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Modelling the Hungarian energy system – The first step towards sustainable energy planning

Fanni Sáfián*

Department of Environmental and Landscape Geography, Eötvös Loránd University (ELTE), Pázmány Péter sétány 1/C, HU-1117 Budapest, Hungary

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ABSTRACT

In Hungary, there is a need for detailed alternatives to its fossil-based, highly import-dependent energy system. In this paper, an energy model of the Hungarian energy system of 2009 is worked out, as a reference model for a 100% renewable-based scenario. The model is created in the EnergyPLAN software and is able to simulate all sectors of the national energy system on an hourly basis. The EnergyPLAN software and the main issues of its first Hungarian application are presented. The model is validated by comparing its results to Hungarian and international statistics for 2009. Two alternative models – 'Natural gas + biomass' and 'Biomass' – were created in EnergyPLAN for an analysis to see how the energy system of 2009 could have been operated in an optimised way from environmental point of view, within the existing infrastructure. In 'Biomass' alternative model, the utilisation of primary renewable energy sources almost doubles, causing a decrease of 10% in carbon-dioxide emission. By changing the distribution of fuels by a different power plant utilisation, more favourable fuel consumption characteristics could have been achieved from the environmental point of view in 2009.

1. Introduction

The World's energy management has reached an important turning point – the age of cheap, seemingly endless fossil fuel sources is approaching its end [1–3], while global energy demand is rising. In Hungary, where fossil fuels play a dominant role in energy consumption, and where they are on average 80% imported, these trends are of critical importance to the country's economy.

However, the shortage of fossil fuels and its economical and societal consequences is not the only reasons for the urgent need to switch to renewable energy sources. The mining and burning of fossil fuels have enormous effects on the global ecological system like decreasing biodiversity, disappearing habitats and damaged natural services. In the case of the energy sector effects on the global carbon cycle can be highlighted, causing change in global climate [4], to which the whole biosphere has adapted. In the case of the Carpathian basin, including Hungary, heat waves, droughts, extreme floods, early and late frosts and degradation of biodiversity can be highlighted as the expected (and already experienced) hazardous consequences [5]. To ensure mitigation and adaptation in Hungary as well, fossil fuels should be phased out of the energy system while the share of renewable-based local energy sources has to be increased. Furthermore, energy sufficiency and higher energy efficiencies are key factors in creating a sustainable energy system.

1.1. Towards sustainable energy systems

The first step on the way to technological change is research and planning. In the last decade, numerous 100 or nearly 100% renewable-based – or from another perspective, low or zero carbon – energy strategies were designed by several research groups and centres. The increasing trend towards sustainable energy planning is indicated by the fact that at least 68 computer tools, designed for renewable integration modelling, were available in 2009 [6]. In Europe, several 100% renewable energy visions or strategies were outlined, both for Western- and Eastern-European countries [7], as well as for the entire European Union [8].

Two countries should be highlighted as they have lead research on this field. The United Kingdom, where one of the first alternative energy strategies was outlined [9] and since then further developed [10], covering a wide range of connected aspects, such as embodied energy minimalisation or land usage optimisation [11]. The other country is Denmark, where sustainable energy planning has a remarkable tradition. Numerous Danish alternative energy strategies have been conducted since the first oil crisis, in the last decade

* Tel.: +36 30 328 2400.
E-mail address: safian.fanni@gmail.com.

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especially focussing on large-scale renewable energy integration [12–15]. Nowadays Denmark is one of the world leaders in renewable technologies and has a 100% renewable energy-based energy strategy (to be achieved by 2050), accepted on governmental level [16], with the renewable electricity production share already reaching 40% in 2011 [17].

1.2. Alternative energy planning in Hungary

In Hungary, the current situation in energy management would require rapid changes concerning import-dependency, fuel mix, and the infrastructure of the energy system. Despite the favourable renewable potentials [18–20] and the urgent need for sustainable solutions for domestic energy production, recent and current energy strategies do not plan to break with present practice. Furthermore, there is a lack of alternative energy strategies, therefore no other possible choices can be seen by society.

The first alternative document called *Hungarian Sustainable Energy Strategy* was outlined by the Hungarian non-governmental organisation Energy Club [21]. This work was drafted in one month only, mainly containing a review of the recent Hungarian energy situation and renewable energy potentials, without detailed calculations. Another energy strategy was worked out and a few years later further developed by Greenpeace International, Greenpeace Hungary and EREC (European Renewable Energy Council) [22,23]. In the latter, two energy scenarios – an 'alternative' and a more ambitious 'progressive' one – were developed, indicating the possibility of a 75% renewable-based energy system in Hungary by 2050. In spite of the more properly grounded calculations and studies connected, there was no substantive discussion on the outlined alternative scenarios afterwards, neither in the scientific community nor in the wider public. On the contrary, the government is expanding the lifetime of the currently operating nuclear power plant, and is to build a new nuclear power plant by a Russian company [24].

The first 100% renewable energy system vision in Hungary was created by a team of professors and students at Eötvös Loránd University, Faculty of Science, Department of Environmental and Landscape Geography, in cooperation with experts from other Hungarian universities and INFORSE (International Network for Sustainable Energy)-Europe [25,26]. The research team (including the author of this paper) worked out an alternative energy scenario called *Vision 2040 Hungary* with the energy planning tool INFORSE. In this best-case scenario, they state, that from the year 2005, it could have been possible to reach a 100% renewable energy system in Hungary by 2040, and a more ecologically sustainable energy system by 2050 [25]. However, while this Vision was outlined by balancing all the supplies and demands in Hungary over every five years up to 2050, the hour-by-hour advanced energy analysis, taking into account fluctuations in the weather – therefore detailed renewable production – could not be carried out. In this case the issue of integration of renewable energy sources was not analysed, although it is one of the main challenges of the present inflexible energy system of Hungary.

2. Scope of the article

There is a need for a 100% renewable energy scenario in Hungary, which could lead to a sustainable energy system and if properly detailed and analysed could be a real alternative to the official energy strategy. As a first step, the aim of this paper is to create and analyse an operational reference model of the present Hungarian energy system, in an hour-by-hour based, advanced energy modelling tool. This model will be the basis of a future 100% renewable-based scenario. Since this model will be a simulation of the current energy system in Hungary, the present energy system's main characteristics will be introduced, highlighting the main issues of energy management and policy, will have to be solved in the long term. The paper presents the creation of a reference model of the Hungarian energy system covering a review of the main data sources, introducing the EnergyPLAN energy modelling tool and the main conclusions of its first Hungarian application and the validation of the model. After the review of the methodology, two alternative models are compared with the reference model. The aim of this analysis is to provide insights into how the Hungarian energy system of 2009 could have been optimised from environmental aspects, to have a higher renewable energy penetration and less CO_2-emissions in the same infrastructural conditions.

3. Main characteristics of the Hungarian energy system

The total primary energy consumption of Hungary has been fluctuating around 1100 PJ since the 1990's. This value was 1055.6 PJ in 2009, reached 1085.0 PJ in 2010, but due to the economic crisis, decreased to 999.3 PJ in 2012 [27]. Final energy consumption reached 698.73 PJ in 2010 (the latest data available) [28], which accounts for only 1.5% of the European Union's final consumption [29]. However, the structure of sources changed in an unfavourable way: the use of domestic sources decreased, while the import of energy sources increased to more than 63% (where nuclear energy production is counted as domestic energy production by the official statistics, although the fuel rods are imported) [29]. The diversification of import sources has been very slow since the political changes of 1989–90, therefore two-thirds of the energy source imports are obtained from only one country, namely Russia. There has been no governmental effort to change this situation, as the Hungarian Energy Strategy 2030 [30] states: "The major part of Hungary's energy supply is imported, and it will remain so for a long time". The situation is most untenable regarding natural gas, where more than 70% of the total domestic demand is supplied from Russia through Fraternity pipeline via Ukraine and the HAG (Hungarian–Austrian Gas) pipeline via Austria [31]. At this point, there is no intention to change this from the government side according to the Energy Strategy: "Russia will remain the most important source of import on the long term (…)" [30].

More than 90% of Hungary's total primary energy supply is based on non-renewable fuels [32], despite the fact that the country is poor in fossil sources. The majority of coal stocks have already depleted or their exploitation is highly uneconomic. An important exception is the low calorific lignite, from which 8–9 million tons per year (65 PJ per year) are extracted [33] and stocks are estimated at 4.45 billion tons, making it the most significant strategic fossil fuel reserve of Hungary [30]. Crude oil and natural gas stocks are almost negligible, supplying only a fraction of domestic demand [34,35]. The main electricity producer of the country is the nuclear plant in Paks with 2000 MW capacity, producing 43% of the electricity alone in 2009 [36].

Carbohydrates dominate in the mix of the primary energy supply of the country – they reach a higher share in the mix of TPES (Total Primary Energy Sources) of Hungary than of the EU average (Fig. 1). This is mainly the result of the high share of natural gas, which is the most popular energy source in Hungary, with an important role in electricity and heat production as well. The Hungarian nuclear power share is almost the same as for the EU in 2009, while the coal and renewable energy penetration are around 30% less than the European average.

Hungary has a diverse and favourable abundance of renewable sources, although they are underutilised due to the lack of political will and therefore the constantly changing and unfavourable regulation system [38]. This explains why Hungary committed to

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