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THE WORLD WITHOUT PAKS II

Energy Vision of Energiaklub by 2030 using EnergyPLAN software

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Study

ENERGIAKLUB Climate Policy Institute and Applied Communication

January, 2015.

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The Energy Vision of Energiaklub by 2030 using EnergyPLAN software

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EXECUTIVE SUMMARY

Energiaklub has prepared and modelled, using the 'EnergyPLAN' energy planning software, the energy vision that offers a reassuring and in a number of respects better solution for meeting future energy demand without Paks II. The results show that all the energy demand in Hungary can be satisfied in 2030 without Paks II, and 27% of the electricity can be produced by renewable energy plants. This can be achieved through the rationalisation of energy consumption, energy efficiency improvements, the priority treatment of renewable sources of energy and the replacement of the centralised energy system with a flexible, decentralised system.

The calculations of Energiaklub indicate that electricity demand will fall short of the projections used to justify the necessity of Paks II, which leaves more time for the installation of the necessary additional capacities. This in turn allows us formulate the energy vision of Hungary after carefully thought-out, broad professional and public consultations, having considered transparent arguments and counter-arguments as well as background calculations. Energiaklub considers that the construction of Paks II would definitively determine whether Hungary will have, in the long term, a nuclear energy driven, centralised energy system dominated by a few large power stations (and large corporations) or a decentralised energy system designed for sustainability and relying primarily on local, renewable resources. These two routes represent different energy paradigms; of these, the vision of Energiaklub is clearly a flexible energy system giving priority to renewable generation.

The research conducted by Energiaklub broke this concept down to concrete, realistically achievable targets for 2030. For this, we looked at and analysed the papers of numerous professional actors: Hungarian and international statistics, trends, forecasts, research papers, potential calculations, background papers, strategies and visions. The existing research results were supplemented by calculations performed by ourselves and the contributing experts so that a complex model with detailed data content is constructed.

Energiaklub used the Danish-developed EnergyPLAN energy planning software to examine the workability of the vision. Since 1999 the program has been used to prepare and analyse numerous research projects and alternative visions, for instance in the UK, Ireland, the US and China. The Danish alternatives worked out by the developers of the software were instrumental in achieving that the official energy strategy of Denmark relies exclusively on renewable energy sources for 2050.
The software models the entire energy economy of a country or region, covering all types of energy requirements of every sectors (residential, agriculture, industry, services, transport). EnergyPLAN models and analyses one year of the operation of the energy system in an hourly breakdown, which was a key consideration in our software selection due to the continuous fluctuation of weather-dependent renewable sources and of electricity demand.
We verified the applicability of the programme to Hungary by setting up a Hungarian energy model for 2011. The results were almost identical with the actual statistical figures.

The modelling of the vision of Energiaklub for 2030 yielded the following results:

- in 2030 the Hungarian energy system would be operable without Paks II;
- total demand for energy will increase at a slower pace than indicated in the official forecasts (50.6 TWh), from 40.2 TWh in 2012 to 47.1 TWh;
- the share of renewable sources of energy in electricity generation will be over 27% even when conservative target figures are selected;
- electricity import is at a minimal level, at 0.7 TWh (in 2013 it was 11.9 TWh);
- the resources necessary to meet the demand for heat will decline by 24% as a result of investments in energy efficiency and new, low-energy buildings;
- the share of alternative-propulsion passenger cars (gas, hybrid, electric) will reach 20%, and 30% of freight transportation will be by rail;
- the total resource requirement of the country will decrease by 3% relative to 2011.

The purpose of the vision of Energiaklub is to demonstrate that alternatives to Paks II do exist; yet their comparison and broad professional consultations are still waiting to happen. In this spirit, Energiaklub will appreciate any feedback or comments on this document, which we see as an issues paper. We will take such feedback into account when preparing the economic assessment of the 2030 vision, which will facilitate a comparison with the costs of Paks II as well. Finally, a model will be prepared for the decades beyond 2030 to examine the operation of the Hungarian energy system without nuclear energy.

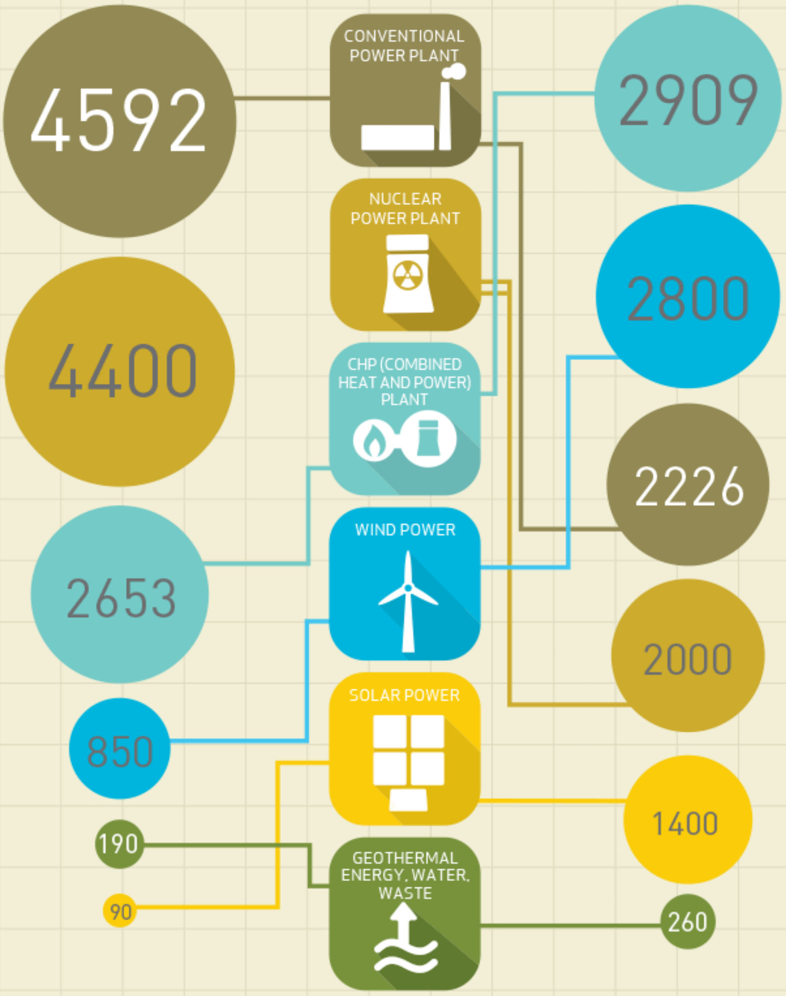
ELECTRICITY PRODUCTION CAPACITIES IN 2030 (MW)

THE OFFICIAL SCENARIO WITH PAKS II

According to the forecast of the system operator MAVIR the majority of electricity will be produced by some centralized power plants in 2030. Priority will be given to nuclear energy and on traditional (natural gas, coal and oil) power plants that only produce electricity. The inflexible capacities and the overproduction of Paks II will result in a low share of renewable energy sources in the long run.

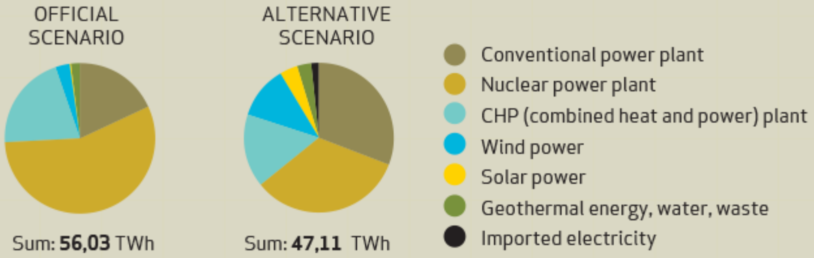
THE PROPOSAL OF ENERGIAKLUB WITHOUT PAKS II

The vision of the Energiaklub is a sustainable and flexible energy system. Renewable energy sources are given priority instead of nuclear energy. Capacities are more balanced, there are small, local, biomass burning CHP plants present in the decentralized system. Only 1,5% of electricity import is needed even without Paks II.



ELECTRICITY PRODUCTION, 2030 (TWH)

The electricity production of particular power plant groups is not proportional with their capacities (e.g. a nuclear power plant produces several times more electricity in a given year than renewable plants with equivalent capacity), therefore, the share of production is also illustrated.



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Prepared for Energiaklub based on the 2014 forecast of MAVIR (the middle and long-term capacity development of the Hungarian Electric energy system 2014) and on the own calculations of Energiaklub using the EnergyPLAN software.

Infographic: infotandem

1. PREFACE

On the first anniversary of the Paks Pact

By signing the Pact of Moscow in January 2014, the Government decided arbitrarily, without any professional or social consultation, that a new nuclear power plant in Paks will be the basis of the future energy management of Hungary. The element of surprise in this far-reaching decision and the fact that a number of its elements are still kept confidential shocked the public. A year has passes and we are none the wiser; instead, new questions have mushroomed. The Government's arguments for the Paks II project are still hard to defend.

- "there is no alternative to Paks II" – while we have been presented with no comparison with other energy supply scenarios;
- "this is the best possible financial arrangement, the cheapest future electricity" – we are supposed to believe this without any bidding procedure or background calculation;
- "this is indispensable due to growing electricity demand and the loss of capacities" – while both electricity consumption and the peak load have been declining since 2010 and a significant part of generation capacities lie idle.

Based on information available to us and our calculations, however, the electricity demand will fall short of the projections used to justify the necessity of Paks II, which leaves more time for the installation of the necessary additional capacities. Consequently it is safe to say that, apart from the intransparent decisions and the agreements concluded in the past year, there is no pressing circumstance in the Hungarian energy sector that would justify the hasty launch of this project. Thus there is room for carefully thought-out, broad professional and public consultation. Based on the confrontation of transparent arguments, counterarguments and background calculations we can decide the future of the Hungarian energy sector, and the Government measures required can be determined accordingly.

We would like to contribute to that professional discussion with the model presented in this publication. We prepared this model last year and will continue working on it in 2015. This model reckons with a possible course of development that can be realistically and with a high degree of certainty achieved until 2030, without the new power plant in Paks.

Why 2030?

As the new energy and climate policy targets of the EU relate to that date, Hungary also has an effective energy strategy up to 2030. Other official and more recent documents (such as the capacity development plan of MAVIR) also reckon with that date. Furthermore, this date is important because even though there is a high certainty that the four old blocks in Paks would still be in operation in 2030, but the two new blocks, proposed to be already operating by then, are disregarded in our model. Also, we have 15 years before that date. And 15 years is a time frame that is manageable for energy policy and sufficient to start changes.

Paradigms

It is important to realise that the issue is not only the future of one power plant. If we were to hold discussions - which the Government is unfortunately unwilling to do – two approaches would clash: energy policy giving preference to fossil and nuclear power plants and paradigms promoting decentralised, local resources and small-scale projects. The former continues with the rationale known since the centrally planned economy of the 1950s and proposes to satisfy the energy needs of the country through the coordination of a few large and several load following power plants. In contrast, the decentralised approach considers the gradual phasing out of larger power plants and the coordination of a high number of small plants to be the best route for the future. Clearly, our preferred decentralised energy system will require several decades to establish, and in the transitory period large plants and smaller renewable capacities will operate side by side. However, we must be aware that the centralised energy system limits the ratio of renewable energy sources and in the long term their side-by-side operation would also be more expensive for the national economy.

Consequently, this is the time to decide on our joint vision that we wish to follow in developing our energy system. Whether we want to create a nuclear energy driven, centralised energy system dominated by a few large power stations (and large corporations) or a decentralised energy system striving for sustainability and mostly relying on local resources, where Hungarian renewable sources of energy have the leading role. We consider that the latter direction is the energy vision (shared by the European Union) that will be able to flexibly adapt to the technological and economic challenges of the future with its diverse technologies, resources and large number of generation units of different sizes.

We make no secret of the fact that its establishment requires close attention, it assumes much more flexible transmission operation and it will be expensive. On the other hand, it improves the domestic security of supply, reduces our dependence on Russian energy imports, creates tens of thousands of Hungarian jobs, increases the ability of the country to retain its revenues, contributes to innovation in Hungary and saves on public funds, creating a system that is transparent, can be financed from the market and, importantly, is significantly more sustainable environmentally and results in better performance.

I invite you to join this exciting exchange of ideas. Please read our study and join us in deliberating the future of a sector or, if you like, the Paks project which has a crucial role in the future of Hungary.

Ada Ámon
Director
Energiaklub Climate Policy Institute
and Applied Communications

2. INTRODUCTION – OUR VISION

Energy policy, which determines what happens to the energy sector, is about much more than the generation and consumption of energy. If you think about it, the energy management of a country mirrors its attitude to people, nature and the economy. Does the profit go to a few large corporations or many small undertakings? Do we expand mines or sustainable forestry? Do we cut utility bills or increase efficiency?

The energy strategies of recent years did not dream big even about the distant future – instead, they insisted on existing, somewhat outdated but established arrangements and systems. Lest us step back for a moment from our immediate problems, assumed or real constraints and focus on solutions – what kind of energy vision would we wish for ourselves? What would be the ideal energy management of Hungary like at the time of our children and grandchildren? Which direction do we want to go?

How do we envisage the energy economy of Hungary sometime in the distant future?

- **It should be good for people** – providing sufficient quantity and quality of energy with security of supply. It should assure self-determination and energy democracy, that is, allow everyone to have a say in the way that the energy they use is produced. Furthermore, it should create and maintain fair jobs in urban and rural areas alike.

- **It should be good for the environment** – it should use gentle, renewable energy sources and technologies, which will not run out when used carefully and through which we can minimise adverse environmental impacts. It should not use methods that entail excessive risks or result in unmanageable waste. It should assure a healthy environment necessary for a full life (clean soil, water and air) and, in the long term, the protection of the climate.

- **It should be good for the economy** – give small enterprises and farms a chance to help provide energy to their neighbourhoods, boosting the local economy. It should allow residents to participate, potentially in the form of local energy cooperatives, in wind turbine investments, for instance, giving them a financial interest in the spread of renewable solutions. Everyone should have access to the energy necessary for them at an affordable price, and as energy producers, have the chance to generate additional income.

Today Hungary is very far from that ideal state: the overwhelming majority of our energy sources are non-renewable, and almost 70% of the fuels used by our power plants is imported. Over 70% of the natural gas, the fuel with the highest annual consumption, is imported from a single country: Russia[1]. The most influential actors in our energy economy are Hungarian and international corporations, which, proportionately, create few jobs, operate with limited transparency and have a strong commitment to fossil fuels.

A lot of energy goes to waste both in our power plants and households, though we could achieve higher living standards with less resources. This is the way leading European countries go. Let us see the three theoretical steps that could take use to this scenario and the ideal vision of the future.

2.1. Implementation of sustainable energy management in 3 steps

Creating a sustainable energy system in a country is a long process, therefore it should be started as soon as possible – as Denmark and Germany did, among others.

2.1.1. Eliminating waste of energy, rationalisation of demand

Total energy consumption has been stagnating in Denmark since 1972 and slightly declining in Germany since 1990, while GDP and living standards have been rising continuously. The cutback of our energy consumption is no sacrifice, all it requires is a little bit of attention – to the way we heat, the times we air the room, whether we do the regular maintenance on our furnace. A little bit of consideration of what makes us happy - not a larger car, new telephone or handvac. And of course stricter rules forbidding, for instance, shops being a blaze of light at night. We need not go back to the Stone Age, just rationalise our energy consumption with a little care – and savings can be measured in power stations not built, that is billions of forints.

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[1] Eurostat [2014]

2.1.2. Improving efficiency

Once we have reduced the demand for electricity or heat, we can further reduce the energy sources necessary for their generation by constructing more efficient power plant, insulating our homes, using energy efficient machines, etc. Various studies have shown that the first two steps may reduce the volume of all the energy sources required to less than one third[2] or even one tenth[3] in 35-40 years even if the existing technologies are used.

2.1.3. Conversion to renewable energy resources

This lowered energy requirement can be covered mostly from renewable sources. Several studies have demonstrated that in Hungary there are enough renewable energy sources available for this as an annual average[4]. Apparently, an energy system relying almost 100% on renewable sources is not utopistic: According to their official energy strategies, Germany will switch to a renewable-based energy system for 60% of its consumption by 2050[5], and Denmark will generate 100%[6] of its energy from renewables by that time.

These figures appear to be unbelievable from Hungary's perspective, where the ratio of the utilisation of renewable energy sources is currently below 10%[7]; where the ratio of renewable-based electricity production decreased for two years after 2010 and has not reached the previous level ever since[8]; and where no wind plants have been allowed to be build since 2011 because the transmission operator thinks that a 1% share of wind power would endanger the secure operation of the system[9].

Why do these developed countries think that basing their future operation on intermittent energy sources is the best decision? What if the wind does not blow and the sun does not shine?

How can such a system work?

2.2. Concept of the present system and the flexible energy system

The integration of intermittent energy sources into the electricity system (their maximum possible use) is certainly a challenge, which requires the system operator to perform functions radically different from its present tasks, which may be more complex but far from impossible.

It should be noted that according to international experience, all the technology necessary for the high (in principle even 100%) utilisation of renewables is available, and is continuously improving, expanding and becoming cheaper. However, the solution hinges not only on technologies but also on the way they are used – the cooperation of producers, consumers and the system operator in a coordinating role, as well as the objectives and rules of such cooperation.

2.2.1. Current practice

Let us see how this cooperation works at present in the Hungarian electricity system (Figure 1).

This system focuses primarily on meeting the electricity demands (from households, industry etc.) that change every second of every minute every day. This is the important variable that is the basis of the planning of the use of power plants by the TSO. Its primary objective is to accurately follow the consumers' demand curve by curtailing or firing up the available (mostly gas and coal-fired) plants, primarily using the plants producing electricity at the lowest cost.

(Interestingly, due to rising gas prices, foreign power plants are one of the cheapest sources today, therefore in recent years our electricity imports soared to the extremely high level of 28% of total electricity consumption[10], while a number of Hungarian power plants, some of them newly built, stood idle the better part of the year.)

Such a generally centralised system (dominated by a few large power plants) consists of a few base load power plants running almost throughout the year (Paksi Atomerőmű, Mátrai Erőmű), so-called load following power plants (usually gas-fired) and peaking plants fired up only when demand is highest (e.g. Litéri Erőmű).

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[2] Munkácsy – Sáfián [2011]

[3] Factor 10 Institute

[4] Ámon et al. f2006], Teske et al. [2007]; Teske et al. [2011], Munkácsy – Sáfián [2011]

[5] Die Bundesregierung [2010]

[6] Danish Ministry of Climate, Energy and Building [2011]

[7] Eurostat [2014]

[8] MEKH, MAVIR [2014]

[9] MEH [2009]

[10] MEKH, MAVIR [2014]

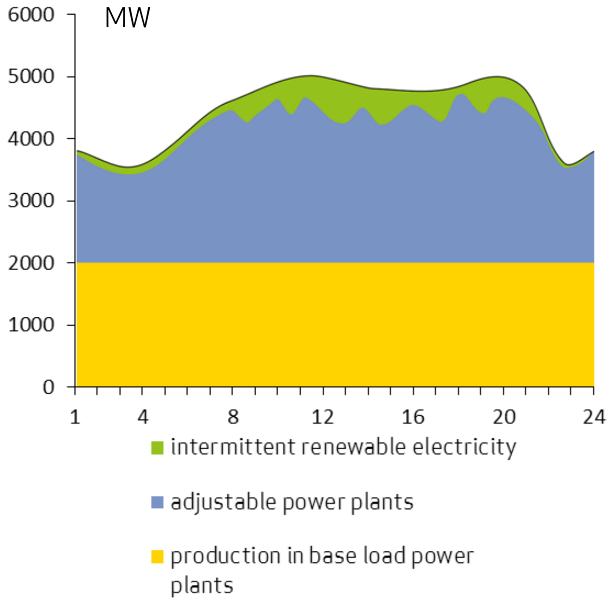

Figure1: Satisfying the electricity demand on an average day in the present electricity system. Prepared based on the figure of Greenpeace (Van De Putte – Short [2011]).

The rationale of the arrangement shows that in this well-thought-out system electricity generated from solar and wind energy, where production cannot be regulated at will, is practically a disruption. Not only does it make the job of the transmission operator more difficult but in certain situations (for instance in the event of sudden overproduction) it may endanger the stability of the system itself. Consequently, in such a traditional centralised energy system, particularly if it includes nuclear power plants with substantial capacities, the ratio of weather-dependent renewables (solar, wind) may not exceed 25% even in the long term[11].

2.2.2. A flexible energy system

A flexible energy system is different from the system outlined above in terms of its physical structure, the technologies used as well as its basic concept.
This system has a decentralised structure, that is, it consists of a large number of low-capacity power plants using as many types of sources and technologies as possible. They include fossil-based (e.g. coal, natural gas) and renewable-based (e.g. biomass, geothermal) co-generation plants (producing both electricity and heat), with heat storage, heat pumps or even syngas production. However, an ever increasing part, preferably overwhelming majority of capacities consists in renewable plants: various types of solar plants, windmills, small hydroelectric plants, geothermal plants, etc. They will be supplemented by various storage (e.g. compressed air, pumping, industrial-scale heat storage) and transformation technologies (e.g. water splitters producing hydrogen, industrial boilers); the latter will play a more prominent role in promoting the use of renewable electricity[12].

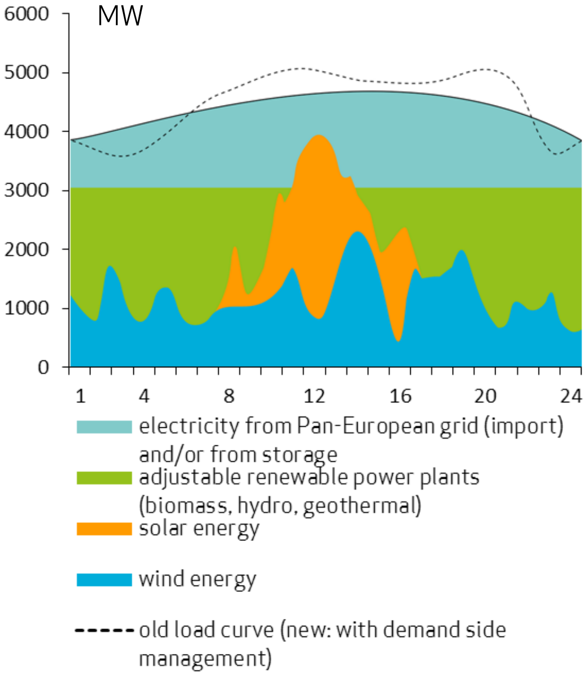

Figure2: Satisfying the electricity demand on an average day in the flexible energy system. Prepared based on the figure of Greenpeace (Van De Putte – Short [2011]).

The flexible energy system has the fundamental objective of using the energy produced from renewable sources, even if at irregular times and without the possibility to regulate, as much as possible while minimising the use of fossil fuels (Figure 2). In this case, production is not based on a continuously producing base load power plant but on the various renewable producers, and everything else (all other producers and even consumption) must adapt flexibly. If the wind blows, it is not wind-generated electricity that is the 'surplus' but the electricity generated by other, fossil-fired plants, which tend to use expensive, polluting, imported sources of energy – consequently, they are the ones to be used sparingly rather than renewables.

In the final analysis, the transmission system operation still has the role of co-ordinating that production and demand are identical. Here, however, it can influence the demand curve. There are various tools to help achieve the balance of

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[11] Van De Putte – Short [2011]

[12] Lund [2010]

consumption and production, including smart systems, time-dependent electricity rates, supply-dependent smart electronic car chargers etc., that is, the active manipulation of the consumption side (demand-side management, DSM).

As the existing Danish experience and model results show, in systems using a high ratio of renewable sources the main challenge will not be the production of sufficient quantities of electricity, as we would expect. Rather, the TSO and other actors will have to efficiently cooperate in assuring that in periods of overproduction (even of potentially dangerous magnitude) the excess electricity can be converted or stored for future use with as many types of technology and as efficiently as possible. In addition, the management of the timing of consumption is also an important tool but this is not the exclusive competence or duty of the TSO but also of the smart systems (e.g. electric car chargers or air conditioners turning on when there is excess production).

Let us see what this would be like in practical terms. Let us assume that on a winter day, wind rises suddenly and all of a sudden a large amount of electricity is expected to be produced. In this case, the TSO may curtail certain (e.g. coal-fired) CHP plants, reducing their output or shutting them down. The possibility of the curtailment of CHP plants is an important element of a flexible energy system. At such times, however, heat generation is also stopped – but these plants tend to have heat storage facilities as well, therefore district heating can continue from these facilities. If there is still too much excess electricity, more CHP plants may be turned off, and heat pumps may carry on with the supply of heat, reducing electricity overproduction even more. If this is still not enough, smart electric car chargers may also help in the efficient utilisation of the sudden surge of electricity.

2.2.3. But what if there is no wind...?

How can we be sure that such an energy system is workable?
Today there are numerous software programmes that can be used to model the entire future energy system of a country under various technological, economic or weather conditions. Thus careful and all-encompassing planning is extremely important for such a system – but also for a new nuclear power plant.

The alternative that we devised and present in this paper is special because not only have we developed a vision but, using a Danish energy system analysis software (EnergyPLAN) we also ran an annual model, with hourly breakdown, to see how such a system would work in Hungary. According to the simulation, it would be much more efficient (use less resources) than the present system.

2.3. Blowing against the wind in Europe

The decarbonisation and energy vision of the European Union clearly takes a stand for flexible energy systems and the development of renewable sources of energy. The exploitation of regional renewable potentials, demand-side management, the expansion of high-voltage international grids and energy storage facilities will be combined into a Pan-European smart grid. In this, the seasonal, daily and weather-dependent renewable surpluses and shortages of electricity can be offset continuously due to the large geographical distances and the diversity of renewable sources, providing a secure background for national energy systems. Hungary would also play an important role in this system: we will be able to participate in the proposed European division of labour primarily through our biomass, solar and geothermal potentials (Figure 3).

In such a system, where the objective is the fullest possible integration of renewable energy sources, they must be given preference over other producers in micro-, regional and European networks as well. If, however, there are several nuclear power plants in a region, this may be problematic in terms of their cooperation with the system, which may have a negative impact on the entire network[13].

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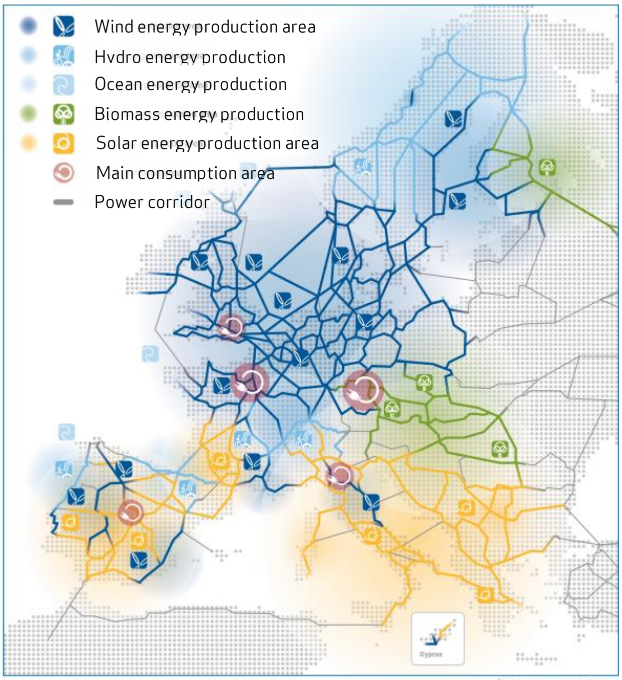
[13] Van De Putte – Short [2011]



Design: www.onehemisphere.se

Figure 3: European renewable energy grid in 2050. Source: EWEA [2011].

The priorities – and thus expectations – of the European Union include energy saving, increased efficiency, diversification of sources as well as the establishment of a flexible energy system on the side of both producers and consumers. As a result, there will be a radical drop in carbon dioxide emission and in the demand for fossil and imported sources, and the total cost of the operation of the future European energy system will also fall[14]. If Paks II is constructed, Hungary will have a decade of lag in complying with these expectations and exploiting its benefits.

2.4. Paks II or a flexible energy system? Nuclear energy or renewables?

Based on the factors presented above and the international simulations of the electricity system it appears clear that a base load nuclear power plant of several thousand megawatts of capacity cannot be implemented simultaneously with a flexible energy system. If we choose both, the investment costs of the nuclear power plant can be recovered only though very high electricity prices due to the lower output resulting from curtailments. The size and utilisation rate of renewable capacities would continue to be limited (as we can see now), and back-up power plants would also be needed. The two technologies impossible to regulate: the nuclear power plant, which must recover the enormous construction and security costs and the mostly weather-dependent renewables represent two entirely different energy management approaches, technologies, networks and attitudes; their simultaneous operation in a single system is inefficient and unviable. Consequently, we must make a choice between a large nuclear power plant requiring a centralised energy system and renewable-based concept that is efficient in a flexible energy system.

We need to make this decision now because the start-up of Paks II would require changes in the Hungarian electricity system that would reinforce its centralised structure, a move in the direction that takes us even further from a decentralised energy system.

If Paks II is implemented, we shall spend many billions of forints on the construction as well as the design and supplementary investments. Renewables and the related technologies and projects are likely to receive even less funding than at present.

The parallel operation of the two nuclear plants in Paks will result in substantial excess capacities alongside the existing power plants. In off-peak periods the system may generate excess electricity corresponding to the output of several nuclear blocks. As a result, a significant part of Hungarian power plants may be forced to shut down for lengthy periods. In such a situation, there may not be any funding or will to build renewable or any other new power plants in Hungary.

2.5. We always have an alternative!

"There is no alternative to Paks II" - we have heard this argument over and over again in discussions about the plant.

Without alternatives, there are no real decisions. What is the alternative to Paks II at present? We may believe that either Paks II is implemented or we are left without electricity; either Paks II is implemented or we will have to pay for the expensive renewables; in other words: "either this power plant or nothing!" This is a typical 'false dilemma' that society needs to face today and is apparently forced to accept.

However, there are always alternatives, which can be compared and rated based on a number of criteria and the most appropriate one chosen on this basis. We have seen no such alternatives for

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[14] Hewicker – Hogan- – Mogren [2011]

Paks II, and we do not know why and based on what considerations they have been discarded if they do exist.

We should note, however, that the spread of renewable energy sources and the large-scale conversion to the new technologies is a radical change, which will have its winners and losers.

International studies have shown that in the long term the winners of such a change could include

- society – more new jobs, energy democracy, strengthened local self-determination, reduction of the depopulation of rural areas, etc.,
- the environment – better air quality, lower carbon dioxide emission, fewer mines, etc., and
- the economy – new small enterprises, jobs, strengthened local economies, more intensive innovation, etc.

Losers may include incumbent energy corporations, power plant owners, entities working in the fossil sector, as well as the related institutions, which would need to undergo radical changes or be closed down to be replaced by successors better suited for the new approach.

It is therefore understandable that the parties with a vested interest in the present centralised, fossil-based energy system – corporations, power plant owners, coordinating institutions, organisations, authorities or even university departments – would want to maintain the status quo as long as possible. Consequently, they have an interest in preventing any alternatives from surfacing, or if they do surface, they are simply shrugged off so that they are not taken seriously ('no wind, no sunshine...'). From their perspective, this is a natural defence mechanism. The important thing is that we should realise: they are out of date. Our energy management must change radically and this is the time when we have a window of opportunity, when our old power plants will gradually be shut down in the forthcoming decades.

The stakeholders of the present system will not present to us the alternative that is really beneficial to society, which assures high living standards, fulfilment and a healthy environment; consequently it must be secured by the public.

This is how it worked in Denmark – there was a long road to the official energy strategy targeting a flexible, 100% renewable-based energy system by 2050. However, the continuous presentation of alternatives, their comparison with official plans and their promotion led from the first proposed nuclear power plant through coal-fired power plants constructed despite promises from the Government to the evolution of the country of wind energy cooperatives.

2.6. An alternative to Paks II

The purpose of Energiaklub is to assure that the first alternatives to Paks II are presented and promoted; that professional dialogue is started, so that we can ask our questions and the broadest possible social dialogue emerges about the vision we would like to see and on ways to implement our ideas.

A lot of decisions have already been taken about Paks II, therefore we are pressed for time. However, the construction of the plant has not been started yet and the plans are treated with utmost secrecy: both the plans and the arguments for the power plant have weak foundations in a number of respects. It is time to present the alternatives, compare them with the official scenarios and commence the debate that should have been started long ago.

Because of the tight deadline and our limited resources we did not set out to come up with a ready-to-implement alternative vision elaborated to the last detail. Instead, we want to show that workable alternatives do exist, and in a way they are better than Paks II – let us talk about them and compare them.

3. SIMULATION OF THE VISION WITH THE ENERGYPLAN SOFTWARE

Before outlining the alternative vision of Energiaklub, first we shall present the software used for the simulation. The structure, capabilities and reliability of the software have a decisive influence on the framework and level of detail of the study, and they leave a certain margin for error.

3.1. Key features of the EnergyPLAN software[15]

The first version of EnergyPLAN was developed by Henrik Lund in 1999; he has been improving the software ever since with the help of the Sustainable Energy Planning research team at the Department of Development and Planning of Aalborg University in Denmark. We used version 11.3, the most recent version available in 2014[16].

The programme has been used for hundreds of energy planning and optimisation publications. The software modelling tool is a widely used around the word; it has been used to prepare 100% renewable-based energy visions not only in Denmark but also in Estonia, Germany, Poland, Spain, Croatia, Ireland, the United Kingdom and Hong Kong.

Its most important applications include a study examining the 100% renewable-based, smart systems of the EU-27 countries up to 2050[17] as well as the 100% renewable vision of the Danish Engineering Association[18].

The most important features of the English-language programme that lead us to opt for it:

- designed to model national or regional energy systems;
- allows for the detailed analysis of a year in an hourly breakdown;

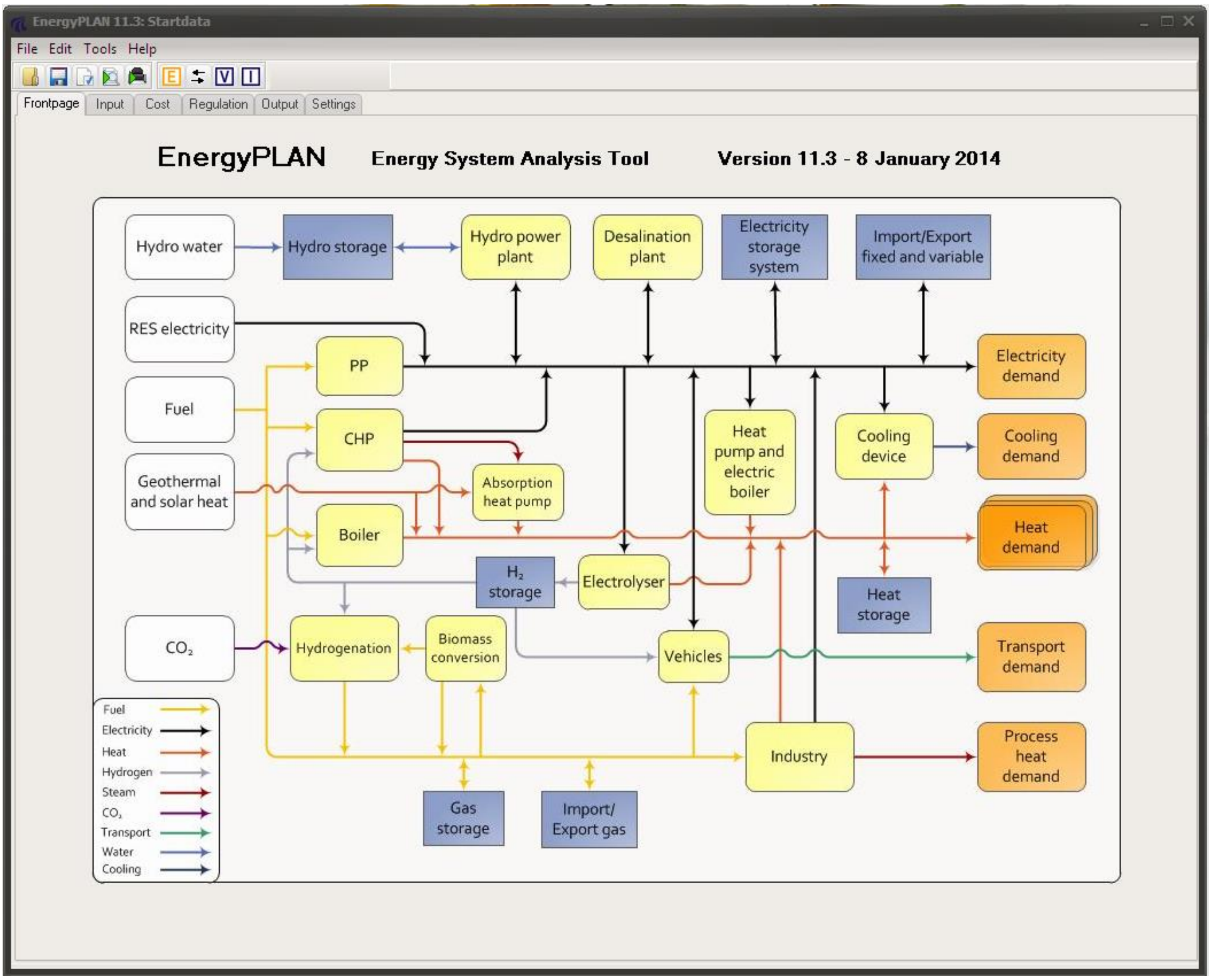

Figure 4: The opening page of version 11.3 of EnergyPLAN. Source: www.energyplan.eu

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[15] Based on Sáfián [2012]

[16] The software can be downloaded free of charge from energyplan.eu.

[17] Connolly et. al, [n.d.]

[18] Lund (ed.) [2011]

- covers every sector of the energy economy (residential, industry, agriculture, services, transport);
- focuses on the optimal integration of intermittent renewable sources of energy into the system, allowing for the simulation of even 100% renewable-based systems;
- in addition to the currently used traditional technologies it can also model the extensive use of technologies such as electric cards, syngas production or compressed air energy storage (CEAS);
- it allows for the choice of different regulatory strategies to facilitate the investigation and optimisation of the energy system on a technological or market basis;
- it can take into account the fix and variable costs of the various technologies, investment costs; taxes or subsidies can be set, etc.

The programme is deterministic, that is, identical input data will always yield the same output. The main input data are the size and timing of the annual energy demand, the capacity of the available renewable sources of energy and the distribution of production over time, the capacities and efficiencies of the various power plants (by groups) as well as the related technologies, costs, and various regulatory strategies. The main output data include annual energy balances, production volumes, total energy source consumption, electricity import and export as well as the costs related to all these elements[19].

3.2. What can this software show?

The software was developed by Danish energy planning experts primarily to model and optimise the technological viability of future energy visions for 2030–2050. Considering that their energy system for 2050 will rely exclusively on renewables, they needed a programme that can simulate such a complex system in small time units (in this case, in an hourly breakdown). It was also important that in addition to simulation and analysis, the software should also facilitate the optimisation of the system based on different criteria (lowest fuel consumption, cheapest operation) – this option is also offered by the software.

It can answer the following questions:

- Can the fossil and/or renewable-based power plants included in the model satisfy a given electricity or heat demand? That is: is the supply of electricity and heating secure 24 hours a day, 365 days a year?
- How much fossil and renewable energy source and imported electricity is required for this in a given year?
- How could renewable capacities be optimised and integrated to the fullest possible extent into the electricity system?
- What supplementary technologies (conversion, storage etc.) are needed to increase the efficiency and security of the system?
- What is the estimated annual carbon dioxide emission?
- At the fuel, investment and maintenance costs (or even tax rates) determined by the user, how much would be the annual cost of operation of such a system?

Our most important consideration was to be able to demonstrate that our model of an alternative energy system is workable and it would securely satisfy the domestic demand each hour of the year – even if there are times with no sunshine and no wind. We optimised our model for technology and dispensed with economic considerations.

3.3. What does the model not show?

- It does not show the ‘right answer’ because there is no single right choice: each country has different conditions, capabilities and constraints to face. Also, it is arguable what makes an energy system the right one: low fuel usage? Efficient power plants? Lots of new jobs? Minimal carbon dioxide emission? These questions are for the users to decide.
- Similarly, it does not propose an optimal energy mix or capacity distribution: we need to enter all these factor into the model and potentially change the input data based on the outcomes.
- It does not take into account geographical location. Thus in most cases we calculate with national averages: in the case of wind power, for instance, we reckoned with average capacity utilisation below the present one (because turbines will be constructed in less and less advantageous locations). Geographical considerations will also be present elsewhere, for instance in the case of the heat produced by CHP

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[19] Lund [2010]

plants and sufficient demand from nearby households or industries.
- We must also determine the system operation rules, for instance what happens where there is excess wind power generation in a certain period: whether the model should curtail wind turbines and co-generation plants, use it to produce heat, charge electric cars or export the surplus.

3.4. Constraints of use in Hungary

In the course of using the software we must take into account possible errors, which may arise for three main reasons. They may result from the inaccuracy of the data series used (e.g. statistical deviations or the use of estimates); or from the simplification (generalisation) required for the model.

The latter are necessary because, as the software models every sector of the entire energy economy – for instance, power plants on the supply side and various industrial facilities, households etc. –, in most cases only averages or aggregate figures can be assigned to these or else the volume of data would become unmanageable. In most sectors the programme reckons with annual consumption values by fuel type. On the supply side, power plants can be classified based on their characteristics (e.g., large and small CHP plants, peaking plants, wind plants, etc.), and their various specifications are entered into the model (e.g., capacity, efficiency, distribution of fuel consumption).

The third possible constraint may arise from the structure of the programme. This means that even though the Danish software developers have been targeting an international audience when working on EnergyPLAN, it still contains some Denmark-specific elements; as a result, it is impossible to model with complete accuracy the characteristics of the Hungarian energy system - because of both the Danish and Hungarian peculiarities.

For instance, geothermal and nuclear heat production cannot be integrated in the system, and the parallel Hungarian electricity imports and exports are also difficult to model. We have managed to work around some of these issues while others were added to the model outcomes subsequently.

The most severe headache was caused by the capacity utilisation of Hungarian power plants, which can be explained by financial considerations but is unreasonable for the purposes of technical optimisation. Quite of few Hungarian power plants have been working only at capacity factors of 5-15% in recent years. This also applies to power plants such as the one at Gönyű, which was opened in 2011: even though this is the most efficient Hungarian power plant, it is threatened with closure because of the considerations described above. This is because imported electricity is becoming cheaper than the electricity produced in many of our gas-turbine plants, thus we use less and less of their output and cover an increasing share of our electricity demand from imports instead. However, understandably, the software would run these power plants at a high capacity utilisation rate - and the model does not allow the input of the number of hours of operation. Eventually, we reduced the capacity of these power plants in proportion to their utilisation rate in the baseline model describing the current (2011) situation.

3.5. Validation – modelling the Hungarian energy system of 2011

To validate the applicability of the software to Hungarian circumstances and its potential constrains, before modelling our vision we ran the programme on the actual Hungarian figures (measured statistics) for the year 2011.

The main source of the necessary detailed energy figures and data series were the International Energy Agency[20], the CSO[21], the annual statistics of the Hungarian Energy Authority (MEH, then MEKH) and the Hungarian TSO (MAVIR)[22], the reports and studies of dr. Alajos Stróbl[23] and the data series used with the consent of FŐTÁV[24]. Some of these data series (for instance the demand curves) were also used for the 2030 model.

3.5.1. Results of the 2011 model

To test its accuracy and workability, we compared the key outcomes calculated by the model with official statistics. This is presented in Table 1.

The model is accurate for all the primary energy sources as its deviation from statistical figures is less than 1%. In a breakdown by energy source, the highest deviation from the values measured in 2011

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[20] IEA [2014]
[21] KSH [2014]
[22] MEKH, MAVIR [2012], [2014]
[23] Stróbl [2012]
[24] FŐTÁV [2014]

is found in the use of coal, which is 3.1% higher than the actual figure.

Table 1: validation of the applicability of the software in Hungary: comparison of the 2011 model results with the statistical data for 2011 Data source: IEA [2014], MEKH [2013], MEKH, MAVIR [2014], own calculations.

TOTAL PRIMARY ENERGY SOURCES USED	**2011 Statistics**[25]	**MODELLING RESULTS**	**DIFFERENCE IN %**
	TWH/YEAR	TWH/YEAR	%
coal	32.1	33.1	3.1
oil	53.1	53.4	0.7
natural gas	104.0	104.6	0.6
renewables and waste	23.1	22.9	-0.9
nuclear energy	47.7	47.5	-0.3
imported electricity	6.6	6.6	0.0
TOTAL	266.6	268.2	0.6
Renewable energy based electricity generation (TWh/year)	2.7[26]	3.03	12.2
Share of renewable-based electricity (%)	6.4[27]	7.1	11.1

It may be attributed to the optimisation tendency of the model that renewable-based electricity production is slightly higher than the actual 2011 figures, mostly due to biomass. However, this will hopefully not cause any error in the 2030 system as our purpose is to model an optimal energy system.

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[25] IEA [2014]

[26] MEKH [2013g

[27] MEKH, MAVIR [2014]

4. ALTERNATIVE VISION – HUNGARY IN 2030

The purpose of working out alternatives is to examine and present how, instead of going ahead with Paks II, Hungary could head towards the implementation of a flexible energy system relying increasingly on renewable sources of energy. To this end, first we outlined (put into numerical terms) the energy vision for Hungary in 2030 as we envisage it. Then, starting from those key figures we created a model, which we checked and analysed using EnergyPLAN.
Below we describe the guidelines for the creation of the vision, its pivotal points and the main steps and calculations in the model building process.

4.1. Concept

First of all we should note: the alternative we created is not a 'best case scenario'; that is, we do not consider it to be one of the best, most ambitious alternatives that we can think of. Such type of visions have been published in Hungary as well[28]; they demonstrated that by 2050 it would be possible to establish a 100% renewable based economy in Hungary.

Energiaklub's vision for 2030 shows how the energy demand of Hungary can be assured, instead of the Paks II project, in an energy system that is the first step towards the establishment of a sustainable – flexible, decentralised, overwhelmingly renewable-based – energy economy.

In view of the narrow time-frame of about 15 years and the difficult socio-economic situation in Hungary, our priority was workability. Thus the consideration of reasonableness often prevailed over arrangements that we would have considered ideal.
This is why we departed from the effective, official energy, renewable or transport strategies at several points, in a positive or negative direction. For instance, we used a conservative estimate for the efficiency of future power plants or the choice of technologies applied in 2030: for one, we do not reckon with the existence of a hydrogen-based economy.

In other words, our vision can be considered to be the 'minimal' version of a different route. With better boundary conditions and more ambitious target figures, even better results and faster changes can be achieved by 2030. Or as one of our editors put it: it appears that our vision 'could be achieved comfortably'.

Where we do envisage a radical change by 2030 is the mode of system operation and the regulatory framework. The commencement of the establishment of the flexible energy system described above is a precondition for getting closer to sustainable energy management within a few decades. However, a new approach is essential for this change because it is necessary for the spread of renewable-based technologies. As long as energy policy envisages the energy system of the future in terms of growing energy demand and centralised base load power plants, we will not make any headway.

The model reveals whether our vision is technically feasible (that is, workable) by 2030. Whether it will actually become reality depends on the openness of energy planners, policy-makers and system operators. In our vision we expect that the establishment of a flexible, decentralised energy system and the use of environmentally friendly solutions that create jobs and rely on local, renewable sources (with strict ecological considerations in mind) will be priorities in future decisions. Thus by 2030 we envisage a Hungary that has similarities with our present country but in some elements is much more novel and liveable. This is what we had to specify in numerical terms for our simulation.

4.2. Creating a vision – sources and methods

There are momentous changes ongoing in Hungary and globally; consequently, it was not easy to quantify the detailed socio-economic and energy state of Hungary in 2030. In most cases we projected the 2030 energy consumption and production values based on the sectoral trends of the past 20-25 years relying on Eurostat's statistics for Hungary[29].

Where a major trend reversal is expected or necessary, we relied on the development trends of other EU Member States. Often even the achievement of indicators already surpassed in those countries (e.g. network losses[30]) is a challenge for Hungary – however, in 15 years the values we set can even be exceeded.

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[28] Munkácsy (ed.) [2011], [2014]; Teske et al. [2011]

[29] Eurostat [2014]

[30] Eurostat [2014]

Naturally, we started our work by studying the various effective, official energy planning documents and background papers – National Energy Strategy 2030[31] and its background paper[32], Hungary's renewable energy utilisation action plan[33] and its background paper[34], MAVIR's resource and consumption analyses[35], Századvég's sectoral analysis[36], GKI Energiapolitikai Füzetek[37] etc. – and we adopted, or used in our calculations, several target figures (for instance during the estimation of power plant capacities).

Knowledge of domestic potentials and their consideration when determining capacities is an important precondition for the sustainable use of renewable sources of energy. In this context we relied on existing Hungarian potential estimates, studies, visions and foreign development trends as well. The most important ones of these, in addition to those already listed, are: the potential estimations of the 'Erre van előre' research team[38] and the MTA[39], calculations of the Eötvös Loránd University[40], the University of Debrecen[41] and the Széchenyi István University[42], the studies of Greenpeace[43], the sustainable energy strategy of Energiaklub[44], the report of KPMG[45], the research papers of REKK[46], the statistics of Eurostat1, EWEA[47] and EurObserv'ER[48].

There have been components, such as the number of electric cars in the field of transport, where we had to resort to estimates. Here we relied on the results of existing studies whose starting data and calculation methodologies we considered reliable, but the future trends they applied did not fit to the other elements of our alternative. Thus we did not borrow their results but used them as signposts for our own estimates.

The temporal (hourly) distribution of electricity and heat demand is essentially identical in our 2030 model with the 2011 ratios (the absolute figures are different). This is partly because of the uncertainty of future changes in consumption and partly our wish to promote comparability.

There are minor differences in the hourly data series describing demand for electricity. On the one hand, because of the characteristics of the software, we had to remove net electricity imports from the 2011 model and add them to the system subsequently. In contrast, the demand curve for 2030 contains imports because its level is determined by the software. The other difference in 2030 is the smart charging of electric cars, which is added to the demand in the form of overnight electricity consumption.

There is a similar situation with regard to the temporal distribution of wind and photovoltaic electricity production. These curves reflect the characteristics of the 2011 weather but they also fit the consumption demand of the same year – for instance, when the sun shone on some winter days (and solar panels worked), the demand for heat from households may have decreased. Because of this, and to assure the comparability of the curves, it was important to retain the renewable production curves of 2011. The volume of production naturally changes (increases) as a function of capacities between 2011 and 2030.

4.3. The key energy-related factors in our vision

Below we shall give a brief overview of the key indicators (and their calculation methods) of our vision which serve as cornerstones of our model and were the input data for EnergyPLAN. In view of the limited space, we cannot always describe them in full detail but we have tried to present the key figures either here or in the annex.

4.3.1. Trends in electricity consumption

We forecast the total electricity demand for 2030 based on the Hungarian electricity consumption statistics of Eurostat[1] for the past 25 years, separately for each sector, using trend line fitting.

In each case, we calculated three growth rates for the various sectors, reflecting the effects of the expected economic growth, energy saving and efficiency measures.

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[31] NFM [2012]
[32] REKK [2011]
[33] NFM [2011]
[34] PYLON [2010]
[35] MAVIR [2013a], [2013b], [2014a], [2014b]
[36] Századvég [2012]
[37] Barta et al. [2011]
[38] Munkácsy (ed.) [2011]
[39] Büki – Lovas [2010]
[40] Bartholy et al. [2013]
[41] Harmat [2013]
[42] Tóth – Csók [2014]
[43] Teske et al. [2007]; Teske et al. [2011]
[44] Ámon et al. [2006]
[45] KPMG [2010]
[46] Szajkó [2009] and Fischer et al. [2009]
[47] EWEA [2010]
[48] EurObserv'ER [2009], [2014a], [2014b]

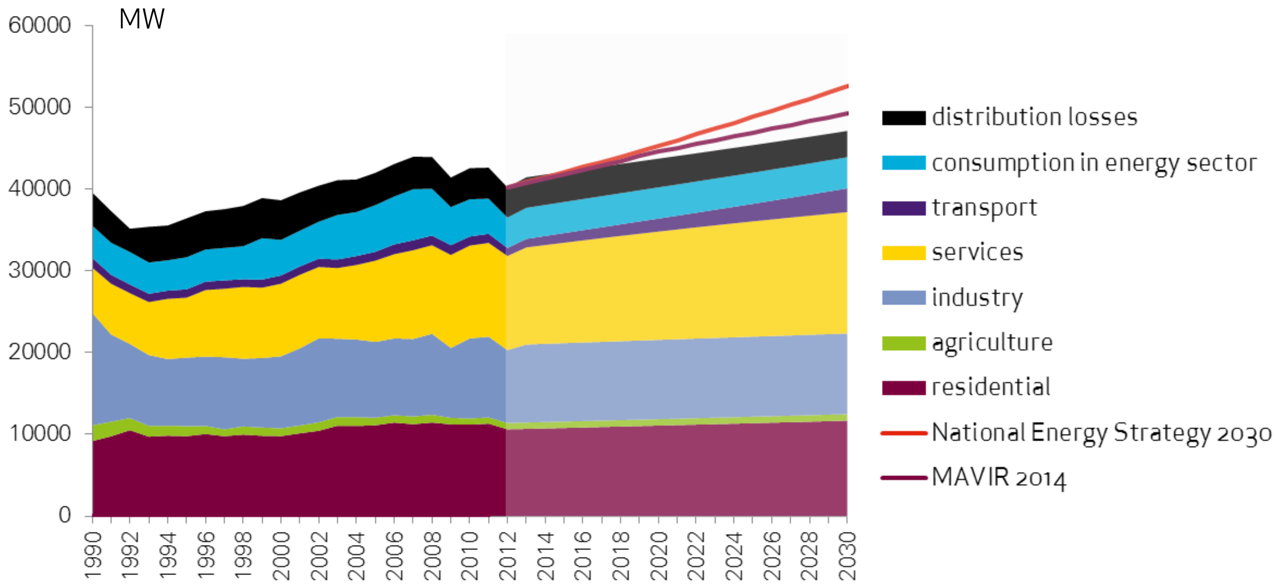

Figure 5: sectoral electricity demand between 1990 and 2012 based on Eurostat data and, from 2012 on, the calculations of Energiaklub, compared to the forecasts of the National Energy Strategy 2030 and MAVIR. Data source: Eurostat [2014], NFM [2011], MAVIR [2014a] and Energiaklub calculations.

Finally we incorporated the medium electricity demand growth trend into our model, reckoning with an annual 0.88% growth on average. This was significantly lower than the annual 1.5% percent featured in the official forecasts effective at the time of preparation of the vision (MAVIR consumption analysis[49] and National Energy Strategy)[50]. From among the growth versions of the most recent consumption analysis[51] of MAVIR, the scenario with the lowest demand growth forecasts contains the approximate growth rate we calculated (0.9–0.7%/year).

It appears that life also confirms the lower growth trends. Between 1990 and 2012 domestic gross electricity demand increased by 0.1% per year on average. In the pre-crisis years between 1990 and 2008 the annual growth rate was 0.6%/year on average, including some years with an exceptionally high rate of growth of 2–2.5% percent. Since 2008, however, the total electricity demand of the country has been *declining* by 2.1% on average each year[52]. There are several reasons why we still used a value close to 0.9% in our calculations.

These include the temporary increase in demand due to the recovery from the crisis and technological adaptation, overestimation to assure security of energy supply, the growing electricity demand from transport (electronic cars, but up to 2030 primarily rail transport), as well as the international trend of more and more energy-intensive services being converted to electricity – such as cooking, heating/cooling (heat pumps), transport, etc.

Figure 5 shows the gross electricity demand of the country by sector, based on Eurostat[53] statistics and, for the period after 2013, the calculations of Energiaklub. We also placed the official forecasts on the graph: the trend of the National Energy Strategy[54] reckons with an annual growth rate of 1.5% while the baseline of MAVIR's 2014 Consumption analysis[55] expects a growth of 1.3% up to the 2020s and 1% thereafter.

According to our calculations, by 2030 the gross electricity demand of the country will be 47.1 TWh. The corresponding value was 42.63 TWh in 2011, and the projection of MAVIR[56] expects it to be around 46.2 and 50.6 TWh in 2030.

The figure above illustrates that the target figures of our vision do not entail scarifies or restrictions. On the contrary, we 'allowed' the service sector and transport to increase its demand substantially, and the same applies to households, were we reckoned with a 10% increase in consumption between 2012 and 2030.

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[49] MAVIR [2013a]
[50] NFM [2012]
[51] MAVIR [2014a]
[52] calculation based on Eurostat [2014]
[53] Eurostat [2014]
[54] NFM [2012]
[55] MAVIR [2014a]
[56] MAVIR [2014a]

4.3.2. Power plant capacities

The list of domestic electricity production capacities drawn up by Energiaklub for 2030 (Table 2) departs from the official plan on two important points. On the one hand, it does not contain the 2400 MW output of Paks II, and on the other hand, it reckons with numerous new, small, decentralised, renewable power plants.

All forecasts agree that by 2030 a number of Hungarian power plants will have to be shut down for different reasons, therefore they will drop out of the domestic electricity system.
Examples include the Tisza II, Oroszlányi and Lőrinci power plants. In line with MAVIR's projection[57], these are excluded from the electricity system in our vision as well. However, in our model they are not replaced by the new Paks blocks or gas-fired units. Instead, we reckon with an increased use of domestic renewable sources of energy, a total purely renewable capacity of more than 5500 MW including the existing facilities, by 2030.

Table2: Power plants in 2030 according to Energiaklub's vision. Source of data: MAVIR [2014b] and Energiaklub calculations. In the case of renewable plants (photovoltaic/geothermal) the efficiency columns show the capacity factors we used.

	CAPACITY	**ELECTRIC EFFICIENCY**	**TOTAL EFFICIENCY**	**ENERGY SOURCE**
	MWe	%	%	
Paksi Atomerőmű	2000	33.0	33.0	nuclear
Ajkai Erőmű	89	9.2	60.1	coal, biomass
Pannon Erőmű	85	10.9	71.5	natural gas
ISD Power (Dunaújváros)	65	7.5	57.5	natural gas
Small solid biomass power plants	825	33.0	84.0	biomass
Gas engines	600	34.2	78.0	natural gas
Biogas power plants	350	27.0	84.0	biogas
Gas turbines	340	29.3	75.9	natural gas
Steam turbines	50	24.0	57.6	natural gas, oil
Kelenföldi Erőmű	186	19.9	74.6	natural gas
Kispesti Erőmű	114	32.5	87.2	natural gas
Újpesti Erőmű	110	33.7	88.4	natural gas
Debreceni Erőmű	95	34.5	76.2	natural gas
Mátrai Erőmű	475	35.3	35.6	coal, biomass, waste, oil
Gönyűi Erőmű	433	54.7	54.7	natural gas
Csepeli Erőmű	410	50.2	61.9	natural gas
Dunamenti Erőmű	408	54.0	54.0	natural gas
New OCGT units	500	30.9	30.9	oil
Waste incinerators	47	46.1	68.9	waste
Photovoltaic	1400	14.8	14.8	renewable
Wind turbines	2800	22.0	22.0	renewable
Hydroelectric plants	66	41.5	41.5	renewable
Geothermal power plants	67	80.1	80.1	renewable
LARGE POWER PLANTS	4970	31.2	60.4	
SMALL POWER PLANTS	6545	35.2	60.7	
FOSSIL + NUCLEAR	5928.5	31.8	62.7	
RENEWABLE	5586.5	34.4	53.1	
TOTAL	**11515**	**33.0**	**60.5**	

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[57] MAVIR [2013b], [2014b]

Table 2 contains the power plants included in our model (boilers producing only thermal energy, solar collectors etc. are not shown). The capacities of traditional power plants, their efficiency and other specifications – as shown in Annex 1 - are based on the various scenarios of the capacity analysis[58] prepared by MAVIR. However, the detailed table in the annex, containing production and fuel consumption values as well, is only a starting point. On the one hand, in MAVIR's calculations they are supplemented by a 2400 MW power plant; on the other hand, the software uses regulatory conditions and fuel saving considerations defined to optimise the operation of these plants, thus it departs from the production and resource utilisation values set by MAVIR. Because of the generalisation, the input data may be specified only for groups of power plants and the software calculates the results on this basis as well.

In the case of renewable capacities, we reviewed a number of Hungarian potential estimates, strategies and energy visions, Hungarian and international statistics (see Section 4.2), and set the target figures appropriate for our vision accordingly. Wherever possible, these future capacities are determined with a conservative approach. Nevertheless, these figures may appear extreme due to technologies considered to be exotic in Hungary and the 'we have neither sunshine nor wing' attitude. Let us therefore make a comparison with some European countries from recent years, which may illustrate the current trends of Europe and the rate of potential development in the field of renewable capacities in a matter of a few years if it is considered a strategic priority or at least receives some support. We should realise: this support often helps exploit the own, local, renewable energy sources of the country in an environmentally friendly manner and creates jobs, thus it should be treated differently than, for instance, the subsidisation of (imported) gas or borrowing to finance a nuclear power plant.

The statistics in Tables 3 and 4, where we present not only countries in the vanguard of renewable technologies but also our neighbours, show that, contrary to public belief, the wind and solar capacities we set for 2030 are conservative even relative to our neighbouring countries. Therefore they should be interpreted more as a minimum level, and the role of renewable-based electricity will hopefully be greater than this in the future.

Table 3: Solar capacities in 2008 and 2013 in some European countries, and future developments in Hungary based on Energiaklub's vision. Source: EurObserv'ER [2009], [2014a], own calculations.

	SOLAR CAPACITY (MW)		
	2008	2013	New capacities built in 5 years
Germany	6019	36013	29994
Italy	458	17614	17156
France	104	4698	4594
Czech Republic	55	2133	2078
Greece	19	2586	2567
Hungary	1	15	15
Romania	1	1022	1022
Bulgaria	1	1019	1018
Slovakia	0	537	537
Our vision (Energiaklub's calculations)	2015	2030	Capacities to be built every 5 years
Hungary	30	1400	457

Table 4: Wind energy capacities in 2008 and 2013 in some European countries and future developments in Hungary based on Energiaklub's vision. Source: EWEA [2010], EurObserv'ER [2014b], own calculations.

	WIND ENERGY CAPACITY (MW)		
	2008	2013	New capacities built in 5 years
Germany	23897	34633	10736
Italy	3736	8551	4815
France	3404	8143	4739
Poland	544	3390	2846
Hungary	127	331	204
Romania	11	2459	2448
Our vision (Energiaklub's calculations)	2015	2030	Capacities to be built every 5 years
Hungary	331	2800	823

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[58] MAVIR [2013b], [2014b]

4.3.3. Production of electricity

However, the electricity generated by renewable-based facilities does not increase in line with the intensive growth of renewable capacities because, due to their weather-dependent intermittent operation, photovoltaic and wind plants operate at significantly lower capacity factors than traditional power plants. However, in a flexible energy system the maximum utilisation of this relatively low availability (which will increase in the case of wind plants, for instance, as they spread geographically) is promoted if the TSO shuts down some of the (CHP) plants when renewables are in operation, giving way to green electricity in the system.

The electricity production of the 2030 vision is calculated and optimised by EnergyPLAN with a view to the lowest possible use of resources and the highest possible share of renewables. This is explained in detail in Section 5.2, which describes the results of the model.

4.3.4. Supply of heat

According to Energiaklub, in the long term the most appropriate strategy, both for the environment and our purses, is supporting energy savings and efficiency; that is, the insulation of existing buildings, modernisation of heating systems, replacement of doors and windows, re-thinking our heating habits, conscious attention as well as the design and constructions of low-energy buildings. Subsidy systems must also reflect these priorities and transfers undermining the recovery of such investments must be abandoned (e.g. gas price subsidy, utility rate cuts). We must also consider that in line with the relevant European Union directives[59], public buildings and residential buildings will have to have close to zero energy requirements after 2018 and 2020, respectively.

According to a previous study of Energiaklub (NegaJoule2020[60]), more than 40% (42 TWh) of the energy used by Hungarian households could be saved. We determined the realistically achievable target for 2030 based on other research results of Energiaklub[61] and the background calculations for the National Building Energy Strategy. Accordingly, 23 TWh primary energy savings could be achieved by 2030 (Figure [62]6Figure 6).

For the renovation of existing buildings we reckoned that of the 4 million households, 1.5 billion will modernise their homes in terms of energy management between 2015 and 2030. This requires a significantly larger scale, better planed and in the long term predictable system of incentives; however, in light of the extremely high number of homes in need of renovation and the EU funds theoretically available for the purpose, the target is not unrealistic.

In our calculation we assumed that, as opposed to past trends, some 70% of the buildings refurbished will be detached houses while the remaining 30% will be split evenly between flats in prefab and brick buildings. We calculated with average size homes (between 55 and 100 m^2) in each case. We assume that 55% of the detached houses engaging in modernisation will perform complex structural renovation (external insulation and replacement of doors/windows), 15% insulate, about 10% install solar collectors for hot water supply and 20% modernise the heating system. We assume that half of the latter group will install modern gas condensing boilers and 10% will replace outdated wood heating by wood gasification boilers.

The 195 thousand tower block flats indicated in our calculations will undergo comprehensive renovation (external insulation, replacement of doors/windows and heating regulation). Households modernising their heating systems will switch to gas condensing boilers from traditional gas heating (convectors or boilers), assuming half of the hot water being produced by electric boilers and the other half by gas boilers.

It should be noted that in our calculations we did not exclusively assume the version that would be optimal for energy purposes; instead, we also took into account the data from our representative national household survey of 2013 and 2014[63] and the modernisation plans of households.

In the case of new buildings we assumed, based on the historic construction volumes published by the CSO, that 200,500 new residential units will be built between 2015 and 2030, 60% of which will be detached housed (120 m2) and 40% condominium flats (70 m2). Heat will be produced by gas condensing boilers in half of new detached houses, 30% will use wood gasification boilers, 10% pellet boilers and another 10% heat pumps. Approximately half of the new boilers will be assisted by solar

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[59] European Parliament and the Council 2010

[60] Fülöp [2011]

[61] Fülöp [2013]; Fülöp – Varga [2013]; Severnyák – Fülöp [2013]; Fülöp – Kun [2014]

[62] Csokonyai [2013]

[63] Fülöp – Kun [2014]

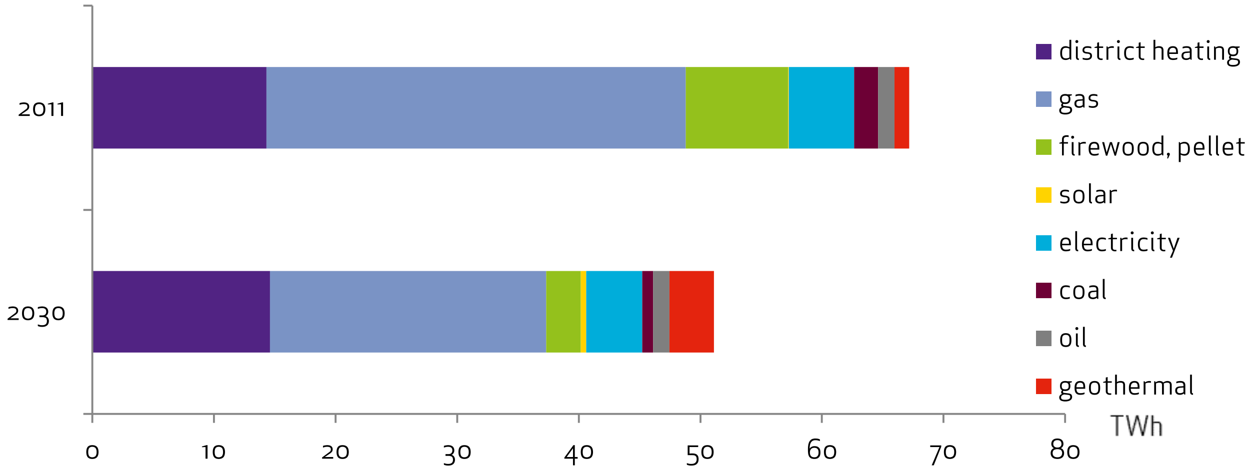

Figure 6: Energy use for heating in 2011 and in the vision of Energiaklub. Source: IEA [2014], own calculations

collectors in heat production. For new condominium units we assumed the use of gas condensing boilers.

We assumed that as new dwellings are constructed, an equivalent number of dwellings will be abandoned: 180 thousand detached houses using wood, coal or electric boilers and 20.5 thousand condominium flats using gas convectors and electric boilers. (Thus in aggregate more than 350 thousand old electric boilers will be removed from operation by 2030.)

As we noted in connection with Table 2 presenting generation capacities, small biomass plants preferably owned or operated by local communities will be an important element of the decentralised energy system of 2030. These will supply hot water to new district heating systems relying on local, sustainable biomass sources. Nevertheless, because of more efficient buildings, district heating systems will supply about the same amount of heat in aggregate as they do today (Figure 6).

Even though geothermal heat production was mostly part of local district heating systems in 2011, in Figure 6 we show this separately from district heating services, in a category of its own. The 2030 figure contains both industrial and agricultural heat supply as well as heat supplied by household heat pumps, or rather the minimum value for 2030. Potential calculations indicate that this 3.65 TWh/year figure may actually be more than double this level by 2030.

We do not separately show the solar collectors participating in district heat production in 2030, only the ones installed on residential or public buildings etc. The heat produced by these units may appear relatively modest; this is because in our vision photovoltaic cells are given priority on the roofs of residential and public buildings, shopping centres, parking garages. The more valuable electricity production from these cells is much more versatile than solar collectors, which produce heat mostly in the summer.

4.3.5. Fuel requirement of industry, agriculture and the service sector

Since the systemic change the total energy demand of the three main sectors has decreased substantially, and our calculations show that this trend will continue up till 2030 because of the increasing efficiency of technologies (Figure 7). One exception to this trend is the primary energy consumption of services, which has been on the increase in aggregate since the systemic change even though the recession years have produce some decline.

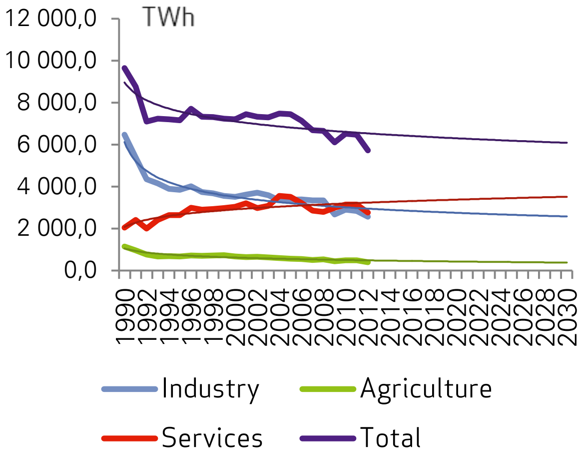

Figure 7: Total energy demand of industry, services and agriculture up to 2012 and its forecast for 2030. Source of the data used for the calculation: Eurostat [2014].

We have projected the future energy demand by sector and by the main energy sources, based on the trends of the past 25 years.

The results are summarised in Figure 8. The role of natural gas is expected to remain substantial in these sectors.

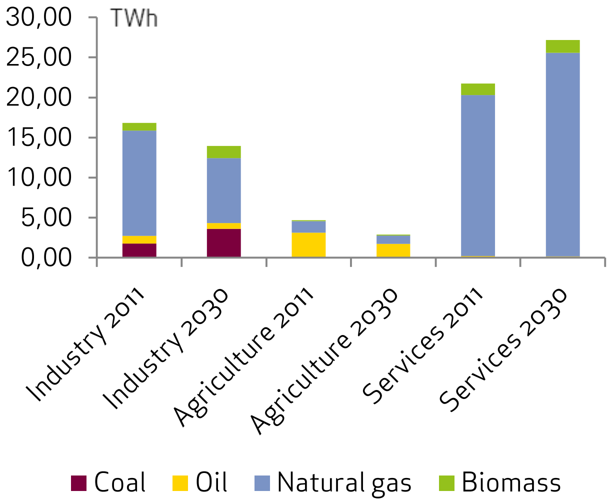

Figure 8: Development of sectoral energy demand between 2011 and 2030. Source: own calculation based on Eurostat [2014]

4.3.6. Transport

Making transport sustainable is one of the main challenges not only in Hungary but also in other European countries. This sector has been growing for decades (partly due to dynamically, or even irrationally, expanding road freight transport), resulting in crude oil consumption increasing year from year, and severe import dependence.

Having reviewed Hungarian and international forecasts[64], transport strategies[65] and estimates of the spread of electric cars[66], we prepared separate calculations for the future development of transport. It should be noted that again, we were conservative in our calculations, setting lower targets than the potential.

In our vision we try to identify solutions in the transport sector as well: by 2030, 30% of road freight transport will be diverted to rail and 20% of passenger cars will have alternative propulsion (excluding bio-fuels generally mixed with traditional fuels). In 2030, 550 thousand of the 4.3 million passenger cars in Hungary will have some hybrid propulsion (hybrid or plug-in hybrid), 120 thousand will be electric, 200 thousand will use compressed or liquid gas.

Even though in the future the prevention of transport needs (by urban planning, for instance), the development of public transport and increasing its quality, the reduction of road freight and passenger transport will need to be priorities, the crude oil requirement of Hungarian transport will still increase by 2030.

4.3.7. Demand curves

For the simulation of the 2030 energy system we needed so-called demand curves, i.e., the temporal breakdown of the annual consumption volume. We had these figures for 2011, and we used the same ratios for 2030 because of uncertain predictability and comparability. We used the data of MAVIR[67] for the annual curve of the electricity demand in an hourly breakdown and the data of FŐTÁV[68] for the heat demand curve.

There are some minor differences, explained above, in the timeline of electricity demand (Figure 9). One is attributable to electricity imports, the other to electric cars. In our vision, in 2030 25% of electric

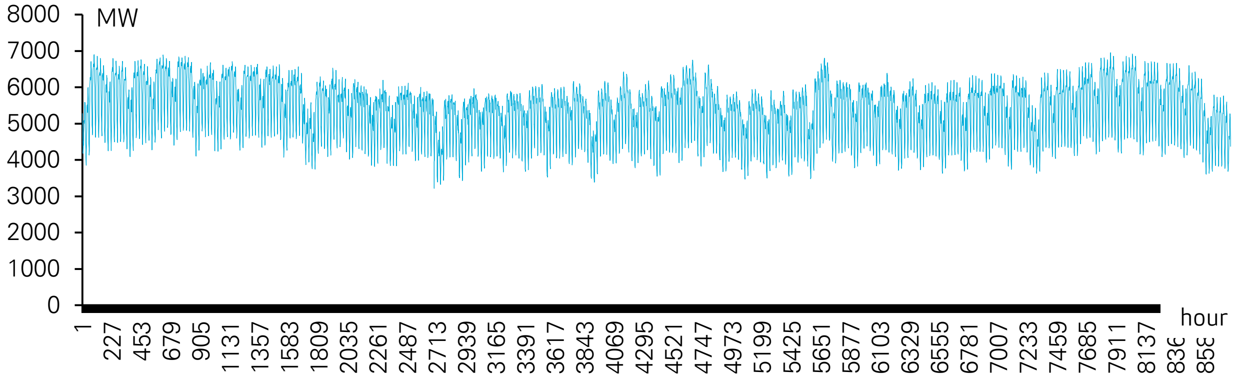

Figure 9: Electricity demand curve in 2030. Prepared using data from MAVIR [2014c].

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[64] REKK [2011]; IEA, UIC [2012]
[65] NFM [2013]; Paár – Szoboszlay [2013]
[66] PwC [2012] Kádár – Lovassy [2012]
[67] MAVIR [2014c]
[68] FŐTÁV [2014]

cars will have smart chargers activated when there is excess electricity available - which will for the time being occur mostly during the night. Thus this not too substantial demand (0.3% of the annual electricity demand) will be added to the night electricity consumption curve each day.

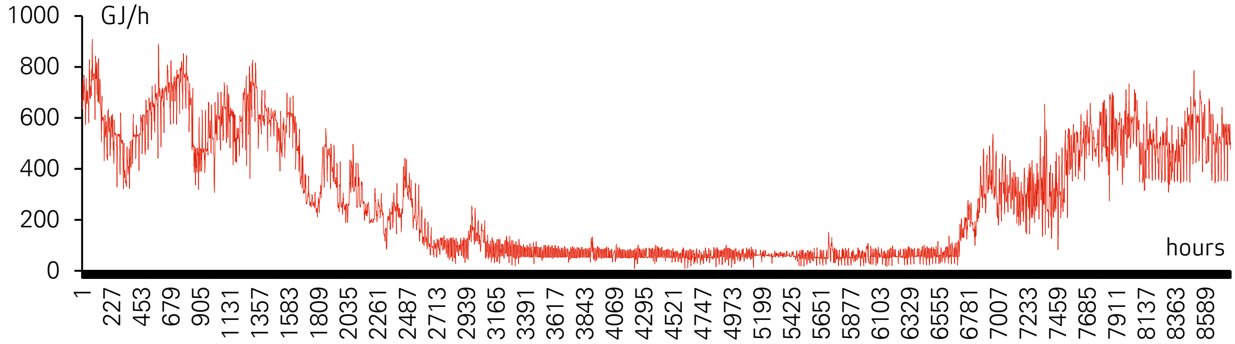

Figure 10: Heat demand curve in 2030. Prepared using the data from FŐTÁV [2014].

The heat demand curve (Figure 10) was prepared based on the 2011 production data of a power plant in Budapest. The horizontal axis shows the hours (of which there are 8784 in the figure), the vertical one the heat production of the power plant in GJ/hour. The curve traces the higher heat demand in winter, as well as the domestic hot water demand, which is more or less constant even in the summer.

5. RESULTS

Having fed the detailed data of the above vision into EnergyPLAN, we ran the simulation and obtained the results. These results describe, based on the cornerstone figures we set, the operation of the Hungarian energy system in 2030, optimised for resource savings and the maximum possible utilisation of renewable energy sources. As we indicated in the introduction, this energy system is a transition towards a flexible energy system, thus the rationale of its operation and its regulatory background is also different from the present arrangement.

When describing our vision above, we also referred to the results of the simulation repeatedly; however, we should like to highlight two important indicators: the total primary energy supply to the economy and electricity production in 2030.

5.1. Total primary energy supply – energy mix in 2011 and 2030.

In 2011 the total primary energy supply (TPES, excluding non-energy use) looked like this (Figure 11, top): approximately 90% of all energy sources used were fossil and renewable sources of energy were dominated by biomass.

In 2012 the ratio of biomass within renewable energy sources exceeded 81%[69], mostly as fuel for household wood heating and low-efficiency power plants converted from old, coal-fired plants. Because of the continuously increasing share of imports and large transportation distances the sustainability of this arrangement is questionable from several aspects.

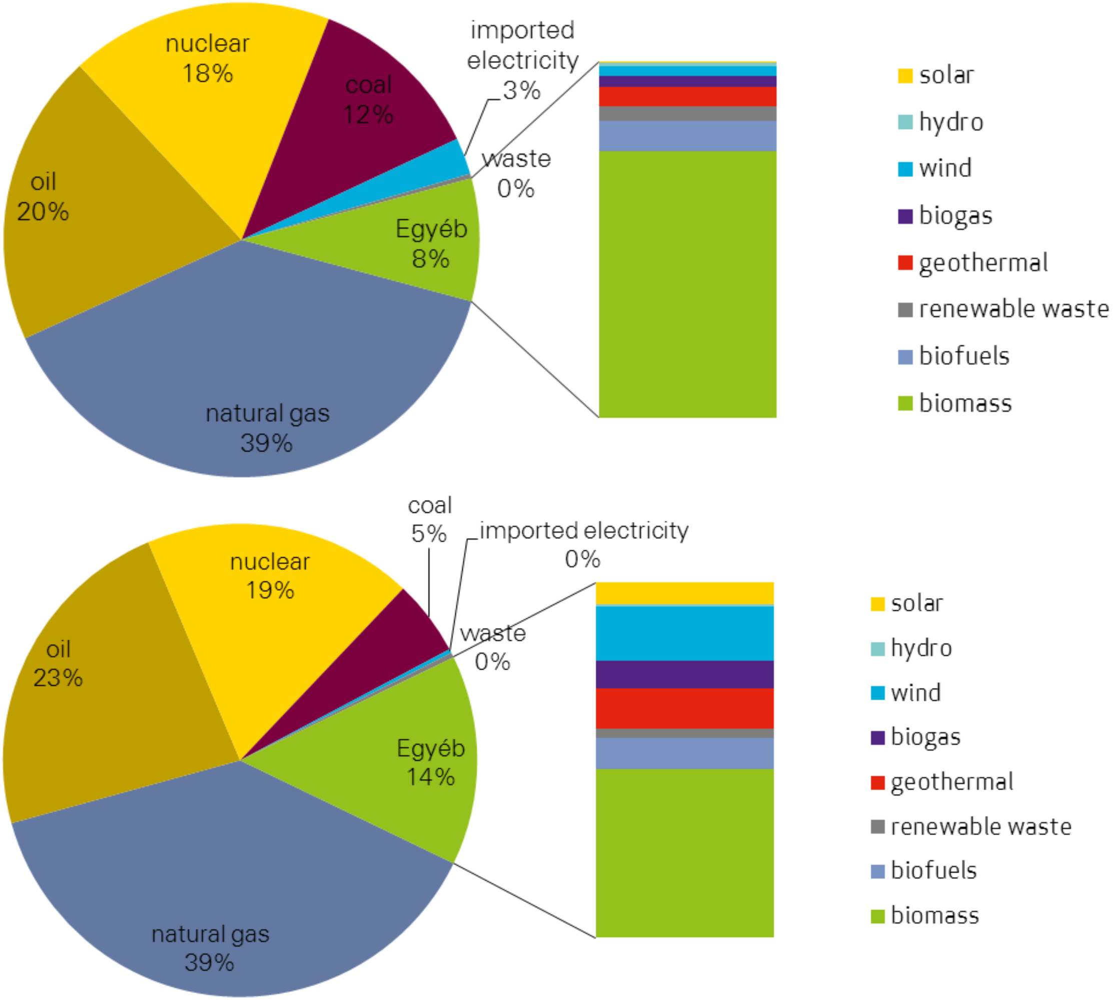

Figure 11: Total primary energy supply in 2011 (top) and in 2030 (bottom) based on the figures of IEA [2014] and the results of EnergyPLAN.

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[69] KSH [2014]

By 2030 the energy mix will have changed as follows (Figure 11, bottom):

- total demand for energy (without non-energy uses) will decline by 3% between 2011 and 2030, while the National Energy Strategy envisages a growth of 10%;
- the use of natural gas, the most important energy source, will decline by 4%, that of coal by close to 60%;
- crude oil consumption will be up by almost 12% mostly due to increased demand from transport;
- nuclear energy production remains unchanged;
- renewable-based energy production will increase by more than fifty percent in 15 years, while the structure of the use of various renewable energy sources will become more balanced: even though the use of solid biomass will increase slightly, its share within renewables will be only 47% in 2030.

5.2. Production of electricity

When describing electricity production, we do not want to focus on changes in the energy sources used; rather, we want to emphasise the shift between various types of power plants, a move towards a flexible energy system and a marked increase in the role of renewable sources of energy.

Figure 12 shows the share of various types of power plants in electricity production. In 2011 nuclear power plants contributed 37%, renewable power plants 6.4% and imports almost 16% to Hungarian electricity production[70].

The column in the centre is the vision for 2030 derived from the two most recent scenarios of MAVIR[71]. As its most notable feature, under this scenario the two new blocks in Paks will be operational in 2030, thus nuclear energy will generate more than half of the electricity in Hungary, with a significant amount needed to be exported. The share of renewable-based electricity production will increase to 15% by 2030[72], but more than 60% of this is biomass.

In Energiaklub's vision increased efficiency and the promotion of the use of renewable sources of energy are priorities. The increase in electricity demand projected for 2030 is lower than in the official version: 0.88% on average each year between 2013 and 2030. The share of renewable electricity generation is 27.2% in 2030. The contribution of the various renewable energy sources (wind, solar, biomass, hydro, geothermal) will be more balanced, the share of biomass decreasing to 50% (while its use will expand).

According to our simulation, without Paks II, improved energy efficiency and the expansion of renewable capacities will facilitate the satisfaction of 98.6% of Hungary's electricity needs from Hungarian power plants in 2030.

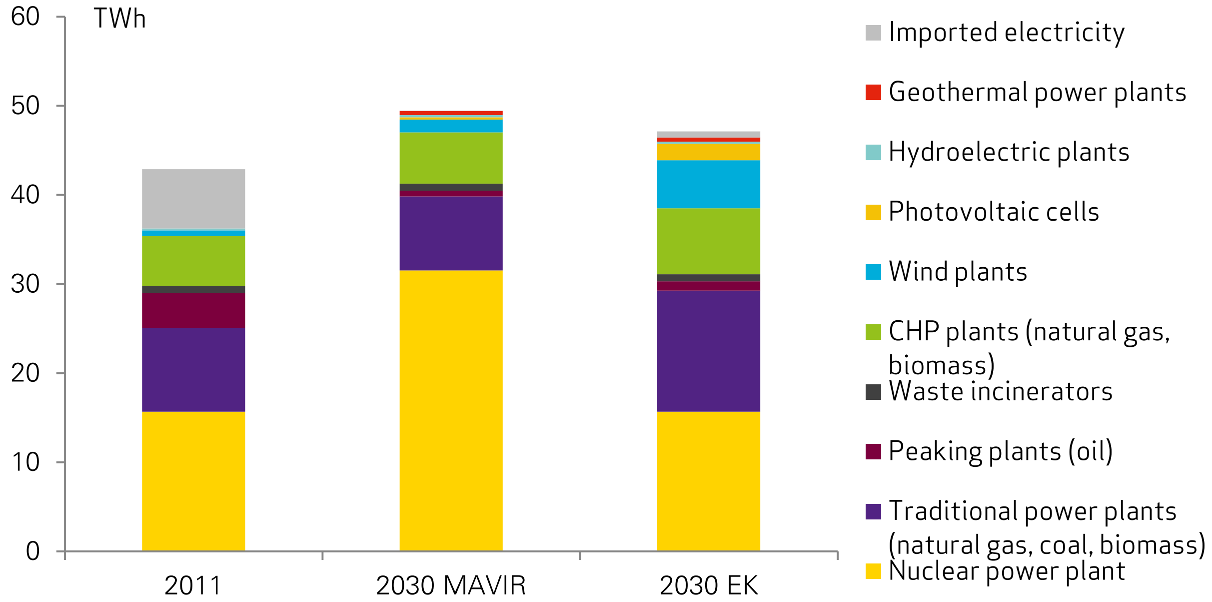

Figure 12: Electricity production in 2011 and 2030 based on the official projection and the model of Energiaklub. Source: Stróbl [2012], MAVIR [2014b], calculation with EnergyPLAN.

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[70] IEA [2014]

[71] MAVIR [2014b]

[72] REKK [2011]

Thus a minimal, 0.7 TWh electricity import will be necessary, compared to 6.6 TWh in 2011[73] and 11.9 TWh in 2013[74].

5.2.1. Electricity supply on the maximum-demand summer and winter days

The graph below shows the results of EnergyPLAN's simulation for the energy production in Hungary on the highest-demand winter (24 November) and summer (25 August) days in 2011 and 2030.

In 2011 we needed continuous electricity import on both days. In contrast, in 2030, even though energy demand are higher, significant imports are needed only in the afternoon and evening hours. On the winter day there was no sunshine or wind to speak of, while on the summer day it was clearly possible to generate electricity with solar cells, and wind energy also contributed in the early hours. The software, to give room to renewable production, curtailed the operation of CHP and load following power plants. As a result of renewable production, a significant volume of resources and electricity imports can be saved.

5.2.2. Energy supply on the windiest day

In 2011 the wind turbines of the country produced the most electricity on 17 December: they satisfied

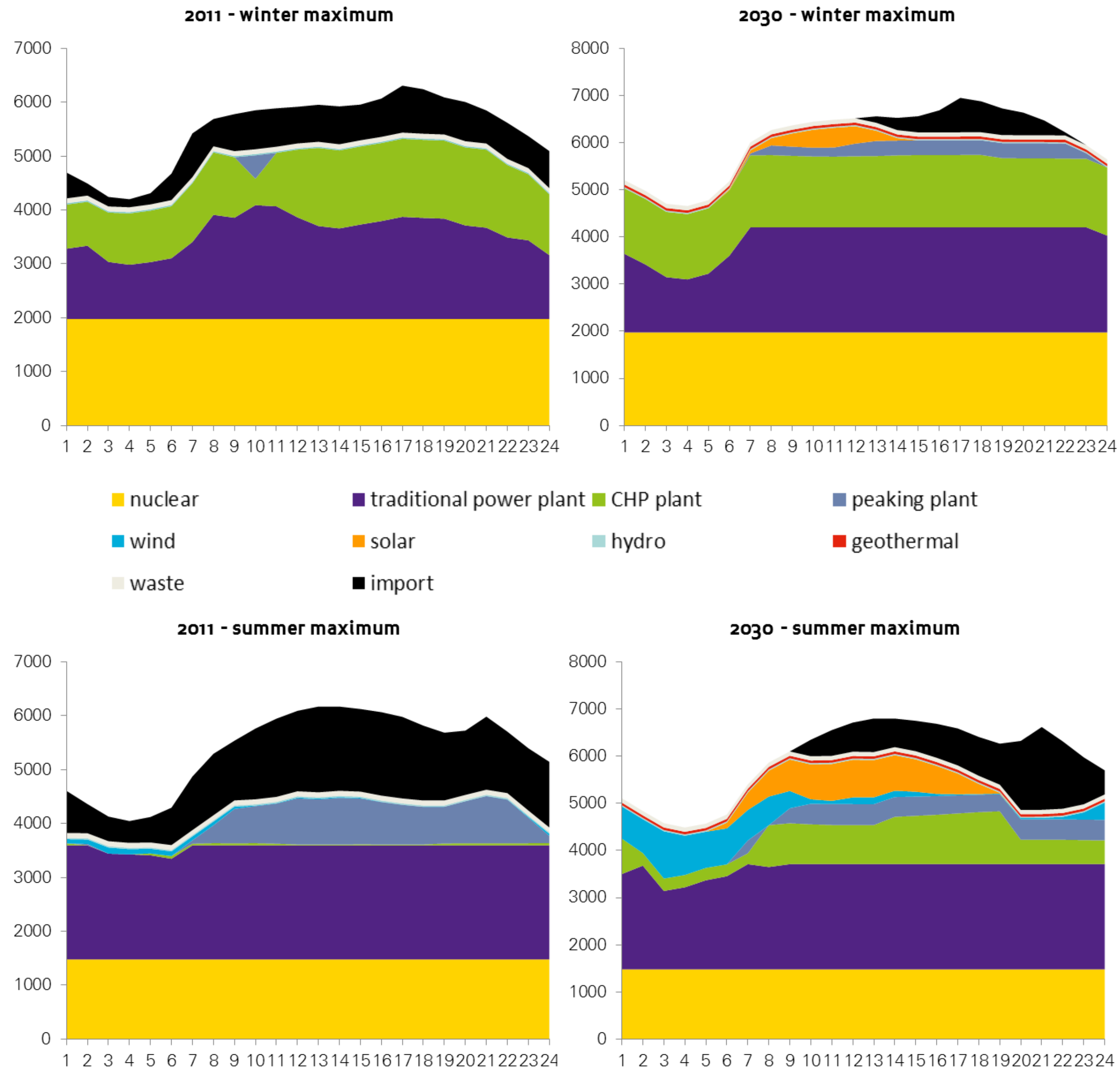

Figure 13: Electricity supply on the winter maximum and summer maximum days in 2011 and 2030. Source: EnergyPLAN modelling based on own calculations, IEA [2014], MAVIR [2014c] and Stróbl [2012].

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[73] IEA [2014]

[74] MEKH, MAVIR [2014]

close to 5% of the demand while import covered almost 14% (Figure 14).

In the model for 2030, however, there is 2800 MW of wind energy capacity, and on that day it will assure such a volume of wind energy production that, aside from Paks, almost all other power plants will be shut down to leave room for renewable production. Naturally, at such times CHP plants will enjoy priority over traditional power plants because, wind or not, the December heat demand must be met – fortunately the sunshine in the morning helps with that.

Thanks to the windy weather, in contrast with 2011, on this day no electricity would need to be imported and wind would cover 27% of the daily electricity demand. This would create significant savings for the country in natural gas, coal and biomass, which in turn would help improve the air quality in a lot of communities.

5.3. It could get better than this!

Above we looked at a scenario which would be realistic as an alternative to Paks II, in the Hungarian environment.

We tried to set renewable targets that represent significant improvement but are also realistically achievable in light of past Hungarian and international renewable trends. It can be regarded as a 'green baseline' scenario.

If, however, a supportive and promotive, rather than merely adequate, environment (political will, regulatory, economic and social framework) could be created in the near future to advance the spread of renewables and the acceleration of technological change, even more substantial renewable capacities would be available in 2030, covering more than 30% of our electricity production.

The use of fossils could be reduced even further if the first local or regional smart systems or the first forms of demand-side management were to be implemented at a substantial scale by 2030.

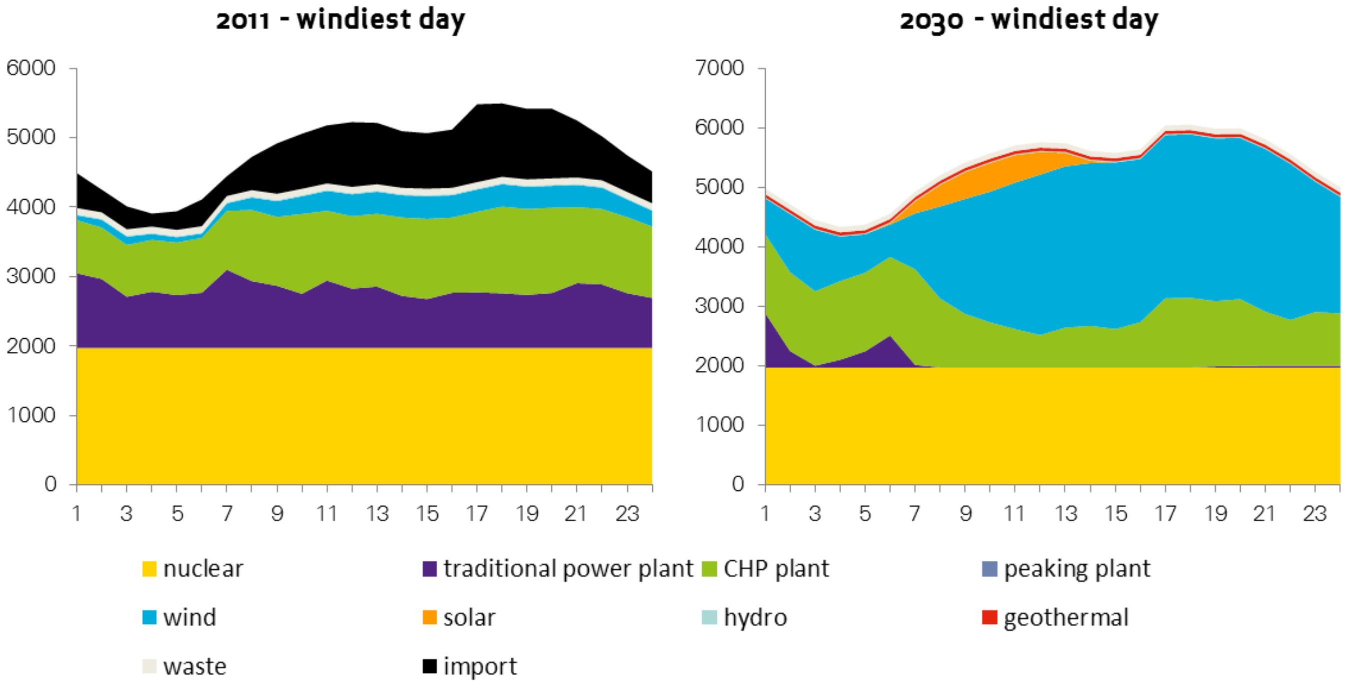

Figure 14: Electricity supply on the windiest days of 2011 and 2030. Source: EnergyPLAN modelling based on own calculations, IEA [2014], MAVIR [2014c] and Stróbl [2012].

6. NEXT STEPS

6.1. Design of the necessary conditions

Whether we aim for the 'green baseline scenario' presented above or a more radical technological change, alterations are needed on a number of points both in our approach to the issue of energy and in the regulatory background. The speed and success of implementation thus depends on the following (inter alia):

- political support;
- new renewables regulations;
- simplification of the authorisation process and other necessary legal changes (e.g., the clarification of the concept of community energy production);
- awareness raising campaigns about potential investments in renewables and energy efficiency;
- support to renewable-based and/or energy saving investments by households and businesses, a system of tendering procedures;
- pilot projects for smart energy systems, smart households, local or regional energy supply chains;
- support to related research (e.g., into the most appropriate energy storage solutions in Hungary);
- the optimal development of the electricity grid, etc.

The clarification and elaboration of the above options and the necessary steps (such as the details of the Hungarian renewable regulatory and support system) would be a very important next step, which would increase the expected rate of development of Hungarian renewable capacities. These are not only preconditions for the vision outlined by Energiaklub: the introduction of the renewable support system (METÁR) is still to be seen, and this has hindered the implementation of renewable-based projects for years.

6.2. Comments are welcome

We intended our alternative vision mainly as a discussion paper, partly because of the limited time and resources that were available to us. We also realised that as an independent non-governmental organisation it is not our job to come up with a complex national energy strategy covering all areas in detail. Such a document could be created only in the framework of a broad professional and public dialogue, involving all stakeholders, professional bodies and NGOs, academics, practical-minded businessmen, politicians and laymen.

As the first step of the hopefully ever broadening professional and public consultation, we presented our alternative vision in a conference on 20 January 2015. We are looking forward to feedback primarily from professional bodies, experts and academics. The comments, recommendations and critical remarks will be incorporated in the second, updated version of the vision, which will also be the basis for financial calculations.

6.3. And how much will this cost?

The computer model described above had the novelty that we used EnergyPLAN to demonstrate: from a technological aspect, the alternative vision of Energiaklub is practicable even in an hourly breakdown. But the next question arises naturally: how much will this cost?

To be able to answer this question, we will subject the second version, to be developed based on the feedback from experts and the updating and adjustment of the model (probably using a new version of EnergyPLAN), to a financially focused examination. EnergyPLAN can optimise the operation of the input energy vision from two aspects: technology (least possible resources used) or financial (lowest possible cost).

The investment costs of the various renewable sources of energy, the various energy conversion costs, the operating and maintenance costs of existing and new power plants, the expected world market price of fuels - these are some of the many indicators that we will examine and model for our vision in the project to be launched in spring, in cooperation with academics from the Corvinus University.

7. CONCLUSION

Paks II does have an alternative. An alternative that really decreases dependence in terms of both energy and politics because it does not make us vulnerable to any country.

And this alternative is workable. At least if we can move with the times and think in new ways about the mode of generating our everyday energy.

If we can appreciate that the issue of energy management is closely related to the position, problems and opportunities of power, democracy, poverty, agriculture, a healthy environment, transport and well-being in general, we can realise that the issue of Paks II is much more than the issue of the power plant itself. Paks II shows the direction we want to move and the way we want to think in the forthcoming decades.

The vision of Energiaklub is only one of many – therefore we do have a choice. This is not a choice between secure electricity supply and Paks II but between Paks II and the other options, one of which we have summarised above. We hope that in the near future we will learn as much as possible about the detailed of as many power policy and supply alternatives as possible, including Paks II.

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9. REFERENCES

Ámon, Ada – Kardos, Péter – Kazai, Zsolt – Perger, András – Tóth, Nelli (2006): Magyarországi fenntartható energiastratégia. Energiaklub, Budapest, 2006.

Barta, Judit – Biró, Péter – Hegedűs, Miklós – Kapros, Zoltán – Unk, Jánosné (2011): A megújuló energia hasznosítási cselekvési terv hatásai a hazai villamos energia piacra. Energiapolitikai Füzetek Issue No. XXIV, GKI Energiakutató és Tanácsadó Kft., Budapest, 2011.

Bartholy, Judit – Breuer, Hajnalka – Pieczka, Ildikó – Pongrácz, Rita – Radics, Kornélia (2013): Megújuló energiaforrások. ELTE TTK FFI Department of Meteorology, Budapest, 2013.

Büki, Gergely – Lovas Rezső (2010): Megújuló energiák hasznosítása. Köztestületi Stratégiai Programok, Magyar Tudományos Akadémia, Budapest, 2010.

Hewicker, Christian – Hogan, Michael – Mogren, Arne (2011): Power Perspectives 2030 – On the road to a decarbonised power sector. European Climate Foundation, 2011.

Csokonyai, Tamás (2013): Épülettipológia a hazai lakóépület-állomány energetikai modellezéséhez - Háttértanulmány a Nemzeti Épületenergetikai Stratégiához. Presentation, 18 April 2013.

Danish Ministry of Climate, Energy and Building (2011): From coal, oil and gas to green energy (website), 2011. http://www.kemin.dk/en-us/newsandpress/news/2011/sider/energystrategy2050.aspx

Connolly, David – Vad Mathiesen, Brian – Østergaard, Poul Alberg – Møller, Bernd – Nielsen, Steffen – Lund, Henrik – Trier, Daniel – Persson, Urban – Nilsson, Daniel – Werner, Sven (n.d.): Heat Roadmap Europe 2050 – First pre-study for EU27. Aalborg University and Halmstad University, Brussels,

Die Bundesregierung (2010): Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung.

Energy Consumption and CO2 Emissions. OECD/IEA, Paris, 2012.

EurObserv'ER (2009): Photovoltaic Energy Barometer 2009.

EurObserv'ER (2014a): Photovoltaic Barometer.

EurObserv'ER (2014b): Wind Energy Barometer.

Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. http://europa.eu/legislation_summaries/internal_market/single_market_for_goods/construction/en0021_en.htm

Eurostat (2014): Energy dependence; Supply, transformation, consumption - all products - annual data; Share of energy from renewable sources data tables

EWEA (2010): Cumulative installed capacity per EU Member State 1998–2009 (MW). European Wind Energy Association, 2010.

EWEA (2011): EU Energy Policy to 2050: Achieving 80–95% emissions reductions. A report by the European Wind Energy Association. Brussels, 2011.

Factor 10 Institute http://www.factor10-institute.org

Fischer, Anita – Hlatki, Miklós – Mezősi, András – Pató, Zsuzsanna (2009): Geotermikus villamosenergia-termelés lehetőségei Magyarországon. Occasional Paper. Regional Centre for Energy Policy Research, Corvinus University of Budapest, 2009.

FŐTÁV (2014): Hourly data for the district heating system of Budapest Kelenföld in 2011. Data supplied by György Sigmond (MaTáSzSz) with the consent of FŐTÁV Zrt.

Fülöp, Orsolya (2011): NegaJoule2020 - Energy efficiency potential of Hungarian residential buildings. Energiaklub, 2011. Available at: http://www.energiaklub.hu/en/publication/negajoule2020

Fülöp, Orsolya (2013): Energy efficiency potential of public educational and office buildings. Energiaklub, 2013. Available at: http://www.energiaklub.hu/en/publication/energy-efficiency-potential-of-public-school-and-office-buildings

Fülöp, Orsolya – Kun, Zsuzsanna (2014): Lakossági Energiahatékonysági Barométer 2014. Energiaklub, 2014. Available at: http://energiaklub.hu/publikacio/energiahatekonysagi-barometer-2014

Fülöp, Orsolya – Varga, Katalin (2013): Renewable energy potential in residential buildings. Energiaklub, 2013. Available at: http://www.energiaklub.hu/en/publication/renewable-energy-potential-in-residential-buildings

Harmat, Ádám (2013): A szilárd biomassza alapú kiserőművek elterjedési feltételei, különös tekintettel Magyarországra. Thesis. University of Debrecen, Faculty of Science and Technology, Pilisvörösvár, 2013.

Lund, Henrik (2010): Renewable Energy Systems: The Choice and Modeling of 100% Renewable Solutions. – Academic Press (Elsevier), USA, 2010.

Lund, Henrik (ed.) (2011): Coherent Energy and Environmental System Analysis. Department of Development and Planning, Aalborg University

IEA (2014): Statistics for Hungary http://www.iea.org/countries/membercountries/hungary/statistics

IEA, UIC (2012): Railway Handbook 2012:

Van De Putte, Jan – Short, Rebecca (2011): Hálózatok harca – 2011. évi jelentés. Published by Greenpeace Hungary based on Battle of the Grids, a publication of Greenpeace International, Budapest, 2011.

Kádár, Péter – Lovassy, Rita (2012): Spatial load forecast for Electric Vehicles. In: Logistics and Industrial Informatics (LINDI), 2012 4th IEEE International Symposium, pp.163-168, 5-7 Sept. 2012

KPMG (2010): A biomassza, mint erőművi tüzelőanyag keresletének, kínálatának valamint árának 2010-2020 időszakra vonatkozó éves előrejelzése. Report. KPMG Advisory, Energy and Utilities, 2010.

KSH (2014): KSH annual data series, data tables 3.8.1-2, 5.7.2-4.

MAVIR (2013a): A Magyar Villamosenergia-rendszer fogyasztói igényeinek előrejelzése 2013. Magyar Villamosenergia-ipari Átviteli Rendszerirányító ZRt., Budapest, 2013.

MAVIR (2013b): A Magyar Villamosenergia-rendszer közép- és hosszú távú forrásoldali kapacitásfejlesztése 2013. Magyar Villamosenergia-ipari Átviteli Rendszerirányító ZRt., Budapest, 2013.

MAVIR (2014a): A Magyar Villamosenergia-rendszer fogyasztói igényeinek előrejelzése 2014. Magyar Villamosenergia-ipari Átviteli Rendszerirányító ZRt., Budapest, 2014.

MAVIR (2014b): A Magyar Villamosenergia-rendszer közép- és hosszú távú forrásoldali kapacitásfejlesztése 2013. Magyar Villamosenergia-ipari Átviteli Rendszerirányító ZRt., Budapest, 2014.

MAVIR (2014c): Turnover figures of the Hungarian electricity system. Data published on the MAVIR website. Available at: http://mavir.hu/web/mavir/ver-forgalmi-adatok

MEH (2009): A magyar villamosenergia-rendszerbe illeszthető szélerőművek mennyisége.

MEKH (2013): Beszámoló a megújuló alapú villamosenergia-termelés, valamint a kötelező átvételi rendszer 2012. évi alakulásáról.

MEKH, MAVIR (2012): Statistics of the Hungarian electricity system for 2011.

MEKH, MAVIR (2014): Statistics of the Hungarian electricity system for 2013.

Munkácsy, Béla (ed.) (2011): Erre van előre! Egy fenntartható energiarendszer keretei Magyarországon – Vision 2040 Hungary 1.0. Szigetszentmiklós: Környezeti Nevelési Hálózat Országos Egyesület, 2011.

Munkácsy, Béla (ed.) (2014): A fenntartható energiagazdálkodás felé vezető út: Erre van előre! – Vision 2040 Hungary 2.0. ELTE TTK, Department of Environ mental and Landscape Geography, Környezeti Nevelési Hálózat Országos Egyesület, Budapest, 2014.

Munkácsy, Béla – Sáfián, Fanni (2011): A Vision 2040 Hungary energia-forgatókönyv által felvázolt jövőkép, In: Munkácsy, Béla (ed.): Erre van előre! Egy fenntartható energiarendszer keretei Magyarországon – Vision 2040 Hungary 1.0. Szigetszentmiklós: Környezeti Nevelési Hálózat Országos Egyesület, 2011. pp. 114-116.

NFM (2011): Hungary's renewable energy utilisation action plan.

NFM (2012): National Energy Strategy 2030. Ministry of National Development, 2012.

NFM (2013): National Transport Concept. Discussion paper. Stratégia Konzorcium, 2013.

Paár, István – Szoboszlay, Miklós (2013): NATIONAL TRANSPORT STRATEGY (NTS) Transport Energy-efficiency improving Action Plan 2013–2020 (2050). Stratégia Konzorcium, 2013.

PwC (2012): A look into the future of e-cars: The expected development of the electric car segment in Hungary. PricewaterhouseCoopers Kft, 2012.

PYLON (2010): Magyarország 2020-as megújuló energiahasznosítási kötelezettség vállalásának teljesítési ütemterv javaslata – Műszaki-gazdaságossági megújuló energiaforrás potenciál vizsgálata, a célkitűzés teljesítésére vonatkozó NCST bontása szerinti forgatókönyvek. Volume C. PYLON Kft., Budapest, 2010.

REKK (2011): Economic impact assessment of the National Energy Strategy 2030. Regional Centre for Energy Policy Research, Budapest, 2011.

Sáfián, Fanni (2012): A fosszilisektől a megújuló energiaforrásokig – a technológiai váltás térbeli vonatkozásai és a hazai energiarendszer modellezése az EnergyPLAN szoftverrel. Thesis. Eötvös Loránd Tudományegyetem, Budapest, 2012.

Severnyák, Krisztina – Fülöp, Orsolya (2013): Épületenergetikai követelményértékek optimalizálása. Energiaklub, 2013. Available at: http://energiaklub.hu/publikacio/energetikai-koltsegek-optimalizalasa

Stróbl, Alajos (2012): A magyar villamosenergia-ellátás előző évi változásainak elemzése, különös tekintettel a kapacitások változására. Research paper. MAVIR – PÖYRY-ERŐTERV, 43 p.

Teske, Sven – Schäfer, Oliver – Zervos, Arthouros (2007): Energia[forradalom]: A fenntartható energiagazdálkodás lehetőségei Magyarországon a 21. században. Greenpeace Central and Eastern Europe, Greenpeace Magyarország Egyesület, Veszprém, 2007.

Teske, Sven – Stoll, Barbara – Zervos, Arthouros – Muth, Josche (2011): ProgresszívEnergia[forradalom]: A fenntartható energiagazdálkodás lehetőségei Magyarországon. Greenpeace International, European Renewable Energy Council, Budapest, 2011.

Szajkó, Gabriella (research man.) (2009): Erdészeti és ültetvény eredetű fás szárú energetikai biomassza Magyarországon. Occasional Paper. Regional Centre for Energy Policy Research, Corvinus University of Budapest, 2009.

Századvég (2012): Ágazati elemzés – Megújuló energia termelés. Századvég Gazdaságkutató Zrt., 2012.

Tóth, Péter – Csók, Levente (2014): K+F tevékenységek racionalizálása, ágazati összehangolása: Kutatóközpont stratégiájának létrehozása – WIND technologies. Széchenyi István Egyetem, Műszaki Tudományi Kar, Környezetmérnöki Tanszék, 2014.

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11. ANNEX

1. Annex : Detailed list of power plants in Energiaklub's vision for 2030, compared with capacities in 2011.

		CAPACITY		EFFICIENCY			ENERGY PRODUCTION		PRIMARY ENERGY USED				
		2011	2030	Electricity	Heat	Total	Electricity	Heat	Coal	Oil	Natural gas	Other[1]	Total
		MW	MW	%	%	%	TWh	PJ	PJ	PJ	PJ	PJ	PJ
0	Paks nuclear power plant	2000	2000	31.0	0.3	31.0	15.0	0.5	0.0	0.0	0.0	164.0	164.0
4	Dunamenti Erőmű	1929	408	54.0	0.0	54.0	1.3	0.0	0.0	0.0	8.0	0.0	8.0
5	New OCGT units		500	30.9	0.0	30.9	0.0	0.1	27.6	0.1	0.6	2.9	31.2
4	Mátrai Erőmű	950	475	35.3	0.3	35.6	3.1	0.0	0.0	0.0	0.0	0.0	0.0
X	Tisza II. Erőmű	900											
2	Gas engines	509	600	34.2	43.8	78.0	2.6	1.0	0.0	0.0	8.6	0.0	8.6
4	Gönyűi Erőmű	433	433	54.7	0.0	54.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0
4	Csepeli Erőmű	410	410	50.2	11.6	61.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0
2	Gas turbines (GT and CCGT)	257	340	29.3	46.6	75.9	1.7	1.8	0.0	0.0	3.3	0.0	3.3
X	Oroszlányi Erőmű	240											
X	Tiszapalkonyai Erőmű	200											
3	Kelenföldi Erőmű	196	186	19.9	54.7	74.6	0.2	0.2	0.0	0.0	0.3	0.0	0.3
X	Lőrinci Erőmű	170	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	Steam turbines	168	50	24.0	33.6	57.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
1	Pannon Erőmű	132	85	10.9	60.6	71.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
X	Bakonyi GT Erőmű (BVMT)	120											
X	Litéri GT Erőmű	120											
X	Sajószögedi GT Erőmű	120											
3	Kispesti Erőmű	114	114	32.5	54.7	87.2	0.2	1.0	0.0	0.0	2.4	0.0	2.4
3	Újpesti Erőmű	110	110	33.7	54.7	88.4	0.2	3.1	0.0	0.1	6.1	0.0	6.2
1	Ajkai Erőmű	102	89	9.2	51.0	60.1	0.1	12.0	0.0	0.0	27.4	0.0	27.4
3	Debreceni Erőmű (DKCE)	95	95	34.5	41.7	76.2	0.2	9.5	0.0	0.0	20.4	0.0	20.4
1	ISD Power (Dunaújváros)	69	65	7.5	50.0	57.5	0.1	1.4	0.0	0.6	3.6	0.0	4.2
2	Old and new biogas power plants	14	350	27.0	57.0	84.0	0.8	12.1	0.0	0.0	0.0	20.4[2]	20.4
2	Solid biomass	105	825	33.0	51.0	84.0	2.2	5.8	0.0	0.0	10.3	0.0	10.3
	Wind turbines	329	2800	99.2	0.0	99.2	5.4	0.0	0.0	0.0	0.0	0.0	0.0
	Photovoltaic	1	1400	1.0	0.0	1.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0
	Geothermal power plants	0	67				0.5	0.0	0.0	0.0	0.0	0.0	0.0
	Hydroelectric plants	52	66	97.2	0.0	97.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	Waste incinerators	27[3]	47	46.1	22.8	68.9	0.8	0.1	0.0	0.0	0.0	1.7	1.7
	Large power plants total	8578	5020	28.5	27.5	56.1	23.1	27.8	27.6	0.8	68.8	166.9	264.1
	Small power plants total	1294	6495	45.9	27.6	73.5	15.9	20.8	0.0	0.0	22.2	22.1	44.3
	Hungarian power plants total	9872	11515	37.2	27.6	64.8	39.0	48.6	27.6	0.8	91.0	189.0	308.4

Notes:

The numbers in the first column denote the power plant groups required for uploading into the software:

0	Nuclear power plant
1	Primarily heat-generating plant (works as a boiler in the model)
2	Small CHP plants
3	Large CHP plants (generally above 50 MW)
4	'Traditional' power plants with electricity generation only (no heat generation in the model)
5	Peaking power plants

Footnotes:

1 Other fuel: nuclear, biomass, waste.
2 Biogas plants use biogas but the software calculates this together with natural gas consumption (in the report, however, this figure is included under renewables).
3 Waste incineration: the year 2011 figure covers organic waste only. In the 2030 model half of the energy from waste incineration is generated from renewable sources, the other half from fossils.

Sources:

- List of power plants and capacities for 2011: Stróbl [2012].
- Capacities and detailed specifications of fossil fuel plants (except for Mátrai Erőmű, new OCGT units): MAVIR [2014b] (by the combination of scenarios A and B of MAVIR)
- Capacities and detailed specifications of renewable power plants, the Mátrai Erőmű and new OCGT units: own calculations of Energiaklub (using the sources indicated in Section 4.2.), MAVIR [2014b], Stróbl [2012].

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