METHODOLOGICAL PRINCIPLES FOR OPTIMAL INTEGRATION OF FUTURE TECHNOLOGIES INTO THE ENERGY SECTOR

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Overview

Decreasing world's fossil fuel reserves, rising fuel and energy prices and climate change, which is strongly influenced by pollutant emissions from fuel burning in energy and transport sector, stimulate growing interest in energy efficiency measures, renewable energy sources and technologies utilizing them, energy storage, carbon capture and sequestration and other innovative technologies. European Union pays special attention for development and implementation into practice of these future technologies. Quite often development and implementation of such technologies are governed by different norms, standards and directives. All this allows achieving the set goals of energy policy but require significant investments. High investment demand needed in energy sector for extensive transition from technologies using traditional energy sources towards technologies utilising renewable energy sources is a big economical problem for less-developed countries. On the other hand, the wider use of renewable energy resources and future energy technologies promotes the development of new industries and economy branches, creates additional jobs, transforms the countries' trade balance and so on. Often this is not visible explicitly and is not taken into account by energy planners and regulators but can be beneficial for the entire society. Thus, evaluation of the interaction between energy sector and the whole economy, as well as maximisation of the overall benefit for the whole society is very important while analysing broader utilisation of renewable energy sources and feasibility and economic effectiveness of the future energy technologies in the medium and long term period.

Methods

The development of the energy sector, as well as introduction of future technologies into energy sector is strongly influenced by many different factors, such as technical, economic, environmental political and others. There are three basic stages involved in the integration of future technologies in energy sector: *planning, implementation, and operation.* Planning stage in this case means stage when possible penetration of future energy technologies is analysed in the scientific manner and their objective and rational integration pathway is investigated. Good results in the growing utilization of future technologies, exploitation of their positive characteristics and achievement of overall societal benefit can be expected only if in the technologies surrounding environment will be no uncoordinated or even conflicting factors in all of these stages. In order to minimize or even avoid influence of all these negative phenomena it is necessary to elaborate and implement into practice mechanisms that already in the planning stage allow reflection of factors affecting technologies in their implementation phase (support schemes, legal regulation, etc.) and in the exploitation phase (legal; environmental conditions, pricing, etc.). On the other hand, factors or means designed for effecting technologies in their implementation and operation phase should have scientific background that can be taken from analysis results of the planning study. Above mentioned mechanisms can be successfully implemented into traditional bottom-up mathematical models for analysis of energy system operation and development that can be realised using MESSAGE [1], MARKAL [2] and similar programming packages. Information taken from dual solutions is used for forming objective quantitative background of various support schemes and pricing. Mentioned mathematical models are able to describe various technical and economic parameters, political, environmental and other factors from all stages of technology integration. Nevertheless, their ability in covering relationship between the energy sector and the whole economy is limited.

Despite of the fact that energy-economy nexus is a widely analysed topic in the scientific literature, there is no conclusive evidence concerning the direction, strength, and even existence of the causal relationship (see [3] or [4] for a large-scale survey of the literature). Moreover, strong confidence in the evidence about past relationships can be inadequate for the analysis of the future development of the energy sector, inasmuch as the characteristics which were correct in the past can be not relevant in the future, when different energy technologies will be in the operation (it may be well that the technological change is one of the reasons for differences in the results of econometric studies of energy-economy nexus). In this context, the hybrid modelling of energy-economy development can be seen as a possible solution seeking for adequate and realistic recommendations regarding to the optimal integration of future energy technologies. However, representation of all peculiarities of energy technologies and of the whole energy sector in the hybrid model is also problematic because of size of the nonlinear model. In this relation coordinated use of both mentioned models is necessary in order to justify correctly attractiveness of future technologies and promote their integration into energy sector.

Results

Two mathematical models have been developed for Lithuania in order to implement into practice presented method for justification of integration of future technologies into energy sector. The first one realized in the MESSAGE programming package is used for very detailed analysis of energy system operation and development in the planning stage. It represents energy sector on municipal level and incorporates mechanisms for reflection of conditions in implementation and operation stage of technologies. It also has a special module for information exchange with the hybrid model, witch has been developed in the GAMS [5] mathematical programming environment. The hybrid model is composed of two modules. One of them represents the whole economy and another one in smaller details represents the energy sector. Energy part of the model is based on bottom-up approach and includes a description of technical and economical attributes of current and future energy technologies as well as features of the Lithuanian energy sector, whereas economic part employs top-down approach and reflects the behavior of the remaining economy. In this part, a dynamic computable general equilibrium model encompasses financial and commodity flows within the domestic economy as well as the connection with the rest of the world.

In the economic module, the demand for various production factors, including energy products, is modeled using nested constant elasticity of substitution functions. Another kind of a link between the modules is inputs of the energy technologies, which appear as an additional consumer in the economic module. Consumption of this consumer is determined by installation and activity levels of energy technologies that require a particular product as an input.

Conclusions

Present methodology of optimal integration of future energy technologies covers three stages: planning, implementation, and operation. Practical realization of methodology is based on coordinated application of the hybrid model representing energy sector and the whole economy and very detailed model for analysis of energy system operation and development.

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