g. TIMES), statistical validation such as specification tests or t-statistics (Kotitalouksien), discrete choice surveys to assess consumer preferences (e.g. CIMS), backcasting, public meeting and comments periods (e.g. NEMS), consult with external parties (e.g. CIMS), and a cross check of input data and/or model results with other forecasts possibly from other countries (e.g. EES, CIMS, TIMES).

3.5 Important challenges and improvements

The modelling approaches pose several important challenges for their development and use, now and in the future. For some approaches solutions have been found and improvements made. A short summary is given here:

- Clearly the main current challenge for many modelling approaches is obtaining evidence data. Either evidence is lacking or it cannot reasonably be acquired. This particularly concerns data on usage of appliances, for example there is a lack of actual measurement data, and some appliances in general (e.g. cooling).
- A well known challenge is creating the reference or business as usual scenario.
- Main expected challenges for the future are to evaluate past policies, how to include unknown (new) products and expected 'smart' appliances, to improve modelling for the non-residential sector, to incorporate behavioural aspects, to achieve realistic results for far future years, to improve flexibility, and to deal with a complex model as a user.
- Other challenges found are: matching sum of end uses for validation (e.g. EES), computer capacity (TIMES), deciding on the optimal level of detail in a module, representing proposed legislation, modelling learning (e.g. NEMS), available data on development of energy labels in stock and technological input assumptions (e.g. EVA).

3.6 Other findings

Several other findings are worth mentioning:

- The EES approach indicates to check with previous projections for learning rather than for validation. This implies a quality check, for example on modelling assumptions done.
- The main software used for the accounting approaches, but also by other approaches for accounting purposes, is Excel (with or without using Visual Basic for macro programming). Other examples of software used are Fortran (e.g. NEMS), propriety software based on Del-

phi (e.g. ELMODEL), Java (e.g. CIMS), Access (e.g. ECM), Chrystall Ball add-on (e.g. NEMS-LCC), GAMS for modelling, and ANSWER, VEDA-FE and VEDA-BE for input and results handling (e.g. TIMES).

- Most modelling approaches deliver results for every five years (e.g. 2000, 2005 etc.). This probably implicates that model results for years in between are primarily based on interpolation. This can particularly limit the usability of results for evaluating past policies, a modelling activity actually hardly seen among the approaches reviewed.
- For several modelling approaches background studies have been mentioned that provide additional information. Some references to these can be found in the modelling approach presentations and input documents.

4. Potential options for the MTP modelling approach

4.1 General remarks

The options described in this chapter reflect potential actions for AEA to improve the cost effectiveness of the modelling approach. More specific, the goal of the options is to increase the quality and flexibility of the modelling approach at minimal investment cost, in order to decrease future costs required for operating and maintaining the modelling approach.

In this chapter *potential* options are recommended. The options are suggestions for choices that AEA can make about which activities or model features to improve or change and how this might be done. For most of them, possible decision options are formulated.

The options are categorised according to *key areas*: these are the areas in which the MTP modelling approach could be improved by increasing quality and efficiency.

The options evaluated do not affect the very nature of the MTP modelling approach, but are rather confined to modifications within the current basic set-up. Given the required results, it appears to be undesirable to radically change the fundamental (technology, bottom-up) nature of the modelling approach. Basically the approach seems to be suitable for its objective or purpose, as confirmed by literature and the modelling approaches applied by the participants of the workshop. These included almost solely engineering, bottom-up stock models (either stand-alone, or as module within a broader modelling framework). Such approaches are widely used for purposes similar to those of the MTP programme and seem to be recognised by experts consulted as the most suitable modelling approach for its purpose.

Whether the potential options indeed provide improvements depends on the requirements of Defra, the user requirements of AEA, and the detailed (technical) adjustments needed. ECN has insufficient insight in these aspects to assess the detailed consequences of the options..

4.2 Potential options in key areas

The key research questions that have high priority for AEA and the research findings were at the basis of selecting the key areas and options evaluated for each area.

This chapter will describe the identified potential options for the MTP programme, clustered in the following key areas:

- Focus in scope and detail.
- Evidence data analyses and calculations.
- Output possibilities.
- Validation and verification.
- Evidence data used and data collection methods.

An important part of the options has consequences for the balance between the activities within the modelling approach. The MTP modelling approach comprises a core calculation model, which is fed by external analyses. These external analyses are not standardised, and only part of the information that is generated in the external analyses is transferred to the core model. As defined earlier, the options apply to the MTP modelling approach as a whole: the core model as well as the external analyses including the evidence base that supports the model and MTP programme in general. Many options imply a (partial) transfer of functionality that is currently part of the external analyses to the central core model. This would also require further standardisation of the way in which the results of the external analyses are realised. Other options involve inclusions of activities that are currently not conducted as part of MTP approach. In this report, the term 'internalisation' or 'making endogenously' refers to the transfer of functionality from the external analyses to the calculation model, and 'expansion' to the inclusion of functionality that is currently not provided by the MTP approach.

All the options evaluated can be implemented in different degrees of intensity. For example, including in the approach of the external analyses in the model algorithms can be done completely or only partly, and choices with regard to focus and detail more or less represent a continuum.

There are some general advantages and disadvantages attached to modifications in the key areas, which are discussed in the next chapter. Advantages and disadvantages specific for the options for each key area are described in the separate sections of this chapter.

4.2.1 Key area 1: Focus in scope and detail

The first key area for AEA is to focus the modelling approach and efforts on the most important specific products and parameters. The MTP model is quite impressive in terms of its extensiveness and detail of inputs and outputs. Focus here means choosing the level of efforts, i.e. which activities to conduct in collecting evidence data, performing analysis and calculations and deriving assumptions, and feeding input into the model.

Choices of focus in scope and detail can be made on different levels present in the calculation model (product area, product, sub product, or modes level). This key area therefore reflects the key question of complexity. Complexity is defined here to consist of scope complexity (which products are modelled), detail complexity (which parameters are modelled for each product), and conceptual complexity (how sophisticated are calculation methods and modelling techniques). Here the focus is only on scope complexity and detail complexity.

Focus in scope and detail is perceived to be the logical first key area, as it will probably mostly define efforts required for other areas discussed in the next sections.

Options

Decide which products to focus on
The main driver for choosing which products to focus on are the products targeted by current and expected future policies of Defra and other (government) clients, e.g. the MTP and other policies. The key policy questions of these clients for which the approach needs to provide 'answers', should be the main criteria for the focus.

There are other important drivers, which are listed below in logical order as to their decisiveness for choice of focus :

- Focus on products for which evidence data is available. Here, 'available' implies several criteria: the evidence data should be sufficient, should have reasonable quality (reliable, representative etc.), and should be obtainable at a reasonable cost. Such criteria hold for availability of data both now and in the future.
- Focus on important products ('energy-relevant products'). For example, put more effort in products that represent a significant share of total energy consumption, significant share of the energy saving impacts, or a significant share of policy attention.
- Focus on products which have possible modelling synergies. An option could be to look for synergies in modelling similar products. An example would be the similarity of calculations required for the fridge and the refrigerator, as their ownership, usage pattern and technical characteristics are rather similar.

The MTP model has a large scope of products and parameters modelled, as can be seen from the list of modelled techniques provided by AEA. Particularly the large numbers of sub-products and modes modelled in the calculation model leads to many modelled combinations for which inputs are required. A suggestion would be that AEA focuses only on key sub-products and modes, which in turn is only done for key products (or even product areas). More focus may result in leaving out particular appliances, or combining them in one category.

The EVA model presents an example of how such a focus can be modelled in practice. Here, only the single products representing significant shares of consumption have a stock model (e.g. 'white goods'), whereas for domestic lighting also sufficient detail is modelled, albeit with another method. For the other product areas the only input data are average ownership, average usage and average power.

Decide which modelled parameters to focus on
For this step largely the same considerations apply as those mentioned for products.

Modelling the choice of focus and detail
Focus on certain products should not necessarily imply that other products are left out. Instead, it may also be possible to differentiate between a coarse, default way to describe a less important product, as opposed to a more detailed, tailor-made approach for more important products. This could be facilitated by creating a 'dashboard' (a choice module) allowing the user to set the model for each run. Depending on the type of policy questions the dashboard can be set differently. This could be done manually, or automatically by the model in a more sophisticated manner . The selection model would be comprise a collection of 'buttons' that can be switched on or off in the model. Switching a button on or off would imply that a combination of appliances and parameters is run in a different way or not run by the calculation model. The EVA model is an example where such a method is available in the model. Another example could be the DEESY model, although the technology matrix in that approach seems to be used for simulation or optimisation (a technique not incorporated in the MTP approach).

Importance analysis may also help in determining which assumptions and product categories are most important for the results, and where efforts yield most in terms of accuracy of the results. This requires a systematic survey of the variance in specific assumptions and their impact on the results, for example by running the model several times, modifying the individual parameters one-by-one. An elaborate importance analysis of this kind is only feasible for the part of the model that is fully automated. Therefore, only a limited importance analysis seems practical for the current MTP-approach. Expansion of the model with (elements of the) analyses that are now conducted externally would allow for more elaborate importance analyses, and would facilitate easier identification of the most essential products and assumptions. A more detailed description of this approach can be found in McMahon et al. (2000).

Specific advantages and disadvantages of options
The advantage of focus on specific products is that this option is relatively easy to implement. A disadvantages of focusing on parameters was mentioned in the workshop. A modelling approach should not limit the number of different parameters that are modelled too much , as these reflect developments underlying the model results. Underlying developments might be particularly important topics in policy questions.

An important consequence of focusing on the most important appliances is that results for the other appliances will be (much) more uncertain. An option to reduce this uncertainty is to model developments for these products in line with historical or projected (assumed) trends of the explicitly modelled products. This approach would require an assessment of how representative the dynamics of the important products are for the other products.

4.2.2 Key area 2: Evidence data analyses and calculations

The second key area for AEA is internalising the analyses, assumptions and calculations conducted on the collected evidence data. This key area does not include the output calculations and validation, which are addressed in the following two sections.

Currently, the evidence data analyses and calculations are performed outside the MTP calculation model. Much of the information and data required to perform the activities is not directly available from the calculation model. The model provides limited options for understanding results. Consequently, the model has a ‘black box’ character with useful information being ‘hidden’, and documentation of the external analyses being required to obtain this information. More specific, the model itself does not provide insight in intermediate steps that lead to the final model results. This can lead to questions from policy makers that cannot be answered by the calculation model, at least not without additional analysis or laborious exegesis of external documentation and other (sub)models.

AEA indicates that the external analyses take up the major part of the efforts, depending largely on the product area considered and on data availability. Calculations to arrive at average unit energy consumption and at market shares per efficiency level are perceived to require the largest efforts, in this order of importance. In addition, AEA states that by far the most time is required for gathering and analysing data and making assumptions for future projections for the scenarios.

This area can comprise the following activities:
- Determining the impact on energy consumption and savings of factors that are not part of the calculation model. For example behavioural factors. Economic impacts from energy prices and welfare for example can be modelled using price or income elasticity and GDP developments, and (perceived and realistic) cost-effectiveness can be modelled using discount factors. Non economic impacts are for example comfort demands, which can also be incorporated in discount factors, factors representing rebound effects, user behaviour or learning effects.
- Determining which analysis methods should be used. For example, a method to derive direct input data for which direct evidence data is not available. This can involve interpolation for historical years and assumptions for future projections. An example would be calculating average unit of energy consumption in any given future year, for products for which an Ecodesign regulation or Eco-label exists.

Options

Explicit modelling of behaviour
An option would be to explicitly include in the calculation model the influence of behavioural aspects such as economic motives and/or other behavioural influences.

There are various ways to simulate behaviour in a model. For example, potential purchasers of an appliance may respond to the financial benefits of energy savings by more efficient appliances. Based on economic criteria, there may be a distinct threshold value for an individual case, above which one option becomes more attractive than another. However, actors may not behave in a rational manner, they may not be aware of the actual economic benefits, and moreover, threshold values may vary for individual cases. The resulting dispersed relation between the economic attractiveness and the share of the actors that prefers the more efficient variant may be approached by modelling S-curves. These may describe the response of a population to changes in the attractiveness of an option, for example expressed in cost/benefits ratios or internal rate of returns. This concept is illustrated in Boonekamp (2005, pp. 126-127, 143-145) and Daniëls and Van Dril (2007, pp. 853-855).

Financial policy measures such as subsidies or energy taxes result in a movement along the S-curve. S-curves also allow for the incorporation of non-financial policy measures such as energy labelling or information campaigns by modification of the shape of the S-curve.

As further suggested by the NEMS approach, modelling rebound effects might also be important to consider. This may especially apply to specific policies for which the approach is used , such as direct support by policy measures.

Explicit modelling of the 'average unit of energy consumption' calculation
An option is to create a standardised calculation within the calculation model of the average unit of energy consumption of appliances. This can be designed in such a way that it can be adapted for key (frequently demanded) policy scenarios. This option overlaps with the previous option, because behavioural factors may be incorporated into this standard calculation.

To illustrate this option with an example, minimum efficiency requirements from Eco-design regulations are considered. Once regulations are formally adopted, normally the calculation method to determine the maximum level of power allowed for new products is known from the legislation. This calculation of the specific unit of energy consumption might be needed as direct input in the policy scenarios of the MTP model. It can therefore be created within the model. This is convenient as the calculation is probably rather straightforward and will not methodologically change in the near future. Initial steps needed to create this standard calculation is to determine key input parameters required and data sources for these parameters.

A related option is to explicitly model the external calculations. AEA provided an example of calculations and input that might be internalised. A suggestion is to incorporate and automate the comments and references made in these example external calculations in the calculation model.

Specific advantages and disadvantages of options
An obvious disadvantage of the S-curve approach, as with other ways of incorporating behaviour, is the fact that the empirical basis is often poor .

An advantage of creating a standard calculation to determine future average units of energy consumption, is that this expertise and the costs incurred are expected to be once-only, apart from possible future revisions. A disadvantage is that external, technical expertise is probably required in another way or at some other time. For example, education of MTP modellers might be required.

4.2.3 Key area 3: Output possibilities

The third key area for AEA is to internalise and or to expand output calculations. This would imply an expansion of the MTP calculation model with additional output sheets or workbooks.

Which output calculations need to be internalised depends largely on the policy questions of Defra and other clients. Aspects like policy time frame, type of policy analysis (evaluation or projection, focus on existing or on future policies, or a combination), policy target formulation (point-in-time savings compared to base year, or yearly saving rates) determine the type of outputs required. ECN has no exact information about which output calculations are currently done as part of the external analyses and should therefore be added.

For which products or parameters output calculations should also be modelled depends on the type of policy questions to be addressed and choices made in focus and detail. Today's and tomorrow's key policy questions, including aspects such as the minimum efficiency requirements and labels from UK government standards policy, are product-specific.

Options

Include an 'energy use decomposition method'

The current MTP results delivered by the calculation model, incorporate all important factors that are covered in the external analysis. However, from the model results themselves it is not clear which factors have what effect. An option is to include an 'energy use decomposition method' as an output. This provides insight in the effects of different components on the energy use, such as volume effects, structural effects and efficiency effects. Respectively, these effects arise from developments in number of households (volume), production and consumption factors like usage hours or product size increase (structure), and energy savings or efficiency such as lower power usage. This type of analysis is explained and discussed by ECN (2004, p 22) and Boonekamp (2005, p 19 and pp. 22-24).

In case of the MTP-approach, this method implies the inclusion of derivative results from the external analysis. These results could for example represent series of results for the successive inclusion of various factors, such as number of households, purchase and possession of appliances, utilisation, size, efficiency. Such results would provide insight in changes in these assumptions, without the need to perform additional model runs. In addition, this also allows for a decomposition of the impact of policies into the various factors.

Important for the inclusion of the energy saving decomposition method is how the different effects are exactly defined. Furthermore, it might be better to also endogenise the external analyses, which was mentioned as option before, as this allows for quick and reliable analyses of the impact of different assumptions.

Explicit modelling of saving calculations

Another option is to internalise or expand the model with several types of savings calculations. Examples are: autonomous (policy independent) and policy induced savings, relative or absolute savings, yearly or cumulative savings, expression in different units (TWh, PJ), expression per unit or energy intensities (savings per new product, per average product in stock, per household, per dwelling) and others. Boonekamp (2005, p 19) illustrates a number of savings analysis methods which might be useful for the MTP approach.

In case many calculations of energy savings are already present in the calculation model but maybe not directly visible (not without additional manual intervention), standard output formats can be created. Useful outputs can be directly reported with such formats. A stand-alone workbook or worksheet might be the most appropriate location for these output calculations, as for example in the MTP 'overview model'. As far as direct reporting of relevant other outputs per product is useful, the product models would be the logical location.

Specific advantages and disadvantages of options

An advantage of the decomposition method is that it is possible to directly see the impact of a change in number of households, or ownership, or increased efficiency of appliance over time. These impacts are expressed as an amount of energy saving, with which energy consumption has increased or decreased. A disadvantage that particularly holds for creating the decomposition method, is the expert knowledge that is required for a proper modelling (design and use) of this method. Understanding the results also requires certain experience with the method.

Advantages of explicitly modelling multiple (useful) outputs in the calculation model are diverse. A major general advantage is that this may help in estimating the effects of different assumptions without requiring additional calculations on the model results. So, carefully selected additional outputs may offer additional quality as well as efficiency gains.

Having useful savings calculations directly available facilitates a quick understanding of the impacts from drivers such as policies. It further provides more (visible) insight in the diversity of impacts. Another advantage became clear from the webinar, which showed that changing certain output details such as units in which is reported, is possible by changing the macro code in the calculation model. This would no longer be necessary when different outputs are directly provided by the calculation model.

4.2.4 Key area 4: Validation and verification

The fourth key area for AEA is the validation, verification and uncertainty analysis methods that are or can be used on the MTP model and its results, simply referred to here as validation methods. This may e done in various ways, partly depending on the modelling approach.

The MTP calculation model itself includes neither a validation or verification method nor any kind of uncertainty analysis. However, validation is performed for the MTP approach, albeit in a non standardised way and on an ad hoc basis. The workshop actually showed that almost none of the other modelling approaches explicitly model validation methods.

Options

Explicit modelling of calculation checks
On a very basic level, this might imply the inclusion of various checksums, to verify internal consistency of results. Furthermore, comparison of results on an aggregate level against values that are expected by experts could help identify unlikely outcomes.

Explicit modelling of output and input validity checks
Explicitly modelling output validity checks implies the inclusion of calculations that compare model results against empirically derived information or against other models. For example, the validity of results may be tested by running the model for a historical time period and comparing the results with external historical data, or to compare past scenarios with recent realisations. Inevitably, part of the differences found will be accounted for by deviations in the input assumptions (e.g. economic growth). After compensating for such deviations, the remaining differences give insight in the accuracy of results. In addition, such analyses may also point towards specific developments, for example discontinuities in economic growth, which the model finds difficult to reproduce. A lighter variant could compare only samples of results.

Another option for AEA is to explicitly model input data validity checks, such as consistency checks, which are automatic checks of consistency of direct input data. This may be very relevant, for instance when there is overlap between sources used as evidence data for one product. Consistency checks can be conducted through simple calculations like checksums.

Explicit modelling of sensitivity analysis
Another option is to explicitly model sensitivity analysis. This delivers an indication of the sensitivity of outputs to changes of input data. This may be done by checking the change of the model results resulting from the change of a single assumption.

Such analysis is useful if, for example, major drivers for energy consumption or savings are to be determined. As described earlier, the NEMS model provided the example of importance analysis which can be useful here. The importance analysis as performed in NEMS in essence involves the replacement of point estimates for input variables by probability distributions (which is referred to as ‘uncertainty analysis’), and a subsequent investigation of the influence of each input variable on the results through sensitivity analysis. The results help to identify areas in which efforts for data collection and analyses should be concentrated or reduced.

Another option could be to switch to other evidence data or other assumptions used for input data modelled. Examples are evidence data for replacement of stock (e.g. NEMS model, non normal distribution instead of usually assumed normal distribution), for discount rates (e.g. CIMS model), market shares or purchase prices

Explicit modelling of uncertainty analysis
Another option would be to explicitly model uncertainty analysis. This is a way to deal with uncertainties of modelling results that follow from the uncertainties in assumptions and inputs used. This makes it possible to interpret results in a better way (Mundaca et al., 2010 and Kavgic et al., 2009). Whereas sensitivity analysis researches possible variability of outputs, uncertainty analysis researches the uncertainty around a specific output level. The link between both methods has been mentioned for the option previously described.

Uncertainty analysis might imply the inclusion of Monte Carlo Analysis. This can be done by post-processing, by calculating the uncertainty range based on uncertainties as estimated by the experts. However, the preferred option is to randomly vary input data in successive model runs. This provides a more reliable representation of the uncertainties, as the results naturally reflect the dynamics of the model itself. In case of the MTP approach, this would probably require incorporating the analyses that are now conducted exogenously, because the basic inputs and the steps that process these inputs into the results have to be present in one automated sequence.

Explicit modelling of a calibration method
One option linked to several options presented in this section, is to model a calibration method to act on findings from validation and verification methods. This implies (partial) automation of changing model inputs, to satisfy validation criteria or achieve 'fit' of the model with results that are being compared with. Individual assumptions may be automatically changed in the calculation model while other assumptions are held constant, until a fit is reached. A simple Excel function can be helpful to perform this task ('Scenario manager'). The EES approach offered the suggestion how a model can be used to optimise sales and ownership to arrive at a likely lifespan of products. This method can also be used for calibration.

However, whereas calibration may lead to better fitting overall results, the modification of the input parameters required to achieve this may not improve these input parameters themselves. For this reason, it is important to make the modification visible and to store both the original and the modified data.

Specific advantages and disadvantages of options
Internalising or expanding the calculation model with a number of validation methods has the advantage that it reduces the chance of human errors as validation implies automated checks. Disadvantages might be that model users tend to put more trust in (and potentially pay less care and attention to) the validity of inputs and outputs, once validation can be done by the model itself. Moreover, the validation analyses that are created should be solid enough to cope with adaptations to other parts of the calculation model.

4.2.5 Key area 5: Evidence data used and data collection methods

The fifth key area for AEA comprises evidence data and methods used for collecting evidence data.

Current data used by AEA are government statistics (mainly energy statistics and Defra studies). Collection methods include studies performed by external consultants. AEA has further indicated that it is difficult to assess which activities for obtaining evidence data require the largest efforts, as these vary considerably per product, depending on data availability.

Options

Change or expand evidence data collection methods
It could be valuable to obtain access to survey data. Most countries reviewed use survey data as source for evidence data, some of which realised by government funding. In the Netherlands, for example, the key source used to update inputs of the EVA model every year is the HOME survey. It delivers sample data, representative for the average Dutch household, on ownership of several key appliances and lighting. The scope of appliances is quite large. Survey data can also be a good source for usage data, as mentioned in the workshop. What was also mentioned in the workshop was that the only option to obtain similar evidence data might be from energy audits, which are very costly. Surveys might also provide good data on lifetime of products or distribution of sold batches of products over their lifetime. The workshop showed that simple survey questions like 'how old is your refrigerator' provides valuable data. An option is to have surveys or measurement studies conducted under the responsibility of the UK government (e.g. Defra) or other interested parties. If this turns out not to be an option, it might be feasible to use results of similar studies performed in other (preferably comparable) countries, e.g. from publicly available research studies. Examples are the European IEE Selina project on standby power of new appliances.

Another option is to use high frequency or high 'resolution', measured actual energy use data, such as demand or behaviour (e.g. usage) patterns for individual products. This would be the main source for acquiring reliable evidence data on actual daily usage of products. The EES and Kotitalouksien approaches are examples for which such metering data are used.

Another option mentioned in the workshop, is that it sometimes pays off to have a less-frequent, but more intensive (e.g. at a more elaborate detail level) data collection. Especially for rather stable input parameters (such as lifetime), this could improve the quality of the input parameters.

Standardise data collection from external consultants
An option would be to standardise the process of outsourcing data collection, by standardising the way in which AEA asks external consultants for data and the way in which external consultants deliver the data. AEA has opportunities here, as external consultants are said to generally be experts in the products for which they deliver data, have experience in doing so, and use the same sources repeatedly to collect data.

To standardise data requests, AEA could set up a standard format prescribing the type of data an external consultant should provide and the methodology (e.g. calculation) that should be used. The standard format can provide space for external consultants to enter all underlying factors, i.e. input parameters required for the calculations that have been brought into the MTP calculation model.

Standardisation is useful when it is feasible: this is valid only for those data requirements where standardisation is possible. It is up to AEA to determine for which products or parameters this holds. For the products and parameters where the same data are delivered time after time, standardisation opportunities are probably the highest.

Specific advantages and disadvantages of options
An advantage inherent to more detailed but also more costly data collection methods such as surveys or actual metering, is that it will probably only be required for a few key parameters for which a lack of data exist. It would therefore not be required to conduct or outsource an extensive survey or metering (in terms of appliances included). A focused approach might provide less but still very valuable key evidence data.

Using other data collection methods or changing existing methods can be beneficial in several respects. It can increase available data on a product or parameters (ownership, usage, specific appliance consumption), it can deliver additional data to be used for validation, and it can deliver more reliable data and decrease uncertainty. For example, including survey results can be a solution for appliances where it is difficult to get reliable data or to get data at all (as AEA indicates is the case for example for computers, or for market shares data).

An advantage of standardising data collection from external consultants is that creating a standard format automatically results in more transparency of input used. The workshop confirmed the high importance of documentation of input assumptions (for example the experience from the NEMS approach). Intermediate steps for the transition from evidence data to direct input data are documented, which increases transparency of assumptions and opportunities to track the drivers of model results. Another advantage is that AEA gains more internal control of the quality of the input data.

Particularly, evidence available from high frequency actual measuring can specifically decrease uncertainty about usage data to a great extent. The input document on the Kotitalouksien statistical analysis showed the example of Finland, where the actual number of washes is much lower than the standard average assumption applied in expert studies. The ELMODEL approach illustrated that survey data in Denmark showed how actual average lifetimes of products turned out to be lower than generally was assumed.

A disadvantage of actual measuring is mentioned in the input document on the Kotitalouksien statistical analysis. It was stated that 'measurement studies suffer from selection problems including self selection: if measurements have an average household size of three you cannot state that the measurements are representative for a population with an average household size of two.' This risk of sample selection should be sufficiently tackled in actual measurement studies AEA might chose to set up or use. This implies another disadvantage, i.e. the need for expert knowledge on statistical analysis, which needs to be present either at AEA or externally.

5. Discussion

5.1 General advantages and disadvantages of the options

A general advantage of the options as mentioned is that efforts on data collection and modelling maintenance will probably be reduced. In some cases this can be substantial.

Further, the options that involve internalisation of activities directly lead to standardisation of these activities. Bringing activities into the model means these will become a predefined process. The intermediate steps of this process, e.g. the input data put in and calculations performed, will also become visible in a structured model format. Another advantage of internalization is self documentation or bookkeeping of intermediate modelling steps, as these will be automatically recorded. Standardization and self-documentation can increase transparency of the modelling approach. This offers more direct insight and possibly better comprehension of model results and has opportunities for tracking and quality audits.

The general disadvantage of the options mentioned is that they require initial additional investments for modifying or expansion the calculation model. This means that there is a trade-off between additional investment costs on the short term versus lower operation and maintenance costs on the long term, along with enhanced functionality in some cases. The balance between initial additional costs and later benefits depends on the actual implementation.

Another disadvantage may be that the approach becomes less flexible, and (parts) of the external analyses that are now tailor-made are exchanged with internal ready-made approaches. The options imply some loss of flexibility of the approach.

A further consequence may be that the division of required knowledge and activities among the parties involved may change. The EES approach raised the suggestion regarding this point, that knowledge retention and limiting the number of model users is important for efficient modelling.

5.2 Limitations to the research

The recommendations in this report comprise the potential options and their advantages and disadvantages as described in chapter 4. These recommendations are rather general: they do not describe the required actions in detail that are needed for direct implementation in the MTP modelling approach. Also no quantitative analysis of advantages and disadvantages of options in terms of performance, and amount of efforts and costs, can be given. Reason for this are limitations of this study in the amount and detail of information that could be collected on the MTP modelling approach and the alternative modelling approaches. This should be kept in mind clearly when interpreting the results from this study.

The limitations of the study make that AEA and Defra should determine the extent to which the options provided by ECN are beneficial for the MTP approach. The decision should be made which option(s) are perceived to be most attractive in terms of cost effectiveness, considering the current capabilities of the MTP approach and conditions it needs to meet now and in the future.

This study does not allow for an in-depth analysis of the risks of possible government budget reductions for the MTP modelling approach. In the event of such reductions, a decrease in modelling efforts could become required or less attention could be paid to evidence data and obtaining it. Importance analysis, mentioned as option in the previous chapter, might provide a means to indicate where and what impact these consequences could have on the quality of the MTP approach.

5.3 Suggestions for further research

Some options for further research in line with the objective of this study, are suggested that AEA might consider. Further research can support the implementation of any options AEA might decide to pursue.

One suggestion is to have an in-depth audit of the modelling approach performed. Such an audit could particularly focus on the quantitative part of the approach, namely the calculation model and (remaining) outside calculations.

Another suggestion is to perform an in-depth study on one or more of the modelling approaches reviewed. The aim could be to learn about specific characteristics of such approaches, for example specific functionalities, analyses or methods, to see if and how these can be applied for the MTP approach. Approaches similar in nature to the MTP modelling approach might be best suited for this (other selection criteria are possible). To achieve more added value, cooperation of the experts consulted for this research can be helpful.

References

Literature and websites

Boonekamp, P.G.M. (2005): *Improved methods to evaluate realised energy savings*. Dissertation, December 2005.

Daniëls, B.W. and A.W.N. van Dril (2007): *Save production: A bottom-up energy model for Dutch industry and agriculture*. B.W. Daniëls and A.W.N. Van Dril. Energy Economics 29 (2007) 847–867.

eceee (2011a): *Website: http://www.eceee.org/Eco_design/*. Consulted February 24th, 2011.

eceee (2011b): *Website http://www.eceee.org/Eco_design/Energy_labelling_directive*/. Consulted February 24th, 2011.

ECN (2004): *Realised energy savings 1995 -2002 - According to the Protocol Monitoring Energy Savings*. P.G.M. Boonekamp (ECN), A. Gijsen (RIVM/MNP) & H.H.J. Vreuls (SenterNovem). ECN, October 2004.

European Commission (2011): *Website: http://ec.europa.eu/enterprise/policies/sustainable-business/Eco-design/index_en.htm*. Consulted February 24th, 2011.

Kavgic, M. et al. (2009): *A review of bottom-up building stock models for energy consumption in the residential sector*. M. Kavgic, A. Mavrogianni, D. Mumovic, A. Summerfield, Z. Stevanovic, M. Djurovic-Petrovic. Building and Environment 45, 2010. September 2009.

McMahon, J. et al. (2000): *Uncertainty and sensitivity analyses of ballast life-cycle cost and payback period*. J. McMahon, X. Liu, L. Turiel, S.H. Hakim & D. Fisher. Lawrence Berkely National Laboratory, Environmental Energy Technologies Division. June 2000.

Mundaca, L. et al. (2010): *Evaluating Energy Efficiency Policies with Energy-Economy Models*. L. Mundaca, L. Neij, E. Worrell & M. McNeil. Annual Review of Environment and Resources 35:305–44, 2010.

Modelling approaches and experts consulted

CIMS modelling approach. Presented by Steven Groves, Simon Fraser University Canada.

DEESY stock model modelling approach. Presented by Antoine Durand, Wuppertal Institute Germany.

ECM Environmental costing model. Presented by Kathleen Briffaerts, Vito Belgium.

EES residential end-use model (2008) modelling approach. Presented by Kevin Lane, private consultant Australia.

ELMODEL-domestic modelling approach. Presented by Troels Fjordbak Larsen, IT Energy Denmark.

EVA modelling approach. Presented by Paul Vethman, ECN.

Kotitalouksien sähkönkäyttö. Statistical approach for analysis and support of policy on electricity using appliances in households. Presented by Virve Rouhiainen, Adato Energia Oy Finland.

MTP modelling approach. Presented by Paul Drummond, AEA United Kingdom.

NEMS modelling approach, RDM and CDM modules. Presented by Frances Wood, Onlocation United States.

NEMS modelling approach, LCC and NIA analyses for NEMS modelling approach. Presented by Jim McMahon, Lawrence Berkeley National Laboratory United States.

TIMES modelling approach. Presented by Birgit Götz, IER Germany.

Appendix A Concepts and definitions applied[2]

Modelling approach
An information source as least consisting of a *quantitative analysis method* (e.g. calculation model), that is used for the support and analysis of energy policy. A modelling approach usually also consists of an additional quantitative or qualitative *information base*, containing documented knowledge and experience.

Energy using products (EuP) and electricity using products
Energy using products are defined as products ‘using, generating, transfering or measuring energy (electricity, gas, fossil fuel), such as boilers, computers, televisions, transformers, industrial fans, industrial furnaces etc.’ (European Commission, 2011).

Electricity using products are defined as energy using products (EuP) that consume electricity (but possibly also other energy carriers). Here we mean appliances (for example 'white goods' like refrigerators, dryers etc., audio/video/IT/TV), lighting, and installations (for example for heating, hot water, cooling, airco, pumps etc) used in buildings and homes.

Energy related products (ErP)
Defined as products which ‘do not use energy but have an impact on energy and can therefore contribute to saving energy, such as windows, insulation material, shower heads, taps etc.’ (European Commission, 2011a).

Standards policies
These are defined as policies that *oblige* a maximum level of energy consumption, by prescribing a certain standard. An example of such standards is the EU Eco-design directive, prescribing a maximum amount of power for certain appliances (eceee, 2011a).

Energy label policies
These are defined as informational policy instruments, usually aiming to *stimulate* (but not oblige) energy efficiency. An example of such as a standard is the EU Energy labeling directive, prescribing a certificate (label) for certain appliances indicating their energy consumption and relative energy efficiency. (eceee, 2011b).

[2] An adaptation to the definitions provided is a possibility. One can also define ‘energy related products’ as comprising all products influencing energy consumption or savings. These can be either energy using (e.g. electricity using products) or non energy using products (e.g. well insulated windows, shower heads).

Appendix B Overview of modelling approaches

Table B.1 *MTP modelling approach*

Model name	***MTP modelling approach***
Model owner	*AEA*
Main clients	*Government (Defra)*
General description modelling approach	• *Stock-based, bottom-up, accounting modelling model.* • *Collated research and stakeholder evidence* • *Very extensive and detailed with regard to the data required. For 140 energy using products inputs and outputs are modelled separately.*
Main inputs	*Stock, efficiency and usage rates of EuPs, and costs (unit prices) and benefits of EuPs as well as of policy measure packages. important characteristic: many of input derived from not standardised, external calculations and analysis.* *Main source(s): Government statistics (Defra studies) and consultant studies.*
Main outputs	*Energy consumption, savings and costs&benefits, for different scenarios. Electricity, gas, oil, biomass. Reporting mainly in GWh (other possible), per 5-yrs period.*
Validation methods (among others)	*Consistency checks in outside calculations. Calibration of outputs on historical data.*
Software used	*Excel and Visual basic*

Table B.2 *EVA modelling approach*

Model name	***EVA (ElektriciteitsVerbruik Apparaten)***
Model owner	*Energy research Centre of the Netherlands (ECN)*
Main clients	*Government (several Departments)*
General description modelling approach	• *Stock-based, bottom-up, accounting modelling model* • *Very extensive and detailed with regard to the data required. For 172 appliances (19 product groups), inputs and outputs are modelled separately.* • *Assessment current and future policy (past policy analysis under construction)* • *Linked to modelling system of ECN (other ECN models)*
Main inputs	*Stock (ownership and lifespan), specific energy consumption (label scale level), usage rates and certain factors. No direct economic inputs or outputs. Direct input derived standardised, but derived from external analysis and calculations.* *Main source(s): statistics, survey (Home), consultant input, literature*
Main outputs	*Energy consumption, savings, decomposition of volume, structure and efficiency effects over time. For all products, in five different scenarios. Only electricity. Reporting in several units (e.g. PJ, kWh/yr/hh), for 5-yr periods.*
Validation methods (among others)	*Consistency checks in outside calculations. Validation by calibration of outputs on historical data.*
Software used	*Excel and Visual basic*

Table B.3 *EES residential end-use modelling approach*

Model name	***EES residential end-use model (2008)***
Model owner	*EES, funded in part by Australian Government*
Main clients	*Government*
General description modelling approach	• *Engineering bottom up* • *For Australia a recent reconciled end-use model for the residential sector. Components or versions of model used by various consultants. Model version referred to here (2008 version) was used for policy questions.*
Main inputs	*By product: household ownership, sales volume, technology efficiency, usage.* *Household numbers, carbon/price/other factors. Also building thermal, climate* *Main source(s): National statistics, surveys, actual metering data, registration*
Main outputs	*National (and state) energy consumption/savings, carbon, financial*
Validation methods (among others)	*Validation of implementation done (cross-checks). Check sum of end-uses against totals. Metered consumption in situ. Comparison with other countries. Check previous projections of variables (learning, rather than validation).* *Furthermore: validation efforts depending on the context change.*
Software used	*Excel, other*

Table B.4 *ELMODEL-domestic modelling approach*

Model name	***ELMODEL-domestic***
Model owner	*Danish Energy Authority, Danish Energy Association, Danish Energy Saving Trust and Energinet.dk (grid operator)*
Main clients	*Same as owners*
General description modelling approach	• *Bottom-up stock model*
Main inputs	*Ownership levels(by dwelling types), frequency of use(by dwelling types) and unit consumption for 32 major appliance types.* *Main source(s) ?*
Main outputs	*Projection for electricity consumption in domestic sector of Denmark. Development in consumption distributions on major end-use groups and standby. Scenario calculations of different developments based on alternative assumptions for future technical and legislative changes.*
Validation methods (among others)	*Comparison to historical data and electricity stats utilities. Big deviations examined. New scenario: changes in context are checked.*
Software used	*Propriety software developed by IT Energy ApS, based on Delphi.*

Tabel B.5 *DEESY modelling approach*

Model name	***DEESY Stock Model***
Model owner	*Wuppertal Institute*
Main clients	*Umweltbundesamt (Federal Environment Agency)*
General description modelling approach	• *Stock-based, bottom-up, accounting modelling model.* • *Very extensive and detailed: up to 100 generations of EuPs / EuP category* • *Interface and logic support generation of required data (usually most data unknown). also used to generate the composition of the stock in the base year.* • *Model is synchronised with DEESY Energy Model (including the supply-side)*
Main inputs	*Depending on scenario: stock volume, average specific energy consumption in the market (reflecting the effect of policy packages). collated research and stakeholder evidence used as inputs. Some more input necessary (e.g. investments). Technologies data given manually, or generated.* *Main source(s): Stats and surveys, Eco-design preparatory studies*
Main outputs	*Market and stock shares EuPs, purchases, characteristics (e.g. specific energy consumption, investment, O&M costs, annuity…)*
Validation methods (among others)	*Calibration BAU scenario parameters. Sensitivity analysis if possible. Historical results and other study results*
Software used	*XLS-based model synchronised with DEESY Energy Model (running on MESAP/Planet). Fully stand-alone XLS-based model currently developed.*

Table B.6 *ECM modelling approach*

Model name	***ECM Environmental costing model (Flanders)***
Model owner	*LNE - VITO*
Main clients	*Government*
General description modelling approach	• *Techno-economic bottom up approach, all sectors (excl. transport) Flanders.* • *Extended database (Access) of energy/emission technologies* • *Linear programming model Markal (cost optimisation), in second step. Results are analysed in Access.* • *Modelling of electricity using products (EUP) is part of this ECM. Only key EuP separately for residential and services sector (scarcity of reliable data)*
Main inputs	*Energy savings (%). implementation degree and application degree. Investment, operational cost – fuel cost. Energy consumption in base year. Direct link to (modelled) electricity sector.* *Main source(s): government stats, billing data, survey, literature*
Main outputs	*TJ electricity consumption 2005-2030. Societal costs. Input to electricity sector.*
Validation methods (among others)	*Scenario analysis, fit with nat. energy balance statistics*
Software used	*Access (incl. Visual Basic) - Markal*

Table B.7 *TIMES modelling approach*

Model name	***TIMES (The Integrated MARKAL-EFOM System)***
Model owner	*Model generator: International Energy Agency, Energy Technology Systems Analysis Program (ETSAP). Dataset: IER*
Main clients	*Government agencies, energy supply companies, etc.*
General description modelling approach	• *Bottom-up, multi-period energy system model. partial equilibrium approach* • *Representing, optimising, analysing energy systems. Different scales.* • *Optimises total energy system costs to meet exogenously set sectoral energy demands, with constraints.*
Main inputs	*energy prices, technical and economical parameters of all processes, stock, sectoral demand for energy services/useful energy. For EuPs, different processes (efficiency classes) are integrated with the correspondent cost levels.* *Main source(s): Stats, surveys, results from other models, etc.*
Main outputs	*energy demand by fuel, emissions of GHG, other air pollutants, capacity of technologies, electricity and CO_2 prices, energy system costs. EuPs: choice of technology (efficiency class), electricity demand, savings, emission reductions.*
Validation methods (among others)	*Sensitivity analyses, parametric programming techniques. Comparison to other model results. Cross-check input data with other studies. Consistency checks.*
Software used	*Modelled in GAMS (General Algebraic Modelling System), Input data handling system: ANSWER or VEDA-FE, Results handling system: VEDA-BE.*

Table B.8 *Kotika statistical approach*

Model name	***Kotitalouksien sähkönkäyttö statistical approach (two prior studies (1993, 2006), update planne***
Model owner	*Adato Energia Oy (?)*
Main clients	*Government (ministry for aggregated country level info and scenarios, Motiva for reference households)*
General description modelling approach	• *Survey, measurement information, auxiliary data* • *Used for decomposition of household electricity consumption to end uses* • *Household level and aggregated (post stratification) to country level* • *2006 study: assessment of saving potential (by accounting approach).*
Main inputs	*Decomposition: Large survey data households, smaller measurement survey, auxiliary information on appliances and population and housing* *For scenarios: forecasts population and housing trends, info technologies* *Main source(s): stats, billing data, surveys, metering, other (=?)*
Main outputs	*End use decomposition for the year in question at country level and in housing categories. Reference households. Empirical distribution for defined house-hold categories, distribution described via percentiles.*
Validation methods (among others)	*Comparison population stats with survey. Statistical specification tests. Probably of modelling rejection. T-test statistics.*
Software used	*for the decomposition: statistical software SURVO, results presented in excel* *for scenarios: excel*

Table B.9 *CIMS modelling approach*

Model name	***CIMS***
Model owner	*Energy and Materials Research Group, Simon Fraser University*
Main clients	*Government, researchers, non-governmental organisations*
General description modelling approach	• *Technologically-explicit hybrid model* • *National and regional energy-economy system, key end user sectors* • *Simulates capital stocks over time (retirements, reftrofits, purchases)* • *Large database of energy using technologies to choose from* • *Role of Energy and Materials Research Group (SFU), over past 20 years*
Main inputs	*Forecast of energy price. Sector activity. Technology database incl. capital cost, maintenance cost, energy use of each technology.* *Main source(s): government statistics.*
Main outputs	*Energy consumption and GHG emissions, by fuel and technology, for each sector. Outputs typically modelled to 2030 or 2050.*
Validation methods (among others)	*Calibration on historical data, compare with forecasts other sources, update of assumptions, consulting experts*
Software used	*Custom built, self-contained software. Spreadsheet system designed in Java used for model inputs. Outputs generated as CSV files, but generally compiled in Excel.*

Table B.10 *NEMS modelling approach*

Model name	***National Energy Modelling System (NEMS) Residential &Commercial Models***
Model owner	*Energy Information Administration, U.S. Department of Energy*
Main clients	*Government*
General description modelling approach	• *Integrated energy-economy model with production, imports, conversion, consumption, and prices of energy. Modular model, different analytical techniques.* • *Residential (RDM) and commercial (CDM) models: bottom-up structural models, endogenously projected equipment, technology characteristics and consumer behaviour for most end-use services (heating, lighting, etc.).*
Main inputs	*Energy prices, housing starts or floorspace growth, population. Other: current building stocks, retirement rates, stocks and life expectancy, energy intensities, equipment characteristics (incl costs), short-term price elasticities, other.* *Main source(s): stats, surveys, billing data energy companies*
Main outputs	*Energy demand by service and fuel type (in Btu units), change in stocks, efficiencies, technology shares, investments (RDM and CDM). GHG (NEMS)*
Validation methods (among others)	*Comparison to historical data. Updates (e.g survey results).*
Software used	*Fortran. Inputs and outputs are in text or spreadsheet form.*

Table B.11 *LCC and NIA analyses underlying NEMS modelling approach*

Model names	***(1) Life Cycle Cost (LCC) & (2) National Impact Analysis (NIA)***
Model owner	*U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy*
Main clients	*National government: U.S. Department of Energy, Appliance Standards Program*
General description modelling approach	*LCC: population distribution of lifetime costs to purchase, install, operate, & maintain one product* *NIA: 30-year(annual) projection of national energy, costs, savings, & emissions*
Main inputs	*LCC: manufacturing costs and energy (& water) use for technology options, markups (to retail price), energy prices, lifetimes, discount rates* *NIA: average LCC outputs, stocks, shipments, proposed standard levels* *Sources: manufacturers, government and private surveys, analysis*
Main outputs	*LCC: Distribution of LCC impacts from policy.* *NIA: Annual energy consumption by product type, purchase and operating expenditures, net present value, and emissions (CO_2,SOx,NOx)*
Validation methods (among others)	*Government, industry, & commercial data. Public meetings & comment periods. Updates at regular intervals.*
Software used	*LCC & NIA: Microsoft Excel and coding.* *LCC uses add-on (Crystal Ball)*

Workshop 'Strategic modelling approach review' project

Input document

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1. Introduction

The Energy Research Centre of the Netherlands (‘ECN’) conducts the ‘Strategic modelling approach review’ project for consulting firm AEA Technology (‘AEA’) from the UK, which is acting on behalf of the Department for Environment, Food and Rural Affairs (‘DEFRA’).

DEFRA’s Market Transformation Programme (‘MTP programme’) is used for the development and implementation of UK Government policy on sustainable energy using products, with a primary focus on electricity demand in the built environment.

The aim of the *research project* is to benchmark the modelling approach and evidence base which AEA uses to support DEFRA’s MTP. The project will evaluate the strengths and weaknesses of different alternative existing modelling approaches with comparable objective as the MTP. Furthermore, the project will identify and recommend areas for potential improvement of the modelling approach of the MTP, focusing mainly on performance and cost and time savings.

To learn from the experience in different countries the *workshop* is organized, to consult experts on “their” modelling approaches. The scope remains limited to the (part of the) model that supports the evaluation of policies on energy using products. Again, the primary focus is on effects on electricity demand in the built environment.

This *input document* aims to 1) provide background information to the participants of the workshop and to 2) collect the necessary input information from the participants in advance of the workshop to ensure an efficient and effective workshop.

Chapter 2 provides a general introduction on different modelling approaches based on a limited literature study, with some specific remarks on modelling approaches similar to MTP.

In Chapter 3 the questions are presented in each section. These questions need to be answered by all participants **before Wednesday March 16th** to allow a proper preparation of the workshop. Further instructions are provided in this chapter to guide your answers. For most of the questions, a short theoretical background is provided to further support your input.

To achieve a common understanding of concepts used in this study, certain definitions of frequently used terminology are clarified in Appendix A. A diversion from these definitions in practice is of course possible. Appendix C provides a literature overview of other modelling approaches that can be relevant for the study.

2. Background

2.1 Introduction

In this chapter a literature background is given on the *modelling approach* that has the focus in this study, which is the modelling approach and evidence base (or all documented knowledge and experience and that supports the MTP programme) used by AEA. With modelling approach we explicitly mean not only a quantitative analysis method (e.g. calculation tool), which usually is considered when the term 'model' is used, but also the quantitative and qualitative information base which contains documented knowledge and experience. Both may be used for the support and analysis of energy policy (see also here our list of definitions in Appendix A).

The scope of the MTP modelling approach is the analysis and support of policies for energy using products in the built environment, the residential and non-residential sector, and industry. More specifically, these are policies that created energy efficiency standards and energy labels for electricity using products. General policy questions that need to be answered by the approach is how the electricity that is used by electricity using products will develop in the future and what the impacts of policies are or could be.

For the workshop and this input document, the – sometimes contradictory - categorizations found in literature are not always convenient. Although they will be referred to, they will not be strictly used. Instead, the input document focuses on individual characteristics of a model, without labeling the entire model.

Theory, or literature, tends to classify modelling approaches into separate categories according to their *characteristics* or elements. This is a difficult task, and in doing so different and sometimes contradicting findings and conclusions can be found in literature. Approaches from practice never perfectly fit into a defined category. An approach may belong to a certain group of approaches having similar key elements, but might also have features from another group of modelling approaches to compensate for certain drawbacks from the group it initially most strongly belongs to.

In practice, many different modelling approaches (in literature also referred to as types, methods, techniques, or similar terms) are found. Although there can be strong similarities between approaches, each has its own typical characteristics.

The AEA approach has characteristics of both a *bottom up distribution modelling approach* and of an *accounting modelling approach*. In Section2.3 the characteristics of the MTP type of approach are explained. These approaches are the starting point of the workshop and this input document. In Section2.2, other modelling approaches to be used for energy products policy support are first explained briefly. These do not have the focus here, but are meant to illustrate alternative approaches that could very well deliver suggestions for improvement of the approach of AEA. In Appendix C more literature background is provided on these approaches.

2.2 Literature background on modelling approaches

The energy consumption of the residential sector, which includes the electricity consumption of electricity using products, is significant and requires a detailed understanding of the drivers for this energy demand and opportunities in order to determine strategies to reduce it. Policy aims to influence these drivers, is a driver itself, and can also be influenced by these drivers.

Quantitative models, or modelling approaches, can be useful for policy analysis and policy decisions (Swan and Ugursal, 2008). Various approaches to model the impacts of policies are used in practice as well as described in scientific or other literature. Overview studies generally provide a categorization of modelling approaches.

Literature usually categorizes modelling approaches based on a limited number of key characteristics. Regarding approaches focusing on energy use in the built environment level, the (more or less data detail oriented) distinction between *top down and bottom up approaches* and the (methodology oriented) distinction between *optimisation, simulation and accounting approaches* receives significant attention. Both top down and bottom up approaches are common for modelling the energy consumption of the residential sector (e.g. Swan and Ugursal, 2008).
Other modelling categorizations, typologies and contrasts exist and are found in literature (for example Catenazzi, 2009).

It is difficult to label a model from practice as a specific type of approach, since many models have a hybrid nature. Approaches in practice can be 'scored' on the extent to which they have characteristics of opposite approaches, for example those of top down approaches versus bottom up approaches. Literature often labels models that contain elements of various approaches as 'hybrid' models. Usually this term is applied for models combining both top down and bottom characteristics. Here the term hybrid is not explicitly used, since most models vary in the extent to which they have characteristics of specific approaches.

The picture below shows an example of how literature illustrates this for energy policy models (Hourcade et al., 2006). A remark needs to be made on the 'ideal model' being denoted in the picture: For a specific purpose, the model shown as the "ideal model" may not be ideal at all, as definition of ideal is dependent on the objective.

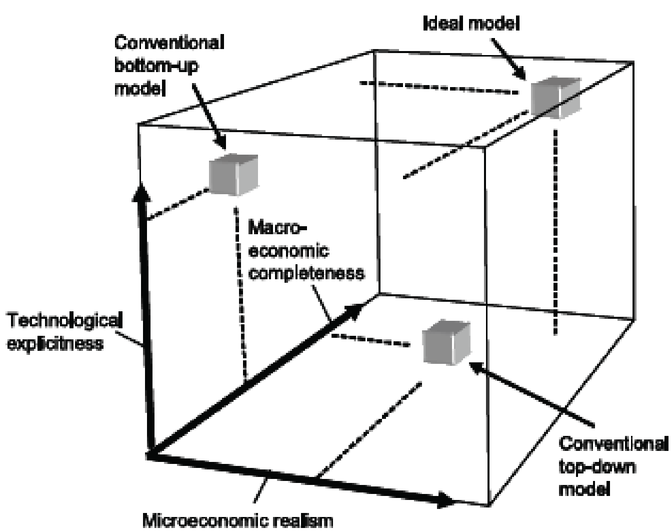


Figure 2.1 *Labeling of modelling approaches (Hourcade et al., 2006)*

2.3 Background on the Market Transformation Program (MTP) modelling approach

The documentation on the MTP modelling approach provided explains the background of the approach. The MTP modelling approach contains many elements of what literature mentions as the *distribution modelling approach.*

The focus of the workshop and this input document is on this approach and other bottom-up approaches, as the purpose of the MTP-programme is best served by an bottom-up approach. The requirements of the MTP programme limit the number of suitable modelling approaches. The programme requires the quantification of energy savings and other impacts from individual energy using products, and the planning of policy measures that aim to transform the market for these individual products. Mainly based on this requirement of detail, bottom-up models are the logical choice. Therefore, this document dwells more elaborately on this class of models.

The distribution modelling approach is a type *engineering modelling approach,* in literature categorized as a bottom up approaches. For an overview of the categorization of bottom-up approaches, please see Appendix C. Literature states that the engineering approach is useful to model the impact of new technologies (Swan and Ugursal, 2008) and identify efficient technologies which can support policy making (Kavgic et al., 2009). An example is the introduction of a new electricity using product (Swan and Ugursal, 2008).

Distribution approaches calculate the energy consumption of different individual "energy using products" (e.g. an appliance) based on distributions of ownership, usage and power, and aggregate these to a higher level of total energy consumption. Distribution methods determine individual energy consumption of energy using products, in a disaggregated manner. For some products, the modeling of subproducts (e.g. LED TVs and plasma TVs) is done separately. It will depend on the chosen modelling approach whether interactions between these subproducts are taken into account properly. These models are useful for estimating energy consumptions on lower levels in this way, such as regional energy consumption (Swan and Ugursal, 2008).

Swan and Ugursal (2008) review a few model examples of distribution methods from literature.

Engineering approaches seem to be well capable of addressing certain policy questions, such as what would be the impact of standards, labels or pricing policies that target specific individual technologies, such as major energy using products.

The MTP modelling approach also has key characteristics of an accounting approach. Such approaches calculate energy use and savings effects based on the expected development in the energy use of specific energy using products, applying straight forward trends for which input data are collected. These models generally do not incorporate the underlying (intelligent) analyses leading to the trends, which might still be available (but outside the accounting model).

The following literature quote illustrates the essence of accounting approaches.

> "Accounting models primarily aim to manage data and results. These models can be prescriptive or descriptive. Whereas the former can look at the impacts coming solely from the adoption of highly efficient technologies, the latter would approximate the portfolio of technologies resulting from one or various policy instruments. Instead of addressing the behavior of market agents and the resulting technological change, accounting models require modelers to determine and introduce technology choice exogenously."
>
> Source: Mundaca et al. (2010)

3. Questions

3.1 Instructions

Chapter 2 explained how literature tends to categorize modelling approaches found in practice, based on similarities of key characteristics. Models in practice possess these characteristics to a varying degree and generally do not fit one pure modelling approach only. Therefore, the following sections pose questions on the specific characteristics of the modelling approach you are involved in.

For a number of questions a short, specific literature background can be provided. Also instructions are given to provide guidance for answering the questions.

These characteristics involve:

- Drivers for energy using products policy modelling.
- Modelling scope and context.
- Input, output and validation.
    - Data collection and input.
    - Output and results.
    - Validation.
- Challenges.
    - General strengths, limitations, challenges and solutions.
    - Complexity.
    - User friendliness.
    - Costs.
- Satisfaction with the approach.
- Alternatives.

As mentioned in Chapter 2, with modelling approach we explicitly mean not only a quantitative analysis method (e.g. calculation tool), which usually is considered when the term ‘model’ is used, but also the quantitative and qualitative information base which contains documented knowledge and experience. Both may be used for the support and analysis of energy policy (see also here our list of definitions in Appendix A).

The next sections contain the questions.

3.2 Questions: Drivers and modelling objective

3.2.1 Questions

Before filling in the questions in this section, please read Appendix E: it serves as an example of how the questions of this section have been answered, by ECN and AEA, for the MTP model.

Please also consider the literature background referred to in Chapter 2 and (if necessary) in Appendix C.

Question 1: Please provide a general description of your model specifying the following aspects:

Answers:

Model name	
Model owner	
Main clients (e.g. government, researchers)	
General description of the modelling approach	
General description of main inputs	
General description of main outputs	
Which type of software is used for the modelling approach?	

Question 2: What is the specific subject of the model?

A few studies mention objectives or goals of modelling approaches. Hourcade et al. (2006) and Worrell et al. (2004) provide different objectives of modelling, that are mentioned here as general objectives affecting model design choices and complexity of a model. ECN has used and reframed these for the following questions. Examples of subjects of models can be:

- energy consumption
- energy savings (from techniques, or from policies)
- greenhouse gas (GHG) emission
- air pollution
- productivity
- costs and benefits
- other.

Answer:

Question 3: What is the geographical scope of the subject?

For example: global, continental (e.g. EU), national, regional, or other.

Answer:

Question 4: What is the usual time frame of the subject?

For example, analyses to support Kyoto obligations have a different time frame than temporary or short term policies (Hourcade et al., 2006).

Answer:

Question 5: What type of analysis is needed: policy assessment, selection, development and improvement, a combination, or other?

Examples provided by Hourcade et al. (2006) and Worrell et al. (2004) are:

- Calculating impacts of policies (policy assessment).
- Identification of best technology options (policy selection).
- Definition of target levels (policy development).
- Assessing benefits, costs and surplus (e.g. least social costs, those of proposed policies, distribution or sectoral costs and benefits of policy choices (policy assessment).
- Assessing interactive effects of various policies (policy assessment).

Answer:

Question 6: What type(s) of specific policy analyses can the model perform?

A: Monitoring the impacts of existing policies
B: Ex ante estimates of future policies
C: Ex post evaluation of past or existing policies
(multiple answers possible)

Answer:

Question 7: Why has the current approach been chosen for the main application?

Please try to answer the extent to which (existing or future) energy using products policies have influenced this choice.

Answer:

Question 8: approach been chosen for the main application?

Answer:

3.3 Questions: Modelling scope and context

3.3.1 Question

Before filling in the questions in this section, please read Appendix F: it serves as an example of how the questions of this section have been answered, by ECN and AEA, for the MTP model.

Please also consider the literature background referred to in Chapter 2 and (if necessary) in Appendix C.

Question 1: Would you characterize your modelling approach as more top down or more bottom up?

Please label, with an '*X*' mark in one of the cells on the scale, the position on that scale that would best characterize your modelling approach. Please consider the literature overview in Appendix C.

Answer:

Top-down bottom-up

100% 0% 100%

Please explain your choice:

Answer:

Question 2: Which type(s) of techniques are used?

A: Accounting
B: Simulation
C: Optimization / equilibrium based on constraints
D: Econometric, e.g. elasticities
E: Statistical methods
F: A combination, or other.

Answer:

Please explain your answer:

Answer:

Question 3: Which interactions are endogenously modelled?

For example: mutual effects interactions between inputs, between outputs, or between in- and outputs.

Answer:

Question 4: Are intermediate calculation steps explicitly accounted for, i.e. visible, in the model's (intermediate) output?

Answer:

Question 5: When using the model, please indicate when intervention by the user is required (e.g. manual tasks need to be performed)? I.e. which parts of the model are not automated?

Intervention would relate to the following aspects:

- What efforts are required to make a complete model run?
- Which part of these efforts are not performed by the model itself, but outside the model?
- To which extent can raw data be put fed into the model, or does it need further processing?

Answer:

Question 6: How would you characterize the level of standardization of the inputs of your approach?

A: highly standardized
B: moderately standardized
C: hardly standardized
(more than one answer possible)

Answer:

Please explain:

Answer:

Question 7: How flexible is the model: to what degree can it cope with changes of the modelling context? (changing also the scale and/or scope of input and output?

For example: a change in policies that are analyzed with the model.

Answer:

Question 8: Please indicate the level of detail of the required inputs and delivered outputs.

The scope of this study, and thus of the workshop and this input document, is energy savings or energy efficiency policy targeting:

- *energy using products* that are used in
- *homes (e.g. households) and buildings (e.g. organizations)*.

Likewise, we ask you to explain the scope of your model by indicating:

- the technologies (e.g. appliances, renewable technologies etc.)
- the sectors and possibly subsectors (e.g. built environment, industry, transport, residential sector etc.)

that are included as input or output in your model.

For this question we also refer to the concepts and definitions provided in Appendix A.

Answer:

Technologies ***Level of detail of inputs:*** ***Level of detail of outputs:***
Sectors and subsectors ***Level of detail of inputs:***

Level of detail of outputs:

Question 9: Could you explain on the modelling of input and output parameters?

For parameters possibly included in your model, please indicate in the table below:

- whether they are input, outputs, or both *(left two answer boxes)*
- whether they are implicitly 'hidden' in other parameters, or whether they are made explicit (visible) in the model *(middle two answer boxes)*
- whether they are exogenously determined outside the model, or endogenously by the model itself *(right two answer boxes)*

Please indicate with an 'X' in the cells which answers are valid for your approach. Multiple answers are possible. Not all answer boxes need to be relevant for your modelling approach.

If necessary for a better understanding of your answer for a parameter, please provide an additional explanation in the space beneath the answer boxes for that specific parameter.

Table 3.1 *Input and output parameters*

Input/Output Parameters:	**Input**	**Output**	**Implicitly**	**Explicitly**	**Exogenously**	**Endogenously**
Energy consumption of sector(s)						
If necessary, please explain:						
Energy savings or(active or passive) of technologies						
If necessary, please explain:						
Other effects (health, comfort)						
If necessary, please explain:						
Societal costs and benefits						
If necessary, please explain:						
CO_2 emission reduction effects						
If necessary, please explain:						
Characteristics of energy techniques (e.g. capacity/power, usage, efficiency factors or learning effect, or other)						
If necessary, please explain:						
Energy prices or CO_2 prices						
If necessary, please explain:						
Explicit specification and modelling of policies (e.g. subsidy levels, energy taxes,						

standards)						
If necessary, please explain:						
Macro economic data such as: -Income/capita -Growth/productivity/GDP						
If necessary, please explain:						
Demand elasticities						
If necessary, please explain:						
Behaviour (purchase/choice and use of technologies)						
If necessary, please explain:						
Other? Please mention:						
If necessary, please explain:						

3.4 Questions: Challenges

3.4.1 General strengths, limitations, challenges and solutions

Literature provides insights in the strengths and limitations of modelling approaches commonly used on the level of the built environment or residential sector (see Chapter 2).

In the questions below you are asked to indicate:

- Strengths and limitations for your approach, considered its context (which you provided with your answers in Section 3.2.2).
- Improvements to your modelling approach based on its limitations.
- Suggestions for possible improvements for the MTP modelling approach (please see Chapter 2 for background information on the MTP approach).

Question 1: Please mention the three main strengths of your modelling approach:

Answer:

1. 2. 3.

Question 2: Please mention the three main limitations of your modelling approach:

Answer:

1. 2. 3.

Question 3: Please explain for the <u>first</u> mentioned main strength and main limitation, the context that causes them to be a strength or limitation:

Answer:

Main strength: **Main limitation:**

Question 4: If applicable, what improvement(s) have been made to the model that provided a solution for limitation(s) mentioned?

Answer:

Question 5: If applicable, what improvement(s) do you expect to be making in the future?

Answer:

Question 6: Based on the information about the MTP model provided in Chapter 2 and Appendix C, what would be your suggestions for improving the MTP modelling approach?

Answer:

3.4.2 Complexity

Question 1: How would you characterize the complexity of your modelling approach compared to that of the MTP modelling approach?

The complexity of a model is determined by the degree to which it describes the complexities of the real world. Only few studies were found that go into detail about the complexity of a model.

Complexity is defined here as consisting of:
- 'conceptual complexity': the mathematical and logical difficulty level.
- 'detail complexity': the level of extensiveness of the model from included details.

Complexity of a model faces a trade-off with transparency of a model. The following quote illustrates this.

> "The problems of data quality and data use in the model are also related to the transparency of the model. A transparent model makes it easy for the user and policy maker to evaluate and value the quality of the scenario results. However, the increasing complexity of the relationships between energy use, environment, and economy makes it difficult to maintain transparency. The trade-off between transparency and complexity remains essential to evaluate the results."
>
> Source: Worrell et al. (2004) .

For the following question please:
-put a 'C' on the scale, to indicate the position that would best characterize the 'conceptual complexity' of your approach compared to that of the MTP approach.
-put a 'D' on the scale, to indicate the position that would best characterize the 'detail complexity' of your approach compared to that of the MTP approach.

Please also consider here your answers in Section 3.2.2.

Answer:

Less complex ↑ Same complexity level as MTP model ↑ More complex ↑

Please repeat the same exercise, but now to indicate the <u>desired</u> level of both complexities of your approach, compared to your previous answer.

Answer:

Less complex ↑ Same complexity level as MTP model ↑ More complex ↑

Question 2: Which trade-offs would you face if the complexity of your modelling approach would increase?

For example, more or less transparency of the model. Please explain.

Answer:

3.4.3 How user-friendly is each model?

Question 1: Please explain which aspects of user-friendliness you consider important and which ones are most difficult to achieve.

User-friendliness is an issue generally not dealt with by the available literature. Here, the treatment of user-friendliness goes into the various aspects of user-friendliness in model-use. User-friendliness should help the user to apply the model fast and easy, without laborious manual actions or extensive data management, and should help prevent human errors. In addition, the model may provide support in understanding the results and correcting mistakes, for example by offering analysis tools.

That which contributes to a more user-friendly model depends, of course, on the users and the use of the model. For example, for uninitiated users clarity of the interface is very important, and here a user-friendly interface might guide the user step-by-step through the model. However, such an interface might be experienced as a hindrance by routine users who prefer quick and direct interaction with the model.

User-friendliness is not a characteristic of a particular modelling approach, though the various approaches do pose different challenges in this respect. For example, understanding the results of optimization models often requires thorough analysis of the interactions between various components of the energy system. On the other end of the spectrum, top-down models based on price-elasticity may not have a deeper layer that may help in understanding the results: here the analyses done outside the model are required to understand the results.

For each aspect of user-friendliness mentioned in the table below, please provide:

- The grade you would give to your modelling approach for each aspect. Please indicateon a scale of 1 to 10, where 6 or higher would mean an aspect is satisfactory.
- The importance of each aspect, regardless of the grade you gave it. Please use the following scores[1]:
  - M = Must sufficiently have this aspect.
  - S = Should sufficiently have this aspect, if possible.
  - N = Nice to sufficiently have this aspect, but no must or should have.

[1] Derived from the MoSCoW scoring method for prioritization of software requirements. Please see: http://en.wikipedia.org/wiki/MoSCoW_Method (ECN, March 8th 2011).

Answer:

Aspects	**Grade? (1-10)**	**Important? (Please fill in a MoSCoW score: M=Must have; S=Should have; C=Could have; W= Won't have)**
Clarity		
Meaning of results and inputs		
Interface elements, guiding the user		
Help function		
Generating results		
Ease (number of user actions required)		
Speed (calculation time)		
Flexibility (capability of the model to run in different modes, or run for different data sections)		
Formats (availability of predefined formats for various target groups)		
Analysis possibilities		
Transparency of results and easy access to underlying data.		
Graphical representation		
Possibilities to perform analyses on the results in the model		
Is it possible to generate reports on sections of results and inputs.		
Built-in sensitivity analysis		
Data management		
Making modifications to inputs		
Storing model runs integrally		
Logging modifications		
Sharing models with multiple users		

Which of these aspects in your modelling approach need improvement, and why?

Answer:

3.4.4 Costs of modelling

Question 1: What modelling activities and resources mostly determine modelling efforts and modelling expenses?

There is a general lack of studies clearly identifying the expenses of different modelling activities and resources needed and what the opportunities are to reduce them. Literature on modelling approaches generally deals with the outcomes and capabilities of models, rather than with the development, maintenance, or improvement of models. The following quotes and statement based on literature support this lack of information. Although the remarks have been made in specific contexts, the statements are assumed to apply in general.

There is "very limited detailed literature on the development and use of bottom-up energy models" [and]"lack of literature describing development and applications of the modelling of energy efficiency policies", which particularly holds for the building sector."

There is "limited access to related-model and/or modelling documentation."

Source: Mundaca et al. (2010).

Transparency in bottom up models should be a key feature when used for policy analysis. Meeting the criteria for transparency, i.e. replicability of model results e.g. by inter-model comparison, is limitedly possible due the a lack of access for outsiders to data and model algorithms.

Source: Kavgic et al. (2009).

The following table gives a non exhaustive list of activities and resources that determine the expenses that are made for modelling. If known, please indicate for your modelling approach the share of each activity in the total modelling efforts and the share of each activity and resources in the total modelling expenses.

Answer:

Activities and resources	**Share in total modelling efforts (in %)**	**Share in total modelling expenses (in %)**
Activities		
Development of the model		
Maintenance of the model		
Updating historical information (e.g. statistics)		
Updating (future) estimates		
Validation of model inputs (internal consistency and fit with statistics)		
Validation of model outputs (internal consistency and fit with statistics)		
Resources		
Hardware		
Software		
Licenses, subscriptions		

Question 2: If known, can you indicate the expenses (amount of working weeks or Euros) that the creation / set up of your modelling approach has required?

Answer:

Question 3: If known, can you indicate the yearly expenses (amount of working weeks or Euros) that are required for using your modelling approach?

Answer:

Question 4: For which of the activities and/or resources you mentioned do you see opportunities to reduce modelling expenses?

Answer:

Question 5: Based on the information on the MTP model in Appendix C, do you have suggestions as to how expenses for the MTP modelling activities and resources could be reduced?

Answer:

3.5 Questions: Input, output and validation

3.5.1 Output

Often, literature only highlights examples of the outputs obtained, and does not provide extensive lists. Here, we focus on the outputs that may be obtained by each approach, and the outputs that are required for particular purposes.

Question 1: Please specify the kinds of analyses that are required by the client.

Answer:

Question 2: Please specify the outputs of the model as required for these analyses (e.g. energy use, policy effects, application of the technologies).

Answer:

Question 3: How frequently do these outputs have to be delivered?

Answer:

Question 4: Please specify which outputs of the model are not directly required, but mainly have a supporting role (e.g. consistency checks)

Answer:

Question 5: Can the model produce other useful outputs that are not currently required?

Answer:

3.5.2 Input

Generally, literature does not pay detailed attention to the collection of input data for models.

Question 1: Please explain which of the following data is/are used for your model?

A: energy statistics
B: (economic) growth indicators
C: price elasticities
D: energy prices
E: other
(multiple answers possible)

Answer:

Please specify:

Answer:

Question 2: How is data collection organised for your model?

A: Government energy statistics
B: Billing or metering data from energy suppliers
C: Households surveys
D: Actual (sub-)metering
D: Other
(multiple answers possible)

Answer:

Question 3: Could you indicate problems or issues with the data and with the data collection methods you are using, and the solutions you have found for these issues?

Answer:

Problems or issues with data:

Which solutions, if any:

Problems or issues with data collection methods:

Which solutions, if any:

3.5.3 Validation

Question 1: Could you describe your methods for validation, verification, and sensitivity analysis?

Validation of the model and its results may take place in varying ways, partly depending on the modelling approach.

Validation of a model may comprise a check on whether the code and data are correct, but also to compare the model results with comparable information that has been obtained in another way. For example, the accuracy of model results may be tested by running the model for a historical time period, and comparison of the results with historical data. Another possibility is that only samples of the results are compared with empirically derived information, or with results from other models.

Sensitivity analysis is a method that delivers an estimate of the accuracy of delivered outputs, or input data used. It is a way to deal with uncertainties of modelling results that follow from the uncertainties in assumptions and inputs used, and results can be better interpreted (Mundaca et al., 2010 and Kavgic et al., 2009). Literature suggests to statistically estimate (appropriately chosen) confidence levels for modelling results as a sensitivity analysis method:

> "confidence interval estimations should be used more to account for uncertainty levels (…) The choice of the confidence level (e.g., 95% or 90%, depending on the needed accuracy of the forecasted energy savings) could be left to stakeholders if a stakeholder-based modelling exercise is carried out."
>
> Source: Mundaca et al. (2010)

Please describe below which methods you use for validation.

Answer:

Validation method(s) used:

Question 2: When the context of your model changes, what validation efforts would be required and which of these efforts can you actually perform or have you performed?

A modelling approach should have a robust design to deal with changes in the modelling context. Such changes specifically demand good model validation efforts. From literature the following quote illustrates this.

> "Whereas selected policy instruments and best available knowledge are incorporated at the time of a model's creation, new data, new policy instruments, and new ex post outcomes are emerging all of the time." This requires continuous model verification and validation, by evaluating data used, updating the model and open peer review process."
>
> Source: Mundaca et al. (2010)

Please describe below the validation efforts ideally required and that can (or have been) actually performed, when the context of your model changes (changed).

Answer:

Validation efforts ideally required:

Answer:

Validation efforts actually performed:

3.6 Questions: Satisfaction with the approach?

Please consider all the answers you have provided in this input document.

Question 1: How satisfied are you with the effectiveness of your modelling approach, considering its objective?

Answer:

Question 2: How efficient is your modelling approach, considering the effectiveness and efforts required?

Answer:

Question 3: How useful is your modelling approach for policy makers?

Answer:

3.7 Questions: Alternatives?

Question 1: What would be an appropriate alternative modelling approach or alternative modelling approaches, for your current approach?

Answer:

Question 2: What would be advantages of a switch to this or these alternative(s)?

Answer:

Question 3: What would be disadvantages or risks of a switch to this or these alternative(s)?

Answer:

References

Catenazzi (2009): *Advances in techno-economic energy modelling - costs, dynamics and hybrid aspects.* Dissertation Giacomo Catenazzi, June 2009.

European Commission (2011a): Website: http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/index_en.htm, consulted February 24th, 2011.

eceee (2011a): Website: http://www.eceee.org/Eco_design/, consulted February 24th, 2011.

eceee (2011b): http://www.eceee.org/Eco_design/Energy_labelling_directive/, consulted February 24th, 2011.

EuroWhiteCert (2007): *Handbook for the design and evaluation of TWC schemes*. L. Mundaca, L. Neij. March 2007.

Firth et al. (2010). *Targeting household energy-efficiency measures using sensitivity analysis*. Firth SK, Lomas KJ, Wright AJ., Building Research & Information 38(1):25, 2010.

Giraudet et al. (2011). *Exploring the potential for energy conservation in French households through hybrid modelling*. L. Giraudet, C. Guivarch & P. Quirion. Centre International de Recherches sur l'Environnement et le Développement. January 2011.

Hourcade et al. (2006). *Hybrid modelling: new answers to old challenges - introduction to the special issue of The Energy Journal.* J. Hourcade, M. Jaccard, C. Bataille, F. Ghersi. The Energy Journal, 2006.

Kavgic et al. (2009). *A review of bottom-up building stock models for energy consumption in the residential sector*. M. Kavgic, A. Mavrogianni, D. Mumovic, A. Summerfield, Z. Stevanovic, M. Djurovic-Petrovic. Building and Environment 45, 2010. September 2009.

Mundaca et al. (2010). *Evaluating Energy Efficiency Policies with Energy-Economy Models*. L. Mundaca, L. Neij, E. Worrell & M. McNeil. Annual Review of Environment and Resources 35:305–44, 2010.

Swan and Ugursal (2008). *Modelling of end-use energy consumption in the residential sector: A review of modelling techniques*. L.G. Swan, V.I. Ugursal, Renewable and Sustainable Energy Reviews 13, 2009.

Worrell et al. (2004). *Advances in energy forecasting models based on engineering economics.* E. Worrell, S. Ramesohl & G. Boyd. Annual Review of Environment and Resources 29:345–81, 2004.

Appendix A Concepts and definitions applied

Modelling approach
An information source as least consisting of a quantitative analysis method (e.g. calculation tool), that is used for the support and analysis of energy policy. A modelling approach usually also consists of an additional quantitative or qualitative information base, containing documented knowledge and experience. This information base can have the aim to deliver input for the quantitative analysis method.

Energy using products (EuP) and electricity using products
Energy using products are defined as products ‘using, generating, transfering or measuring energy (electricity, gas, fossil fuel), such as boilers, computers, televisions, transformers, industrial fans, industrial furnaces etc.’ (European Commission, 2011a).

Electricity using products are defined as energy using products (EuP) that consume electricity (but possibly also other energy carriers). Here we mean appliances (for example 'white goods' like refrigerators, dryers etc., audio/video/IT/TV), lighting, and installations (for example for heating, hot water, cooling, airco, pumps etc) used in buildings and homes.

Energy related products (ErP)
Defined as products which ‘do not use energy but have an impact on energy and can therefore contribute to saving energy, such as windows, insulation material, shower heads, taps etc.’ (European Commission, 2011a).

Standards policies
These are defined as policies that *oblige* a maximum level of energy consumption, by prescribing a certain standard. An example of such standards is the EU Ecodesign directive, prescribing a maximum amount of power for certain appliances (eceee, 2011a).

Energy label policies
These are defined as informational policy instruments, usually aiming to *stimulate* (but not oblige) energy efficiency. An example of such as a standard is the EU Energy labeling directive, prescribing a certificate (label) for certain appliances indicating their energy consumption and relative energy efficiency. (eceee, 2011b).

Appendix B Background documentation on the ‘Market Transformation Programme (MTP)’ modelling approach

Please see the document ‘External_version_modelling_approach_doc_v2.docx’ that has been send with the e-mail accompanying this input document.

Appendix C Additional literature background on modelling approaches

C.1 Modelling approaches

This section provides additional literature background on the modelling approaches and typologies mentioned in Chapter 2. Some illustrative examples are described in the next sections. These however are not meant to provide an exhaustive overview of possible modelling approaches for energy using products policy analysis.

As explained in Chapter 2, literature distinguished hybrid models as a separate modelling approach category, mostly to refer to models combining characteristics of bottom-up modelling originating from the engineering and top-down modelling originating from economists (Giraudet et al., 2011).

In literature different definitions for hybrid models are used. For example, models that combine aspects of types of bottom up approaches are also found to be called hybrid, as mentioned for example by Swan and Ugursal (2008) and Kavgic et al. (2009). Two literature findings (with additions by ECN) are highlighted here.

> A way to solve the shortcomings of both bottom up approach methods, i.e. statistical method and engineering method, is to develop a "hybrid" model which combines characteristics of both methods (Swan and Ugursal, 2008). This variant seems to be capable of accurate estimates with detailed information (engineering part) while also able to accurately estimate the effect of behaviour (statistical part). Though inevitably, this leads to an extension of a model and requires more set up, use and maintenance effort.
>
> "Hybrid models basically merge different methodological components from the abovementioned types of models. In addition, some hybrid models are also integrated with top down or general equilibrium models. That is, there is no need for an exogenously determined macroeconomic scenario (employment, income effects, economic growth rate, competitiveness, and so forth), but endogenous relationships between the economy and energy system take place instead."
>
> Source: Mundaca et al. (2010).

Also other terms for hybrid models are used, like 'integrated approach'. An example is provided in the next quote.

> Integrated approaches such as "AMIGA, NEMS, MARKAL-MACRO, and CIMS) include the interaction between changes in energy use and the economy instead of using a preset economic development scenario."
>
> Source: Worrell et al. (2004).

In this input document the term 'hybrid' is only generally assumed to reflect models that significantly combine advantages of opposite modelling approaches. Hybrid modelling is not discerned as a separate modelling category, since it is inherent to modelling that a models has to a certain extent a hybrid character. Although Hourcade et al. (2006) refers hybrid models as a combination of bottom up and top down models, their definition illustrates our assumption in a good way: hybrid models "have made at least one modification that shifts them substantially away from their conventional placement in the cube".

The below quotes and statements based on literature shows examples of how models that combine characteristics of top down and bottom up approaches could look like, and examples found in practice.

- "A TD model that partly renounces the conventional macroeconomist's toolkit (constant elasticities of substitution (CES), and the autonomous energy efficiency index (AEEI)), and relies on innovative ways to represent not only energy supply but also energy end-use technologies as described by BU analysis, and technology adoption as described by microeconomic studies, especially regarding households.
- A TD model that increases its disaggregation level and resorts to Leontief fixed-input ratios to include a reduced-form BU module of some part of the energy system (e.g. in energy supply or the transport sector).
- A BU model that includes: empirically estimated micro-economic parameters related to technology choice; functions to clear markets for energy, other intermediate inputs, and final goods and services based on changes in the cost of production, using either price elasticities or more advanced CGE techniques that utilize consumer utility and firm profit functions; and functions to balance government budgets, exchange rates, and capital and labor markets.
- A composite hybrid model that includes all of the major theoretical and structural characteristics of the most advanced TD models along with the major characteristics of the most advanced BU models, with technological detail in all sectors and behavioral parameters that are empirically estimated from microeconomic and macro-economic research. While such a model would present the greatest challenge in terms of theoretical consistency, mathematical complexity and empirical estimation, it nonetheless represents an objective that some modelers might aspire to, and has been colloquially referred to as the "Holy Grail"

Source: Hourcade et al. (2006).

An example of a hybrid model is the Canadian Hybrid Residential End-use Energy and Emission Model (CHREM)
Source: Kavgic et al. (2009).

Examples are a hybrid framework of the existing Res-IRF and IMACLIM-R models in France, CIMS in Canada, Hybris in Denmark and NEMO-ICARUS in the Netherlands
Source: Giraudet et al. (2011).

Although focusing on top down and bottom up modelling, hybrid models with a focus on building or the residential sector are perceived to be quite uncommon (Giraudet et al., 2011).

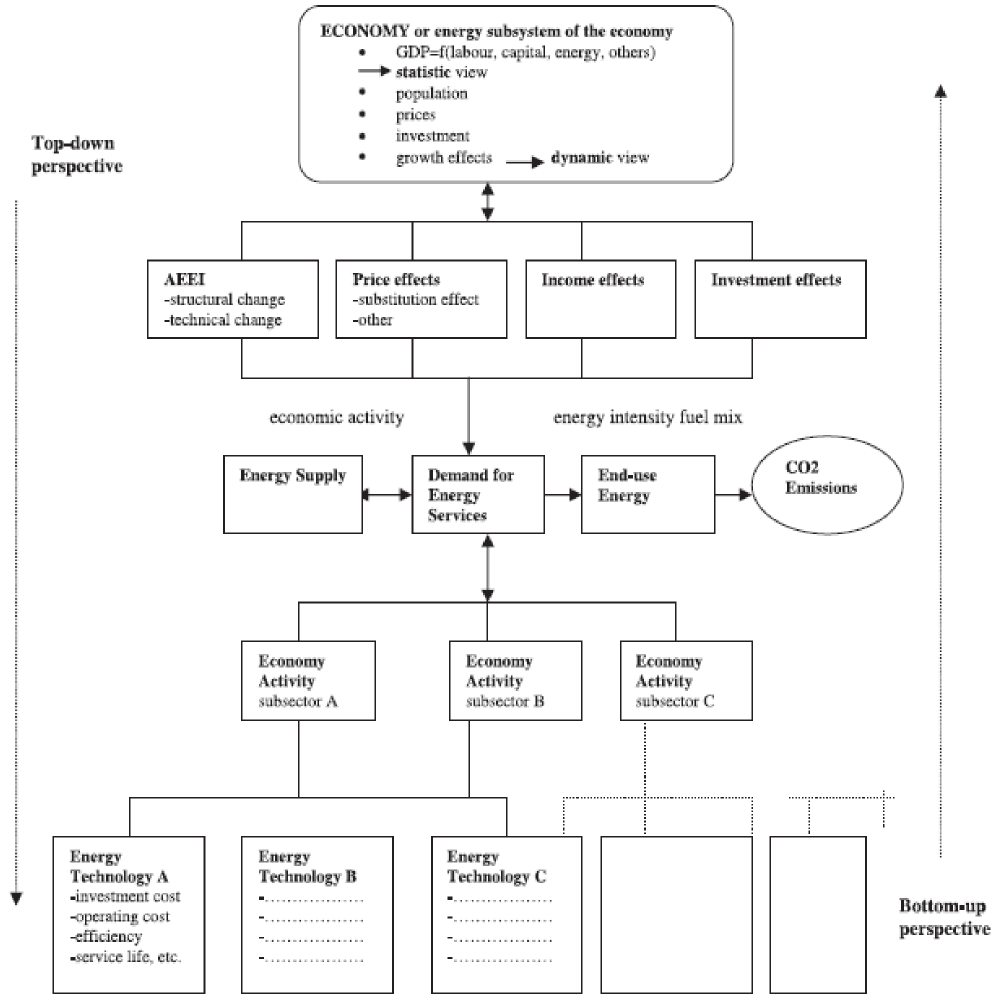
C.2 Top down and bottom up modelling

Literature discusses several modelling approaches for policy analysis. Three common approaches are studies and presented in literature:

- Top down approach
- Bottom up approach

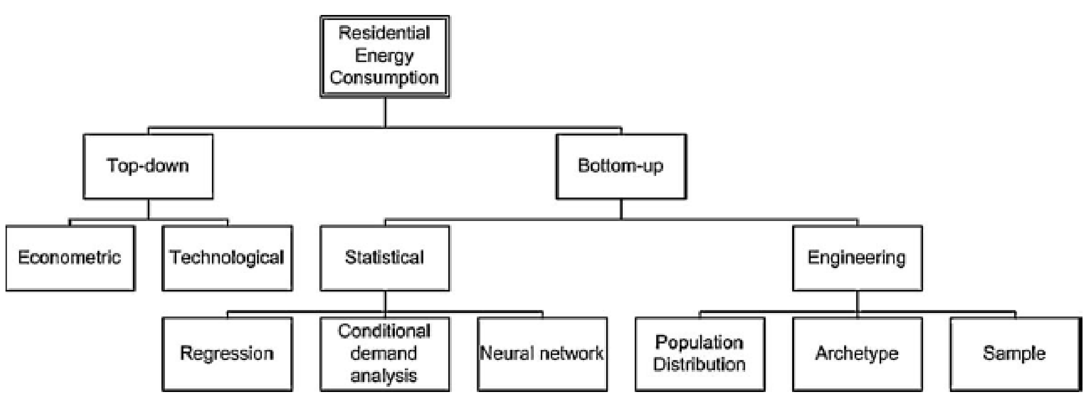
Top down and bottom up approaches are well known energy modelling types, each having its own advantages and disadvantages that have been discussed in research for a considerable time (Hourcade et al., 2006). Each approach "relies on different levels of input information, different calculation or simulation techniques, and provides results with different applicability" (Swan and Ugursal, 2008).

The distinction between top down and bottom up approaches is defined by the hierarchy of data inputs used: with the former approach a part of the total energy consumption is attributed to determinant variables (e.g. an energy saving technique, or behaviour), with the latter approach the energy consumptions of such variables are calculated and summed to derive total energy consumption (Swan and Ugursal, 2008). The below figure (from Kavgic et al., 2009) provides a good picture of this difference in data level:



Figuur C.1 *Difference in data level of top down and bottom up approaches (Kavgic et al., 2009)*

Literature distinguishes different specific modelling methods or techniques as top down or bottom. Different types of top down and bottom up approaches are found in literature. An example is provided by Swan and Ugursal (2008) and shown below.



Figuur C.2 *Modelling techniques categorized in top down and bottom up approaches (Swan and Ugursal, 2008)*

C.3 Top down approach

A top-down modelling approach calculates aggregate energy consumption, without considering the underlying developments for specific energy using products. For these calculations macro-economic indicators or parameters such as GDP, employment rates, prices, climatic conditions, housing construction/demolition rates, and estimates of appliance ownership are used (Swan and Ugursal, 2008). Trends in these parameters are used to estimate resulting changes in total energy consumption. Top down approaches can also be referred to as macroeconomic models (Catenazzi, 2009). The next quotes and statements based on literature are illustrative for typical characteristics of this approach.

> "Top-down approaches are used for supply analysis based on long-term projections of energy demand by accounting for historic response." This modelling approach is mainly used for determining supply requirements"
>
> Top down model rely heavily on historical energy consumptions and macroeconomic parameters are used as indication for the expected change to these statistics.
>
> Source: Swan and Ugursal (2008).

Top down models can be categorised into econometric and technological models. Econometric models mainly use price and income data as input to calculate outcomes, while technological models attribute energy consumption based on more technology characteristics such as appliance ownership trends. A combination of both also exists (Swan and Ugursal, 2008).

> "[Top down approaches] use empirical functions to simulate future developments. The econometric models use econometric analysis, normally on time series but sometimes also on cross-country data, in order to calculate the economic and energy development. However, major technological changes or behavioural (value) changes cannot be simulated by this type of model, as the relationships are based on past data and related behaviours."
> Source: Catenazzi (2009).

Top down approaches are less suitable for analysis of detailed policy, e.g. efficiency standards

C.4 Bottom up approach

A bottom up model can be defined as "all models which use input data from a hierarchal level less than that of the sector as a whole." Energy use of products and saving effects are calculated by modelling technical-economical parameters such as penetration, intensity of use and consumed power of specific energy using products, using a stock model approach (Swan and Ugursal, 2008).

An important strength is that a detailed level can be modelled, for example the effect of behaviour and technological options (Swan and Ugursal, 2008). This enables a more detailed policy analysis. Bottom up techniques can model rapid technological changes, which applies to electricity using products, and are therefore regarded to be useful as policy and strategy development tools (Kavgic et al., 2009).

To arrive at outcomes for the whole residential sector, summing or extrapolating is needed. A way to calculate this is the use of weighting the individual end uses, for example that of a house class within the housing stock (Swan and Ugursal (2008) and Kavgic et al. (2009)).

Bottom up methods basically can be distinguished in *statistical methods* and *engineering approaches* (Swan and Ugursal (2008). The latter is also referred to as physics approach (Kavgic et al., 2009).

Statistical approaches use historical information and types of regression analysis or techniques that are applied to attribute more aggregated energy consumption to individual end users (Swan and Ugursal (2008) and Kavgic et al., 2009). For example the part of the total energy use of a dwelling that is consumed by appliances can be determined in this way.

Engineering approaches calculate the energy consumption of individual end-uses based on their characteristics (or their physics) (Swan and Ugursal, 2008). A common aim of engineering models is that they are used to identify cost effective (e.g. best available) technological options to reach savings targets (Kavgic et al., 2009). Kavgic et al. (2009) provide an overview of existing bottom up physics (engineering) models from outside (see table 2, page 1687 and 1688) and from inside the UK (see table 3, page 1690[2]).

Bottom up models are able to calculate the effect of "free energy" such as passive energy gains (e.g. internal heat load) and behavior (Swan and Ugursal, 2008). Modelling both with bottom up modelling is difficult, because the engineering method is designed to do the former while the statistical model is designed to do the latter.

The below quotes provides different but similar descriptions of statistical as well as of engineering approaches, as found in literature.

Engineering approaches

Engineering methods "explicitly account for the energy consumption of end-uses based on power ratings and use of equipment and systems."
(Kavgic et al., 2009).

"The EM [engineering method] relies on information of the dwelling characteristics and end-uses themselves to calculate the energy consumption based on power ratings and use characteristics and/or heat transfer and thermodynamic principles. Consequently, the engineering technique has strengths such as the ability to model new technologies based solely on their traits."

"Bottom-up engineering techniques are used to explicitly calculate energy consumption of end-uses based on detailed descriptions of a representative set of houses, and these techniques have the capability of determining the impact of new technologies."
Source: Swan and Ugursal (2008)

Statistical approaches
"The SM [statistical method] utilizes dwelling energy consumption values from a sample of houses and one of a variety of techniques to regress the relationships between the end-uses and the energy consumption. SM models can utilize macroeconomic, energy price and income, and other regional or national indicators, thereby gaining the strengths of the top-down approach."

"Bottom-up statistical techniques are used to determine the energy demand contribution of end-uses inclusive of behavioural aspects based on data obtained from energy bills and simple surveys."
Source: Swan and Ugursal (2008)

2 Building Research Establishment's Housing Model for Energy Studies (BREHOMES); Johnston model; UK Carbon Domestic Model (UKDCM), DECarb model; Community Domestic Energy Model (CDEM).

Swan and Ugursal (2008) distinguish a few types of engineering methods: the *distribution approach*, the *archetype approach*, and the *sample approach*. The distribution approach has been explained earlier, the other two approaches are explained here.

- Archetypes approach:
  Probably this approach most commonly calculates on an individual houses level. The stock of houses is classified based on housing characteristics (archetypes), so the interaction between measures within a house level (e.g. appliances) are considered. The energy consumption modelled for each archetype is then aggregated to a higher level (Swan and Ugursal, 2008). In practice only a limited number of archetypes can be developed (Swan and Ugursal, 2008). An example would be the modelling of several theoretically representative energy consuming houses (ECN).
- Samples approach:
  Actual sample data about a large variety of houses are weighted and aggregated to arrive at the energy consumption on a higher level. This requires a large database of houses which is data intensive and causes a low use of this approach, though the variety in energy consumption within a housing stock can be realistically captured. An example would be the modelling of several theoretically representative energy consuming houses (ECN). An example would be the modelling of several representative energy consuming houses found in the real world.

Bottom up modelling probably is the most commonly applied approach for energy using products policy analysis.

C.5 Optimisation (equilibrium), simulation, multi-agent, and other approaches.

Whereas the opposite approaches of bottom up and top down models are mainly based on input required, other typologies have also been found in literature. One is the distinction of approaches according to the way in which outputs are derived, more specifically the extensiveness and intelligence with which this is done.

Examples are accounting, simulation, optimisation and other approaches, which are shortly described in the next sections.

The MTP model has many characteristics of an accounting approach, which has the focus here and has already been explained in Chapter 2.

C.6 Optimisation or equilibrium approach

Optimization models are used to find the optimal set of technology choices, or optimal technological path, to achieve a specified target at the lowest costs ((Worrell et al., 2004, Catenazzi, 2009). Energy use and saving effects are calculated for optimal solutions or goal situations, given certain constraints or conditions such as policy measures. The next quotes elaborate more on the possible characteristics of this approach.

> "The least costly replacement and the minimum additional investments are chosen for the simulated time horizon." "..the supply and demand must be in equilibrium, and these models maximise the demand side."
> Source: Catenazzi (2009).
>
> "Optimization models are prescriptive by definition. They attempt to find least-cost solutions of technology choices for energy systems based on various policy and market constraints. On the basis of a rational model of consumer behavior, the allocation of energy supplies to energy demands is based on minimum life cycle technology costs at given discount rates and determined by an optimization approach (linear programming)."
> Source: Mundaca et al. (2010)

Examples of types of techniques that are referred to in literature as optimization or equilibrium, are computable general equilibrium (CGE) and partial equilibrium models. The former is more widely used. While general equilibrium models focus on an energy system and take into account macroeconomic effects, partial equilibrium models focus on a sector, and are therefore much more detailed but do not consider macroeconomic effects (Catenazzi, 2009). A well-known optimization model is MARKAL (Hourcade et al., 2006).

Optimisation or equilibrium approaches probably are less commonly applied to analyse policy impacts on energy using products.

C.7 Simulation approach

Simulation approaches tend to describe historical and future energy demand and supply situations (which technologies deployed, which costs and which saving benefits) based on constraints of characteristics, such as policies. They mainly consider existing (historical) situations.

The below quotes provide definitions of simulation approaches which describe its characteristics in more detail.

> "Simulation models provide a descriptive quantitative illustration of energy production and consumption, which is based on exogenously determined scenarios. The methodological approach represents observed and expected microeconomic decision-making behavior that is not related to an optimal or rational pattern. These models try to replicate end user behavior for technology choice while considering different drivers (e.g., energy security)."
> Source: Mundaca et al. (2010)
>
> "Simulation models provide a quantitative illustration of exogenously defined scenario strategies. Because of the technical and structural information incorporated, they allow evaluation of impacts and interrelations of different policies in a systematic manner. Cost information plays a central role, but strategies can follow other priorities (such as supply security). "
> Source: Worrell et al. (2004)
>
> "The simulation models (often defined as technology-based models), are another kind of bottom-up model. These models simulate energy-consuming and energy-converting technologies, the diffusion of such technologies (supply and demand side) and related investment and operating costs. Given this structure with drivers and technologies, the calculation of energy supply and demand is a complex aggregation of data."
> Source: Catenazzi (2009)

Simulation approaches are suitable for technology-oriented policy analysis (Catenazzi, 2009).

C.8 Multi-agent approach

Multi-agent approaches aim to simulate a group process, of a group of individual actors (agents), based on established behavioral rules in a scripts. A typical feature is that such a modelling approach also can incorporated interactions between actors. The below quote gives a more detailed explanation of multi-agent modelling.

> "Multi-agent-based models are a new category of model. These models are based on the choices of different groups of stakeholders or energy users. This generally leads to a non-deterministic model: the defined agents (categories of energy users, building owners or investors, industrial producers, etc.) make their own choices, taking into consideration their preferences and decision-making environments (technology availability, prices, policy context), their competitors' choices, manufactures or retailers, and some random components. In this type of model it is possible to model different groups' decision patterns, such as innovators, early adaptors, followers and late-adaptors, thus generating more information about choices, obstacles, and the non-optimal diffusion of new technologies."
> Source: Catenazzi (2009)

Multi-agent are assumed to be less applicable, and in practice are also less applied, for the analysis of energy using products policy.

C.9 Strengths, limitations and challenges of modelling approaches

For approaches with significant top down characteristics and for approaches with significant bottom up characteristics, the table below provides a non-exhaustive list of those strengths and limitations identified in studies.

The tables are a compilation, mainly based on tables provided by Kavgic et al. (2009) and Swan and Ugursal (2008). These have been supplemented with additional literature (EuroWhiteCert, 2007 and Hourcade et al., 2006) and further adapted by and supplemented with suggestions of ECN.

Tabel C.1 *Strengths and limitations of modelling approaches*

Top down approaches	
Strengths	*Limitations*
Can model macroeconomic and socioeconomic variables (i.e. prices, income) and effects (i.e. economic and social costs and benefits)	Reliance on historical consumption information; e..g. depends on past energy economy interactions to project future trends
Simplicity of approach, e.g. - relative simple calculations - uses simple input information, i.e. aggregated (economic) data	No explicit representation of end-uses: e.g. - lack the level of (technological) detail - less suitable for examining technology-specific policies - difficult to analyze change due to policy instruments - economic impacts of (especially on the longer term) changing or new technologies (i.e. difficulty of modelling discontinuity)
Relevant statistical data is available	Typically assumes efficient markets, but no efficiency gaps
Can perform long-term forecasting	

Bottom up approaches in general	
Strengths	*Limitations*
High level of detail - Underlying details and trends can be understood - Specific areas for improvement can be determined	Requires a large database of empirical data
	Calculation techniques can be complex

Statistical approaches (bottom up)	
Strengths	*Limitations*
Can model occupant behaviour	Do not provide much data and flexibility, e.g. can limitedly assess the impacts of saving measures
Relatively easy approach to develop and use	Data issues - Relies on historical consumption data - Requires a large survey sample

Does not require detailed data (only billing data and simple survey information)	Problem of multicollinearity
Can include macroeconomic and socioeconomic effects	

Engineering approaches (bottom up)	
Strengths	*Limitations*
Can model current and future technologies in detail (disaggregated data), e.g. - can assess impact of different combination of technologies on energy - can estimate least-cost combination of technologies	Neglects the relationships between policies and energy use, and economical factors. E.g. - micro economic variables (for decision making) - macroeconomic variables - market interactions - cannot predict and distinguish economic effects (of policies), e.g. market price changes or taxes in energy prices
Determination of each individual end-use energy consumption by type, rating, etc.	Human behaviour cannot be determined within the model, but by external assumptions
Uses physically measurable data (increasing reliability of input)	- Data issues: - Requires a large amount of technical data - Empirical data can be lacking
	Can be computationally intensive

Challenges for modelling approaches follow particularly from the limitations of modelling approaches. These may lead towards problem solving and finding solutions possibly making use of other modelling approaches.

To provide examples, a study by Mundaca et al. (2010) mentions general challenges for bottom up modelling related to some of the strengths and limitations described above:

- The quantification of non energy related benefits (such as comfort, or poverty).
- Modelling (the influence of) transaction costs and administrative costs.
- Combining the of capabilities of more single-technology models with more energy-system models.
- Using experience or learning curves in modelling to gain insight in historical cost developments, enabling the analysis of future cost developments.

In itself however, a certain characteristic of a modelling approach can never be categorized as positive or negative without knowing the objective and context in which the approach is used. Here the context refers to circumstances such as the availability of data, but also issues such as available budget for modelling. For example, intensive data requirements can be a limitation if it demands relatively much human and monetary resources, however this does not need to be the case. Some opinions found in literature (indirectly) support this thought:

> "Advantages and disadvantages of modelling tools should be provided explicitly to better understand and judge whether the model under use has been selected appropriately to answer the policy questions."
>
> "Our analysis highlights that there is no single best method to evaluate energy efficiency policy instruments for the household sector."
>
> Source: Mundaca et al. (2010).

Appendix D Reference table key questions of study

The table below shows to which sections of questions in this input document, the key questions that are to be answered in the Strategic modelling approach review study relate to.

Key question in study:		Input document section:
1)	What modelling and wider evidence base management approaches are applied in each one of the chosen countries? (i.e. top-down/bottom-up methodology or a mixture of both)	3.2 and 3.3
2)	What are the drivers for products policy modelling in the respective country, and how is this reflected in the level of effort expended and the choice of approach?	3.2
3)	What is the cost to set up, run maintain/update and validate each approach?	3.4.4
4)	What is the scope; which industries and products are considered in each programme?	3.2 and 3.3
5)	What are the main outputs obtained by each approach, and how frequently are the outputs delivered? What are the main outputs used for in various countries?	3.2, 3.3 and 3.5.1
6)	How the results from the modelling are validated and verified?	3.5.3
7)	In general, model complexity involves a trade-off between simplicity and accuracy of the model. Considering their predictive power, how complex is each model?	3.4.2
8)	How user-friendly is each model?	3.4.3
9)	How do other programmes obtain evidence data to feed into their models?	3.5.2
10)	Which assumptions are significantly different between each approach?	All questions
11)	What has been the biggest challenge to each approach and what steps are being / were taken to overcome it?	3.4.1
12)	How satisfied are the participants with each approach?	3.6
13)	What are the main strengths and weaknesses related to each approach?	3.4.1
14)	What is driving the trends identified for novel market transformation models? Are those trends local, national or international?	3.2
15)	How does the UK approach compare with the approaches reviewed?	In workshop
16)	What are the risks to the UK for adopting an alternative approach?	3.7

Appendix E Example answers for the MTP model

Question 1: Please provide a general description of your model specifying the following aspects:

Example answers:

Model name	*MTP modelling approach*
Model owner	*AEA*
Main clients (e.g. government, researchers)	*Government (Defra)*
General description of the modelling approach	*The MTP model is a stock-based, bottom-up, accounting modelling tool. The models are built on collated research and stakeholder evidence which are then used as inputs, including stock, efficiency, usage rates and unit prices. The model is very extensive and detailed with regard to the data required. For approx. 140 energy using products, energy consumption and policy effects (energy savings and costs and benefits) are modelled for each product separately.*
General description of main inputs	*Inputs are primarily stock, efficiency and usage rates of EuPs, and costs and benefits of EuPs as well as of policy measure packages.* *An important characteristic of the approach is that many of the input parameters are derived from external calculations and analysis. The way such calculations are performed is not standardized*
General description of main outputs	*Main outputs are energy savings, emissions reductions, and costs and benefits. These may be calculated for the different policy scenarios. Outputs from the model are summarised per period (e.g. 2010, 2020, 2030) but are also presented annually. Reporting is done mainly in GWh units.*
Which type of software is used for the modelling approach?	*Excel including Visual basic.*

Question 2: What is the specific subject of the model?

A few studies mention objectives or goals of modelling approaches. Hourcade et al. (2006) and Worrell et al. (2004) provide different objectives of modelling, that are mentioned here as general objectives affecting model design choices and complexity of a model. ECN has used and reframed these for the following questions. Examples of subjects of models can be:

- energy consumption
- energy savings (from techniques, or from policies)
- greenhouse gas (GHG) emission
- air pollution
- productivity
- costs and benefits
- other.

Example answer:

> *Energy consumption and savings, greenhouse gas (GHG) emission costs and benefits of EuP policies*

Question 3: What is the geographical scope of the subject?

For example: global, continental (e.g. EU), national, regional, or other.

Example answer:

> *National level and supranational (EU) level*

Question 4: What is the usual time frame of the subject?

For example, analyses to support Kyoto obligations have a different time frame than temporary or short term policies (Hourcade et al., 2006).

Example answer:

> *Results up to 2020 mainly used, but models produce results up to 2030 (1960 initial year, assuming relevant products were on the market).*

Question 5: What type of analysis is needed: policy assessment, selection, development and improvement, a combination, or other?

Examples provided by Hourcade et al. (2006) and Worrell et al. (2004) are:

- Calculating impacts of policies (policy assessment)
- Identification of best technology options (policy selection)
- Definition of target levels (policy development)
- Assessing benefits, costs and surplus (e.g. least social costs, those of proposed policies, distribution or sectoral costs and benefits of policy choices (policy assessment)
- Assessing interactive effects of various policies (policy assessment)

Example answer:

> *Policy assessment (monitoring energy savings and economic impacts)*
> *Policy selection (choice of EuP policies, where and how to set standards)*

Question 6: What type(s) of specific policy analyses can the model perform?

A: Monitoring the impacts of existing policies
B: Ex ante estimates of future policies
C: Ex post evaluation of past or existing policies
(multiple answers possible)

Example answer:

A, B.

Question 7: Why has the current approach been chosen for the main application?

Please try to answer the extent to which (existing or future) energy using products policies have influenced this choice.

Answer:

The requirements of the MTP programme limit the number of suitable modelling approaches. The programme requires the quantification of energy savings and other impacts from individual energy using products, and the planning of policy measures that aim to transform the market for these individual products. Mainly based on this requirement of detail, bottom-up models are the logical choice.

Question 8: approach been chosen for the main application?

Answer:

The requirements of the MTP programme limit the number of suitable modelling approaches. The programme requires the quantification of energy savings and other impacts from individual energy using products, and the planning of policy measures that aim to transform the market for these individual products. Mainly based on this requirement of detail, bottom-up models are the logical choice.

Appendix F Literature and example answers for the MTP model

Question 1: Would you characterize your modelling approach as more top down or more bottom up?

Please label, with an '*X*' mark in one of the cells on the scale, the position on that scale that would best characterize your modelling approach. Please consider the literature overview in Appendix C.

Example answer:

Top-down bottom-up

								X	

100% 0% 100%

Please explain your choice:

Example answer:

The model is very extensive and detailed with regard to the data required, since it calculates inputs and outputs separately for approximately 140 energy using products. It therefore has a strong technology focus and incorporates many detail on a level lower than that of sectors.

Question 2: Which type(s) of techniques are used?

A: Accounting
B: Simulation
C: Optimization / equilibrium based on constraints
D: Econometric, e.g. elasticities
E: Statistical methods
F: A combination, or other.

Example answer:

A.

Please explain your answer:

Example answer:

The MTP model primarily aims to manage data and results. Most of the actual modelling of input parameters is done exogenously.

Question 3: Which interactions are endogenously modelled?

For example: mutual effects interactions between inputs, between outputs, or between in- and outputs.

Example answer:

No interactions are modeled, besides some specific assumptions in the outside input calculations that *consider interactions or overlap.*

Question 4: Are intermediate calculation steps explicitly accounted for, i.e. visible, in the model's (intermediate) output?

Example answer:

All calculations performed within the model are visible in calculation sheets – e.g. stock turnover, estimate of sales from stock, calculation of total energy demand, etc.
Intermediate calculations to arrive at the direct input parameters are not visible in the model.
Many information is contained and therefore 'hidden' in the outside calculations, and probably not all the calculation steps needed to arrive at results allow insight or are recorded in the model. For example, separate volume, structural and efficiency effects (decomposition of different developments) cannot be determined by the model itself.

Question 5: When using the model, please indicate when intervention by the user is required (e.g. manual tasks need to be performed)? I.e. which parts of the model are not automated?

Intervention would relate to the following aspects:
- What efforts are required to make a complete model run?
- Which part of these efforts are not performed by the model itself, but outside the model?
- To which extent can raw data be put fed into the model, or does it need further processing?

Example answer:

Once model inputs are provided, no intervention is required to achieve model outputs. The vast majority of effort is required in exogenous modelling and calculation to achieve these inputs.

Question 6: How would you characterize the level of standardization of the inputs of your approach?

A: highly standardized
B: moderately standardized
C: hardly standardized
(more than one answer possible)

Example answer:

B

Please explain:

Example answer:

Direct inputs are well standardized, however the major part of the calculations to arrive at these direct inputs are not.

Feeding input into the model and creating or adapting a new product model is done via a standardized procedure. Standard excel templates are used on different product levels (individual products, areas of products) for input. Users fill in a questionnaire with relevant input parameters and other input data, which is then plugged into the model via a macro code. There are a standard range of answers that must be given by the user, to determine what inputs the model requires.
Automatically, this template ensures a standardized output for each product..

Question 7: How flexible is the model: to what degree can it cope with changes of the modelling context? (changing also the scale and/or scope of input and output?

For example: a change in policies that are analyzed with the model.

Example answer:

The current model is somewhat inflexible regarding adaptations needed in the model in case of changes in policy regulations.

Certain adaptations to input and output are possible, if needed for specific demands of clients. In the case of a change of policy, the majority of the effort required would be in exogenous calculations to provide the model with new inputs. Depending on the changes (i.e. a change in carbon factors, or a change in sub-product classifications and numbers), may be relatively easily implemented in the model.

Question 8: Please indicate the level of detail of the required inputs and delivered outputs.

The scope of this study, and thus of the workshop and this input document, is energy savings or energy efficiency policy targeting:

- *energy using products* that are used in
- *homes (e.g. households) and buildings (e.g. organizations)*.

Likewise, we ask you to explain the scope of your model by indicating:

- the technologies (e.g. appliances, renewable technologies etc.)
- the sectors and possibly subsectors (e.g. built environment, industry, transport, residential sector etc.)

that are included as input or output in your model.

For this question we also refer to the concepts and definitions provided in Appendix A.

Example answer

Technologies

Level of detail of inputs:
Individual energy using products, currently involving appliances, lighting and installation and others.

Level of detail of outputs:
See above.

Sectors and subsectors

Level of detail of inputs:
Input are on the level of individual products.

Level of detail of outputs: *The inputs are aggregated to output on the level of the built environment, with a separation between the residential sector, services sector, and industry (separate models for domestic and non-domestic).*

Question 9: Could you explain on the modelling of input and output parameters?

For parameters possibly included in your model, please indicate in the table below:

- whether they are input, outputs, or both *(left two answer boxes)*
- whether they are implicitly 'hidden' in other parameters, or whether they are made explicit (visible) in the model *(middle two answer boxes)*
- whether they are exogenously determined outside the model, or endogenously by the model itself *(right two answer boxes)*

Please indicate with an 'X' in the cells which answers are valid for your approach. Multiple answers are possible. Not all answer boxes need to be relevant for your modelling approach.

If necessary for a better understanding of your answer for a parameter, please provide an additional explanation in the space beneath the answer boxes for that specific parameter.

Input/Output Parameters:	**Input**	**Output**	**Implicitly**	**Explicitly**	**Exogenously**	**Endogenously**
Energy consumption of sector(s)		***X***		***X***		***X***
If necessary, please explain:						
Energy savings or(active or passive) of technologies		***X***		***X***		***X***
If necessary, please explain:	*Calculated in the model – from stock/sales, average energy demand per unit, lifespan.*					
Other effects (health, comfort)	***X***	***X***		***X***	***X***	***X***
If necessary, please explain:	*Factor as part of the model, not inputted by user.*					
Societal costs and benefits		***X***		***X***	***X***	***X***
If necessary, please explain:	*Both – marginal capitla cost is an input.*					
CO2 emission reduction effects		***X***		***X***	***X***	***X***
If necessary, please explain:						
Characteristics of energy techniques (e.g. capacity/power, usage, efficiency factors or learning effect, or other)	***X***			***X***	***X***	
If necessary, please explain:						
Energy prices or CO_2 prices				***X***		
If necessary, please explain:	*Added centrally, not by user. Values present in viewable calculation sheets.*					

Explicit specification and modelling of policies (e.g. subsidy levels, energy taxes, standards)		***X***		***X***	***X***	***X***
If necessary, please explain:						
Macro economic data such as: -Income/capita -Growth/productivity/GDP						
If necessary, please explain:	*Not considered in MTP models*					
Demand elasticities	***X***		***X***		***X***	
If necessary, please explain:						
Behaviour (purchase/choice and use of technologies)	***X***		***X***		***X***	
If necessary, please explain:						
Other? Please mention:						
If necessary, please explain:						