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Analysis of energy models and their adaptability for Estonian energy market

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In recent years, a large number of models have been developed for energy system analysis including demand and supply forecasts and impacts of policy shifts on overall energy systems. Energy models are based on different fundamental approaches and concepts, and employ a range of mathematical algorithms. As a consequence, these models vary considerably, and the question arises which model is most suited for a certain purpose or situation.

Estonia is the only country in Europe that has a significant oil-shale mining industry, and 95% of Estonian electricity is produced by oil-shale power plants. The Baltic countries are facing a complex situation in breaking up the monopoly and solving the free electricity market issues. Also, Estonia has applied (for a transition period) for the oil shale-based energy sector development. The trend of liberalization and changes in the Estonian energy market, related to European Union strict technological and environmental requirements, needs developing new scenarios for the energy sector in Estonia to mitigate the environmental impacts of electricity production by using new, less environment-damaging technologies. This paper presents an ongoing research project where the objective is to analyse energy planning models to elaborate scenarios of developing the Estonian energy system in the conditions of oil shale-based electricity supply shortage, taking into account the main engagements and figures of the electricity sector by year 2015.

Key words: energy planning, modeling, energy model, supply, demand, forecast, optimization, economic equilibrium, simulation

1. INTRODUCTION

Energy models were first developed in the 1970s because of the increasing availability and development of computers and the increasing environmental awareness. Most of the energy models were built and used in industrialised countries, so that the main assumptions about energy systems were mainly based on the experience from these countries. Energy models are based on different fundamental approaches and concepts, and employ a range of mathematical algorithms. As a consequence, these models vary considerably, and the question arises which model is most suited for a certain purpose or situation.

In order to decide which model is better to use, it is important to know the model characteristics, structures, data and modelling methods. The ways of classification are given in this work and the basic distinctions of the types of models such as econometric, macro-economic, economic equilibrium, optimization, simulation, spreadsheet / toolbox and backcasting are described. In practice, it is not feasible to develop our own models for energy planning; it is more effective to use existing models, but the key question is to decide which model should be used. The purpose of this paper is to give information about user-friendly tools for energy planning analysts to perform demand and supply analysis and to elaborate the methodology of planning and forecast. For comparison, we selected and compared different worldwide used energy-planning models.

2. CLASSIFICATION OF ENERGY SYSTEM MODELS

Models are built for various purposes and consequently have different characteristics and applications.

Nine ways of their classification are presented:

1. Purposes of energy models:

• General: forecasting, exploring, backcasting.

• Specific: energy demand, energy supply, impacts, appraisal, integrated approach, modular build-up.

2. The model structure: internal assumptions and external assumptions.

3. The analytical approach: top-down, bottom-up and hybrid.

4. The underlying methodology: econometric, macro-economic, economic equilibrium, optimization, simulation, spreadsheet / toolbox and backcasting.

5. The mathematical approach: linear programming, mixed-integer programming, dynamic programming.

6. Geographical coverage: global, regional, national, local, or project.

7. Sectoral coverage: single-sectoral models and multi-sectoral models.

8. The time horizon.

9. Data requirements.

Such classification of energy models is helpful for understanding their need, their roles and their specificity in relation to the studies under consideration [1].

Table 1. **Characteristics of top-down and bottom-up models**

Top-down models	Bottom-up models
Use an "economic approach"	Use an "engineering approach"
Give pessimistic estimates on "best" performance	Give optimistic estimates on "best" performance
Cannot explicitly represent technologies	Allow for a detailed description of technologies
Reflect available technologies adopted by the market	Reflect the technical potential
The "most efficient" technologies are given by the production frontier (which is set by market behaviour)	Efficient technologies can lie beyond the economic production frontier suggested by market behaviour
Use aggregated data for predicting purposes	Use disaggregated data for exploring purposes
Are based on actual market behaviour	Are independent of the actual market behaviour
Disregard the technically most efficient technologies, thus underestimate the potential for efficiency improvements	Disregard market thresholds (hidden costs and other constraints), thus overestimate the potential for efficiency improvements
Determine energy demand through aggregate economic indices (GNP, price elasticities), but vary in addressing energy supply	Represent supply technologies in detail, using disaggregated data, but vary in addressing energy consumption
Endogenize behavioural relationships	Assess costs of technological options directly
Assumes obsence of discontinuities in historical trends	Assumes that the interaction between energy sector and other sectors is negligible

Generally, recent models offer an integrated approach in the sense that they combine several specific purposes, although some of the models focus on one aspect only (such as some utility expansion or environmental impact models). Beside the purpose, models can also be distinguished according to their structure:

• Internal assumptions: degree of endogenization, description of non-energy sectors, description of end-uses, and description of supply technologies.

• External assumptions: population growth, economic growth, energy demand, energy supply, price and income elasticities of energy demand, existing tax system and tax recycling.

Concerning the mathematical approach, linear programming has a clear advantage in that it allows for simple programming and can easily be understood by planners because no special expertise is needed. In this case, the problem can be solved in a straightforward way by using standard algorithms.

The geographical coverage reflects the level at which the analysis takes place: the global models describe the world economy or situation; the regional level frequently refers to international regions; the national models cover all major sectors in a country, taking into account world market conditions; the local models refer the regions within a country, and the project level is a somewhat special case.

By the sectoral coverage, a model can be focused on only one sector or include more sectors.

The time horizon models are divided into:

• Short-term (5 years or less)
• Medium-term (5–15 years)
• Long-term (10 years or more).

Finally, by the data requirement, a model can require certain types of data: qualitative, quantitative, monetary, aggregated and disaggregated.

We will discuss in more detail the analytical approach and the underlying methodology in the next two sections.

2.1. The analytical approach to energy system models

In the analytical approach, the models can be divided into top-down, bottom-up and hybrid. The distinction between top-down and bottom-up models is particularly interesting because they tend to produce opposite outcomes for the same problem. In top-down models, the functional details of the system are derived from aggregated macro-economic parameters, such as labour, capital, interest rate, etc. In contrast, in bottom-up models the driver is energy service demand, and the results are produced by the structure of the detailed technology system. The bottom-up model is thus rich in technological details, and aggregated values are based on the projection of energy service demand and the properties of these technologies.

The top-down and bottom-up models can be combined in a hybrid approach, depending on the purpose, data requirements and desired output [1].

The different aspects related to the top-down and bottom-up models are summarized in Table 1.

Top-down models are most useful for studying broad macroeconomic and fiscal policies such as carbon or other environmental taxes. Top-down models externalise major structural changes such as lifestyles, urbanisation and technological changes. The strengths of the top-down approach are its consistency, links to historic references and economic frameworks, equilibrating prices and quantities, and its data availability.

Bottom-up models are most useful for studying options that have specific sectoral and technological implications. The bottom-up approach can be useful mainly because the model is independent of market behaviour and production frontiers and because technologies are explicitly modelled. The weaknesses of bottom-up models are that their main drivers such as demand, technology change and resources remain exogenous [1].

The hybrid approach leads to flexible models, because it combines the advantages of top-down and bottom-up models. Both top-down and bottom-up models can be useful for certain purposes of future forecasts, but most of energy planning models are focused on bottom-up or hybrid approaches because of their flexibility.

2.2. The underlying methodology of energy system models

Concerning the underlying methodology there are eight types of models: econometric, macro-economic, economic equilibrium, optimization, simulation, spreadsheet / toolbox and backcasting. In practice, the distinction is not always clear. The literature makes a distinction between simulation, optimization, and spreadsheet methods usually only when referring to bottom-up models, while recent economic top-down models use optimization and simulation techniques as well. On the other hand, econometric, macro-economic, and economic equilibrium methods are generally applied only in top-down models, although there are also some exceptions.

I. Econometric models
Econometric methodologies are methodologies that apply statistical methods to extrapolate past market behaviour into the future. Nowadays econometric methodologies are mainly used as parts of macro-economic models. A disadvantage of this methodology is that it does not represent specific technologies at all and could not be use for long-term planning.

II. Macro-economic models
The macro-economic methodology focuses on the entire economy of a society and on the interaction between the sectors and well known as input-output models. Input-output tables are used to describe transactions among economic sectors and assist in analysis of energy-economy interactions in short-term planning. Input-output models are often developed for exploring purposes, using assumed parameter and scenarios that do not necessarily have to reflect reality.

Similar to the econometric methodology, the macro-economic methodology has the disadvantage that it does not represent specific technologies.

III. Economic equilibrium models
Economic equilibrium methodologies are mainly used to study the medium and long-term energy sector as part of the overall economy and focus on interrelations between the energy sector and the rest of the economy. Economic equilibrium models are sometimes also referred to as resource allocation models. Some energy-economic models consider energy price equilibrium while balancing supply and demand. Price equilibrium energy-economic models can further be divided into two categories: partial and general equilibrium models. Partial equilibrium models only focus on equilibria in parts of the economy, such as the equilibrium between energy demand and supply. General equilibrium models consider simultaneously all the markets in an economy, allowing for feedback effects between individual markets.

IV. Optimization models
Optimisation models are used to optimise energy investment decisions by finding best solutions. Optimisation models assume perfect markets and optimal consumer behaviour that do not exist in real life. Utilities or municipalities to derive their optimal investment strategies often use optimization. Furthermore, in national energy planning, it is used for analyzing the future of an energy system. Underlying assumption of optimization methodologies is that all acting agents behave optimal under given constraints. Disadvantages are that optimization models require a relatively high level of mathematical knowledge and that the included processes must be analytically defined. Optimization models often use linear programming techniques.

V. Simulation models
Simulation models are descriptive models based on a logical representation of a system, and they are aimed at reproducing a simplified operation of this system. Simulation models are a "what if" tool, they calculate what would happen under given assumptions of consumption forecasts and policies. Such models, however, allow the users to explore different hypotheses via scenarios, and typically capture the area of interest at a macro-economic level. These models are used to investigate technologically oriented measures where macro-economic interactions, i. e. price effects are less important.

Simulation models are especially helpful in cases where it is impossible or extremely costly to do experiments on the system itself. They are often used in scenario analysis.

VI. Spreadsheet models (tool boxes)
In the literature the spreadsheet methodology is often mentioned as a separate (bottom-up) methodology. Although the models all make use of spreadsheets (as the term suggests), this term may cause some confusion because other methodologies also frequently use spreadsheet programs as a basis. Spreadsheet models are as "tool boxes" which often include a reference model that can easily be modified according to individual needs.

VII. Backcasting models
The backcasting methodology is used to construct visions of desired futures by interviewing experts in the fields and subsequently by looking at which trends are required or need to be broken to accomplish such futures. This approach is often used in alternative energy studies [1].

3. CURRENT SITUATION IN ESTONIAN ENERGY

Estonia is a small country where electricity production, mining and processing of oil shale is a regional economic complex with their difficulties. Estonia is facing a complex situation in breaking up the monopoly and developing a free electricity market. The strategic objective of the Estonian electricity sector development plan until 2015 is to assure the optimal functioning and development of the Estonian power system in the market economy conditions and to assure in the long-term outlook the proper supply of electricity to the consumers at a lowest price possible, at the same time implementing all reliability and environmental conditions. The main engagements and figures of the electricity sector by year 2015 are followed:

- to achieve 5.1% of electricity production from renewable energy resources in 2010;
- to achieve 20% of electricity production from electricity and heat co-generation in 2020;
- to open the Estonian electricity market for 35% in 2009 and for all consumers in 2013.

Today, the Estonian electricity market is open for 13 eligible customers whose annual consumption is about 16% of energy in Estonia. Non-eligible customers can purchase electricity from the grid company they are physically connected to or from the seller named by that grid company. At present, the electricity production from renewable energy resources is about 1.5% and

Table 2. **Energy model characteristics**

	Macro-economic models	Energy equilibrium models	Optimization models	Simulation models	Spreadsheet models
Timeframe	Short to medium-term	Medium to long-term	Short to long-term	Short to long-term	Medium to long-term
Level of detail	High	Low	High	Partially high	Technically specific
System boundaries	Entire economy	Entire economy	Energy system	Energy system	Entire economy
Flexibility in terms of technically detailed questions	Low	Low	High, dependent upon the level of detail of the tech. database	High for limited complexity	High
Theoretical foundation	Historical analysis of macro-economic interaction matrix	Neo-classical	Optimization with regard to tech.-economic criteria	Primarily tech. determinism of energy systems	Primarily tech. determinism of energy systems
Implementation of the modeling	Econometric estimation of the interconnections of the matrix	Decisions corresponding to nesting and elasticities	Technological database with optimization algorithms	Technological database, expert knowledge	Technological database
Strengths	Broad empirical foundation, sectoral disaggregation	Closed theoretical structure	Applicable to tech. total sys. Flexible application possibilities	Also usable without targeted entities for optimization	Applicable to tech.systems. Flexible application possibilities
Weaknesses	Does not represent specific technologies. No long-term planning	Small empirical basis, often low level of sectoral differentiation	Implicitly rational optimization decisions, strongly influenced by bounds	Economic influences underrepresented, based considerably on the quality of expert knowledge	For local applicability. Variables are indicated exogenously as parameters in future scenarios

Table 3. **Energy planning models and their grouping in the analytical approach**

	Models	Top-down	Bottom-up	Hybrid
1	AIM (Asian-Pacific Integrated Model)			X
2	BRUS (Brundtland Scenario)		X	
3	EFOM (Energy Flow Optimization Model)		X	
4	ENPEP (Energy and Power Evaluation Program)		X	
5	GEM-E3 (General equilibrium model)	X		
6	IMAGE / TIMER (TARGETS-IMAGE Energy Regional Model)			X
7	LEAP (Long-range Energy Alternatives Planning)		X	
8	MARIA (Multiregional Approach for Resources and Industry Allocation model)	X		
9	MARKAL (MARket ALLocation)		X	
10	MARKAL-MACRO (A simplified energy-economy model)			X
11	MEGEVE-E3ME (General energy–environment–economy mode)	X		
12	MERGE (Model for Evaluating Regional and Global Effects of GHG Reductions Policies)			X
13	MESAP (Modular Energy System Analysis and Planning software)			X
14	MESSAGE III (Model for Energy Supply Systems Analysis and General Environment)		X	
15	MIDAS (Multinational Integrated Demand and Supply)			X
16	MiniCAM (Mini Climate Assessment Model)			X
17	MURE / ODYSSEE (Measures d'Utilisation Rationelle de l'Energie)		X	
18	NEMS (National Energy Modelling System)			X
19	POLES (Prospective Outlook on Long-term Energy Systems)		X	
20	PowerPlan (Interactive simulation model)		X	
21	PRIMES (Partial equilibrium model)			X
22	RETScreen (Renewable Energy Technology Screening)		X	
23	SGM (Second Generation Model)	X		
24	WEM (World Energy Model)			X

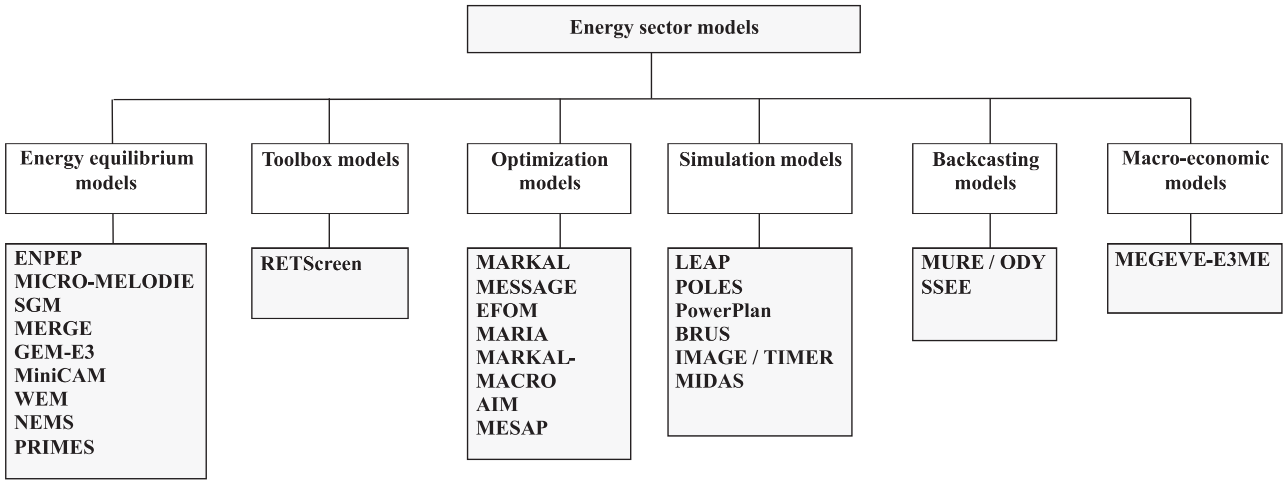

Fig. 1. Energy planning models and their grouping methodology

the electricity production from electricity and heat co-generation is about 7% of gross consumption.

So, the major investments in electricity production will be:

• peat and biomass CHP-s with the gross capacity of 100 MW in 2010–2015;

• wind turbines with the gross capacity of 200 MW by the year 2015;

• the first oil shale CFBC unit with the gross capacity of 270 MW in 2015;

• the second oil shale CFBC unit with the gross capacity of 270 MW in 2016 [2].

4. THE MAIN CHARACTERISTICS AND COMPARISON OF THE MODELS

As described above, there are several types of models based on different fundamental approaches and concepts.

Table 2 summarizes the main characteristics of energy modelling approaches, including macro-economic, energy equilibrium, optimization, simulation and spreadsheet models [3].

Macro-economic models are less useful because they extrapolate the past market behaviour into the future, do not represent specific technologies and long-term planning possibilities. The economic equilibrium models are insufficient because the Estonian market economics is relatively new, and changes in the structure and conditions of its economy are not yet fully formed.

The optimisation models can be useful for Estonia to optimise energy investment decisions by finding best solutions. The assumption of perfect markets and optimal consumer behaviour is suitable for Estonia because a large part of its population reflect consumer behaviour, have access to modern energy, and the economy is market-based.

Another option is simulation models which mostly bottom-up, or hybrid descriptive models which aim at reproducing a simplified task of a system. They tend to be rather useful for Estonia, because they do neither assume perfect markets nor optimal consumer behaviour, but allow scenario analysis for future pathways.

Finally, toolbox models which are mainly bottom-up accounting type models, having the advantage that they are easy to use, which increases their usefulness for Estonia where users do often not have the same financial and training possibilities as in the other countries. The main disadvantage of toolbox models is that all important variables are indicated exogenously as parameters in future scenarios.

Backcasting models are less useful for this country.

Concerning the mathematical approach, linear programming has a clear advantage in that it allows for simple programming and can easily be understood by planners because no special expertise is needed. In this case the problem can be solved in a straightforward way by using standard algorithms.

In practice, it is not feasible to develop our own models of energy planning; it is more effective to use existing models. Energy sector models that are widely used across several countries for carrying out their economic and energy sector planning are presented in Table 3 and grouped in an analytical approach (top-down, bottom-up, hybrid).

4.1. The overview of existing energy models

EFOM comprises national dynamic optimization models representing the energy producing and consuming sectors in each region. They optimize the development of these sectors under given fuel import prices and useful energy demand over a predefined time horizon. The development of national energy systems can be subject to energy and environment constraints such as availability of fuel, penetration rates of certain technologies, emission standards, and emission ceilings. The model databases contain a wide range of conversion and end-use technologies such as conventional, renewable energy, efficient fossil fuel burning, combined heat and power, and energy conservation technologies in the demand sectors [4].

LEAP is a scenario-based energy-environment modeling tool. Its scenarios are based on comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions on population, economic development, technology, price and so on. LEAP has been used to develop local, national and regional energy strategies, conduct GHG mitigation assessments, and train professionals in sustainable energy analysis [5].

MARKAL is a family of bottom-up energy system models that depicts both supply and demand. MARKAL provides policy

Table 4. **Existing energy planning models and their grouping by the analytical approach and methodology**

	Models	Bottom-up	Hybrid	Optimization	Simulation	Toolbox
1	EFOM (Energy Flow Optimization Model)	X		X		
2	LEAP (Long-range Energy Alternatives Planning)	X			X	
3	MARKAL (MARKet ALlocation)	X		X		
4	MESAP (Modular Energy System Analysis and Planning software)		X	X		
5	MESSAGE (Model for Energy Supply Systems Analysis and General Environment)	X		X		
6	MIDAS (Multinational Integrated Demand and Supply)		X		X	
7	PowerPlan (Interactive simulation model)	X			X	
8	RETScreen (Renewable Energy Technology Screening)	X				X
9	EnergyPlan		X		X	

Table 5. **Energy planning models and the main characteristics**

Models	Developer	Home page	Geographic applicability	Data requirements	Default data included	Time horizon	Reference materials	Language
EFOM	European Union	–	Local, national, regional, global	Medium–high	Detailed description of energy supply and end-uses technologies	Medium to long-term	Description in some literature	English
LEAP	Stockholm Environment Institute	www.energycommunity.org	Local, national, regional	Low–medium	Database with costs, performance and emission factors	Long-term	Manual and training materials free on web site	English, French, Spanish, Portuguese, Chinese
MARKAL	IEA/ETSAP (Energy Technology System Analysis Project)	www.etsap.org	Local, national, regional, global	Medium–high	Detailed description of end-uses and (renewable) energy technologies possible	Long-term	Manual available to registered users	English
MESAP	IER, Stuttgart University, Germany	–	Local, national, regional, global	Low–medium	Database with fuel costs and emission factors	Long-term	Description in some literature	English
MESSAGE	IIASA (International Institute for Applied Systems Analysis) Austria	http://www.iiasa.ac.at	Local, national, regional, global	Medium–high	Database with fuel costs and emission factors	Medium to long-term	Description free on web site	English
MIDAS	European Union	–	Local, national, regional, global	Low–medium	Database with fuel costs and emission factors	Long-term	Description in some literature	English
PowerPlan	Center for Energy and Environmental Studies University of Groningen	http://www.fwn.rug.nl/ivem/soft.htm	Local, national, regional	Low–medium	Database with fuel costs and emission factors	Medium to long-term	Manual and demo version free on web site	English, Dutch
RETScreen	Natural Resources Canada	www.retscreen.net	Local	Technology specific	Extensive defaults: weather data, products, costs, etc.	One year in steps of one hour	Manual and training materials free on web site	Multiple
EnergyPlan	Sustainable Energy Planning Research Group at Aalborg University	http://energy.plan.aau.dk/	Local, national, regional	Low–medium	Database with costs, distribution and emission factors	Primarily static analysis	Manual and training materials free on web site	English

makers and planners in the public and private sector with extensive details on energy producing and consuming technologies, and it can provide an understanding of the interplay between the macroeconomy and energy use. As a result, this modeling framework has helped national and local energy planning and the development of carbon mitigation strategies [6].

MESAP is a modular energy planning package developed with the specific needs of developing countries in mind. It is designed as a flexible planning package providing energy analysts and planners with tools to perform complex energy analysis. It consists of basic techniques for energy planning, a set of tested energy modules, and data management and processing software. At the heart of MESAP is a network-oriented database. Its objective is to assist in energy and environmental policy analysis and planning [4].

MESSAGE is generally used for the optimization of energy supply systems. However, other systems supplying specified demands of goods, which have to be processed before delivery to the final consumer, could be optimized. The objectives include resource extraction analysis, estimation of the import / export of energy, energy conversion analysis, energy transport and distribution analysis, analysis of final energy utilization by consumer, recommendations for environmental protection and investment policies, and analysis of opportunity costs [7].

MIDAS is a large-scale energy system planning and forecasting model. It performs dynamic simulation of the energy system, which is represented by combining engineering process analysis and econometric formulations. The model is used for scenario analysis and forecast. MIDAS covers the whole energy system and ensures, on an annual basis, a consistent and simultaneous projection of energy demand, supply, pricing and costing so that the system is in both quantity- and price-dependent balance. The model output is a time-series of detailed EUROSTAT energy balance sheets, lists of costs and prices by sector and fuel, and a set of capacity expansion plans including emission data [8].

PowerPlan is an interactive simulation model with which the future for the electricity supply system can be planned. PowerPlan is a so-called forecasting model: given an existing power system and year, an electricity supply system future will be simulated. It is thus not an optimization model, but a model from which the consequences of decisions can be evaluated (a "What-If" model) [9].

The RETScreen International Clean Energy Project Analysis Software is the leading tool specifically aimed at facilitating the pre-feasibility and feasibility analysis of energy technologies. The core of the tool is the standardized and integrated project analysis software which can be used worldwide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of proposed energy-efficient and renewable energy technologies [10].

The EnergyPlan model is a computer model for Energy Systems Analysis. The main purpose of the model is to assist in designing national energy planning strategies on the basis of technical and economic analyses of the consequences of different national energy systems and investments. The model can be used for different kinds of energy system analyses: technical analysis, market exchange analysis and feasibility studies [11].

We could test three of the selected models (LEAP, RETScreen and EnergyPlan) because of their free availability and distribution in personal and academic projects. The MESSAGE model is available for users with additional request of entering data, and it was not considered in this paper. The PowerPlan model has the only freely available demo version.

The RETScreen and the EnergyPlan models are more useful for single new energy capacity planning. Also, the RETScreen model has the possibility of detailed technical equipment selection and the financial indicator calculation. The EnergyPlan model is more useful for the whole energy sector balance planning of the country, but as compared with the LEAP model have no possibilities to input the external assumption information and data of sectors such as industry, mining, etc. Both models (RETScreen and EnergyPlan) could be used in the pre-feasibility study of the new capacity planning projects. The results of the models give a marginal difference; the models are indicated for scenarios development and could be useful for comparing the fundamental technological processes [12].

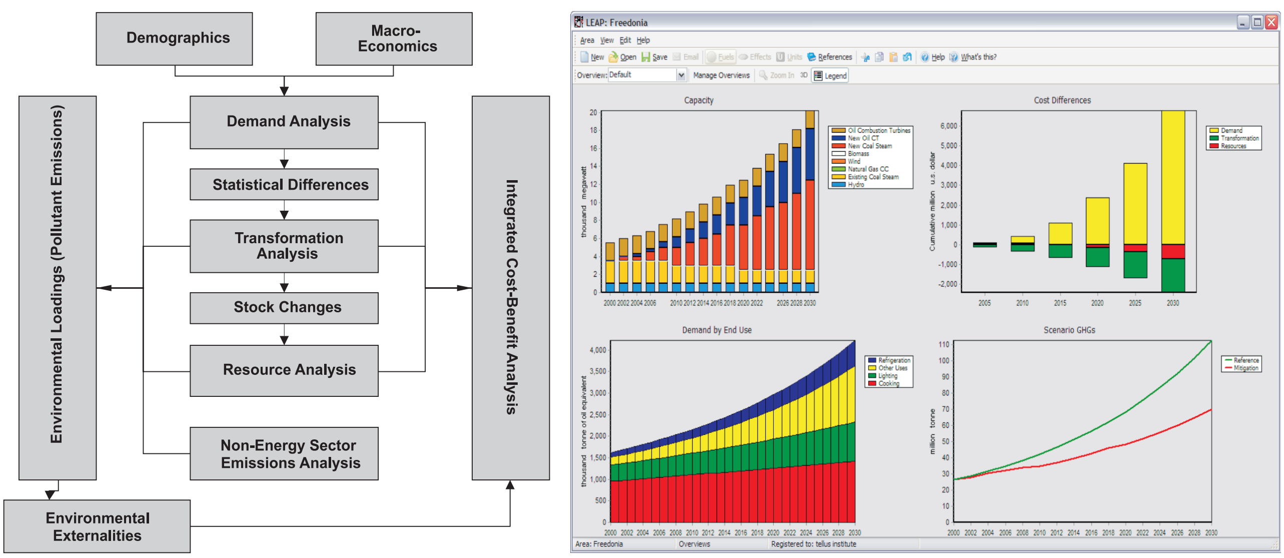

Fig. 2. LEAP calculation flows and the result reporting

For elaborating scenarios of the development of the Estonian energy system in the conditions mentioned above, the LEAP model was selected as the preferred framework in which the most essential reasons for selecting were a free use of the model and training materials, public technical support and discussion, user-friendly interface. It allows for a transparent arrangement of the data, various possible scenarios and can be developed energy system configurations. The main benefit of LEAP is that it is a tool that helps the user to combine and assess data in a consistent framework. This makes it easier to organize the data in an intuitive and accessible manner, and to get a grasp on the information. LEAP calculation flows and the result reporting are presented in Fig. 2 [3].

5. RESULTS

We evaluated different types of energy planning models according to the main characteristics and found suitable ones for the Estonian energy sector. The main characteristics of energy modeling approaches are summarized in Table 2. A wide range of models were reviewed (Table 3), and we selected nine models that have the bottom-up or hybrid approach, linear programming and by the methodology are simulation, optimization and toolbox models. In Table 4, they are grouped by the analytical approach and methodology. The main characteristics of the selected models are presented in Table 5.

Comparing the freely available energy planning models, the LEAP model was selected as the preferred framework for elaborating the scenarios of the Estonian energy system development. The RETScreen and the EnergyPlan energy models are more useful for single new energy capacity planning. The EnergyPlan model is also used for the whole energy sector balance planning of a country, but has low input data for calculation in different sectors of the country, such as industry, mining, etc. compared with the LEAP model.

6. CONCLUSIONS

The paper presents an analysis of energy planning models and the results of investigating the adaptability of energy planning models for the Estonian energy system in the conditions of oil-shale-based electricity supply shortage, taking into account the main engagements and figures of the electricity sector by year 2015.

The description of the main characteristic of the models and their comparison are presented. The different types of existing energy planning models are reviewed, and nine models were selected for a more detailed analysis.

Analysis of the adaptability the freely available models is given, and the Long-range Energy Alternatives Planning (LEAP) as the preferred model selected to elaborate the scenarios of developing the Estonian energy system and mitigating the environmental impacts of electricity production by using new, less environment-damaging technologies are presented.

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ENERGETIKOS MODELIŲ CHARAKTERISTIKŲ ANALIZĖ IR JŲ TAIKYMAS ESTIJOS ENERGETIKOS RINKAI

Santrauka

Pastaraisiais metais sukurta daug modelių, skirtų energetinės sistemos analizei, įskaitant poreikių prognozes, tiekimo prognozes ir politikos kaitos poveikius energetinei sistemai. Šie modeliai pagrįsti skirtingomis fundamentaliomis teorijomis, koncepcijomis, apima daug matematinių algoritmų ir yra labai skirtingi. Kyla klausimas, kurį iš modelių tinkamiausia taikyti.

Estija yra vienintelė Europoje šalis, turinti svarbią skalūnų pramonę. Estijoje 95 % elektros energijos yra pagaminama skalūnų elektrinėse. Dėl griežtų aplinkosaugos reikalavimų iškyla grėsmė ateities elektros tiekimui iš skalūnų elektros jėgainių.

Pateikiamas vykdomas mokslinis projektas, kurio tikslas – analizuoti energijos planavimo modelius, skirtus Estijos energetinės sistemos plėtros scenarijams detalizuoti esant skalūnų elektrinių tiekiamos elektros trūkumui, atsižvelgiant į pagrindinius energetikos sektoriaus duomenis iki 2015 metų.

Raktažodžiai: energetikos planavimas, modeliavimas, vartojimas, paklausa, prognozės, optimizavimas, ekonominė pusiausvyra

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АНАЛИЗ ЭНЕРГЕТИЧЕСКИХ МОДЕЛЕЙ И ИХ ПРИМЕНЕНИЕ ДЛЯ ЭСТОНСКОГО ЭНЕРГЕТИЧЕСКОГО РЫНКА

Резюме

В последние годы разработано большое количество моделей для анализа энергетических систем, включая прогнозы потребления и снабжения, а также влияния политических изменений на общую энергетическую систему. Энергетические модели основаны на разных фундаментальных подходах и концепциях, в них используется целый ряд математических алгоритмов. Поэтому эти модели значительно различаются, и возникает вопрос, какая модель наиболее пригодна для определенной цели или ситуации.

Эстония является единственной страной в Европе, которая имеет сланцедобывающую промышленность. Здесь 95 % электроэнергии производится на электростанциях, работающих на сланце. Страны Балтии переживают сложную ситуацию разрушения монополии и создания свободного рынка электроэнергии в соответствии с договоренностями с Европейским Союзом. Кроме того, Эстония находится в переходном периоде развития сланцевого энергетического сектора. Тенденции либерализации и изменения в эстонском энергетическом рынке, связанные с жесткими технологическими и экологическими требованиями Европейского Союза, приводят к возникновению необходимости разработки новых сценариев развития энергетического сектора Эстонии с уменьшением воздействия на окружающую среду производства электроэнергии и использованием новых, менее вредных, технологий. Эта статья представляет текущий научно-исследовательский проект, цель которого – анализ моделей энергетического планирования для разработки сценариев развития эстонской энергетической системы в условиях дефицита электроэнергии, основанной на сланце, с учетом основных обязательств и целей электроэнергетического сектора к 2015 году.

Ключевые слова: энергетическое планирование, моделирование, энергетическая модель, потребление, спрос, прогноз, оптимизация, экономическое равновесие, симуляция