Perspectives of Renewable Energy in the Danube Region

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Pécs, 2015

The Perspectives of Renewable Energy in the Danube Region Conference (26–27 March 2015) and this book of proceedings were financed by the ***Deutsche Bundesstiftung Umwelt (DBU)*** and co-organised by the Wuppertal Institute, the Institute for Regional Studies of CERS HAS (with its own contribution and partial scientific support from OTKA – Hungarian Scientific Research Fund grant #NK 104985: *New driving forces of spatial restructuring and regional development paths in Eastern Europe at the beginning of 21st century*) and the Regional Committee of Pécs, HAS.

Peer reviewers: László Berényi, Nikolett Deutsch, István Fodor, Willington Ortiz,
Éva Pintér, Gábor Pintér, Damir Šljivac, Márta Somogyvári, Dobi Ildikó Wantuchné

ISBN 978 963 9899 91 9

Technical editor: Ilona Strasserné Csapó
Printed in Hungary by Molnár Nyomda Ltd.

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Preface

Diversity and commonality exist simultaneously in the Danube Region. Along its path from the Black Forest into the Black Sea, the Danube shapes the geography of south-eastern Europe with an outstanding diversity of landscapes. Similarly, throughout the Danube basin a striking cultural diversity has been shaping the socio-political landscape of the region, which today finds its most basic expression in the country borders of thirteen nation states: Germany, Austria, the Slovak Republic, the Czech Republic, Hungary, Slovenia, Croatia, Serbia, Bosnia and Herzegovina, Montenegro, Romania, the Republic of Moldova and Ukraine.

However, commonality sits alongside this diversity; if nothing else because of the common waters that support life throughout the whole Danube basin. On a political level, the European Union Strategy for the Danube Region provides good examples of common challenges and opportunities that the Danube Region nations face for ensuring sustainable socio-economic development [COM(2010)715], of which energy is one of the issues highlighted. Energy production in the Danube Region is predominantly based on fossil energy sources, which contribute to climate change, endanger the ecosystem and lower the quality of life. The large-scale use of nuclear energy passes the problem of nuclear waste to future generations and exports the heavy and dangerous externalities of uranium mining to countries with low environmental awareness, such as Russia, Ukraine and Kazakhstan. Moreover, most of the national energy systems in the region are highly dependent on external energy resources which, in turn, underlines the region's vulnerability to periodic crises and geopolitical shifts. Although the share of renewable energy sources (RES) in final energy consumption has grown steadily in the last decade, the national energy strategies in the Danube Region are still mainly based on fossil and nuclear sources.

Against this background, the Hungarian Academy of Sciences and the Wuppertal Institute for Climate, Environment and Energy initiated the project "Perspectives of Renewable Energy in the Danube Region", which was financially supported by the Deutsche Bundesstiftung Umwelt DBU (German Federal Environmental Foundation). The overarching goal was to provide a platform for international and multidisciplinary discussions on the challenges and opportunities for renewable energy sources in the Danube Region as a central option in the transition towards a post-carbon and post-nuclear era. The project comprised two main elements: a preparatory workshop and an international conference. The workshop was organised in order to establish the main constitutive aspects of the problem and took place at the Institute for Regional Studies at the Hungarian Academy of Sciences in Pécs, Hungary on 26 September 2014. It brought together 35 researchers with diverse perspectives from seven Danube Region countries working in the field of energy. Based on the outcome of the workshop, a call was launched inviting scientific contributions offering valuable insights on the challenges and opportunities for renewable energy sources as an option for energy transition in the Danube Region. The contributions (in the form of abstracts) were evaluated and the researchers who submitted the most interesting contributions were given the opportunity to present and discuss their studies at the international conference, which took place in Pécs on 26 and 27 March 2015.

This book is a tangible product of the discussion process initiated by the project, collating the contributions made by experts from different backgrounds who shared their work at the conference. The book can be understood in terms of an analytical exercise, gradually breaking down the status and dynamics of renewable energy in the Danube Region into more specific issues. This analytical aim is reflected in the structure of the book, which follows the structure of the conference.

The book opens with an introductory paper from Professor Márta Somogyvári, who proposes examining historical energy transitions in order to establish categorisations that can help us to grasp the current dynamics in the energy systems of the Danube Region. Her analysis illustrates, on the one hand, the disparities among the energy transition processes in the region: appreciable towards the 'centre' (e.g. Germany); almost non-existent towards the 'periphery' (e.g. Serbia). On the other hand, it suggests that "the main inhibitor(s)" today might be found in the political economy of the process rather than in the mere technical viability of the transformation. Professor Somogyvári's contribution immediately provides strong indications of the need to approach the topic from a system perspective, i.e. to consider the broader (existing) socio technical energy systems, where renewable energy dominance is expected to emerge. Such energy systems comprise different (non-technical) domains, such as politics, economy and society in general, but also include physical (e.g. power grid and gas networks) and non-physical (e.g. cognitive paradigms and institutional arrangements) infrastructures, which ensure the proper function and maintenance of the systems.

The first part of the book presents contributions which aim to understand the current and future role of renewable energies as components of broader energy systems on different geographical scales, or by considering their interactions with the social or economic domains. Papers relating to those subjects are divided into three sections: "Systemic Components and Constrains", "Social Domain" and "Economic Domain". In contrast, the second part of the book is dedicated to exploring the particularities of renewable energy resources in the Danube Region and contains five sections: Hydro Energy, Wind, Geothermal, Solar and Biomass Resources. The majority of the studies in those five sections aim to provide responses to the question of how specific renewable energy potentials in the Danube Region can be harnessed in an effective and sustainable way.

The first section ("Systemic Components and Constrains") is opened by Professor Tamás Katona's critical analysis of the existing (physical) infrastructure in Europe, particularly the power generation and transmission infrastructure. His analysis suggests that the current infrastructure is "hindering the development of the integration of renewable energy sources". He also points at the huge investment in power generation and transmission required in Europe during the next decade, which does not necessarily emerge from the need for energy transition but rather from the aging power infrastructure in most European countries. The study by Mathis Buddeke, Christine Krueger, Arjuna Nebel and Frank Merten complements this European perspective by investigating the capability of power storage, demand side management and international grid exchange to balance the residual power demand in Europe in a future scenario with a high penetration of renewable energies. Their results underline the need for the integration of European power systems, as well as for the expansion of the grid, in order to effectively manage high shares of renewable power. Jenö Zsolt Farkas, Edit Hoyk and András Donát Kovács discuss the options and constrains of middle-sized Hungarian cities as places for driving the transition towards low carbon energy systems. They find that policies at national level have a strong influence on local considerations and, although renewable energies are often components of cities' climate protection strategies, Hungarian national energy policy is mainly focused on the further development of nuclear power. Against this background, local actors often put greater emphasis on energy efficiency measures, which appear to be more practical at local level from a political and financial perspective. Closing this section, Danijel Topic, Anton Spajic, Stanislav Vezmar and Damir Sljivac provide an overview of the state and potentials of renewable energy at a sub-regional level. Their review covers the Croatian Danube Region, which includes the Vukovar-Sriem and Osijek-Baranya counties.

The "Social Domain" section gathers approaches related to the topic from the social sciences (with the exception of economics) and fully recognises that methods, concepts and topics from the social sciences "remain underutilized, and perhaps underappreciated, in contemporary energy studies research" (Sovacool 2014). The section opens with a contribution from László Berényi, who puts forward and discusses factors that can be used to assess the social aspects related to the increasing penetration of renewable energies. Two papers follow this contribution, both of which use the theory of environmental modernisation as their conceptual framework. Based on his analysis, Dragos Constantin Sanda suggests that the increasing penetration of renewable energies in Europe – and particularly in Romania – are already positive signs of the viability of environmental modernisation. Alexandra Luana Sanda comes to a similar conclusion in her paper, although her analysis focuses on the dynamics of the "green" labour market, which is linked to the growing renewable energy sector.

Contributions in the "Economic Domain" section offer insights into the political economy of renewable energies in the Danube Region. The section begins with a paper from Nikolett Deutsch and Éva Pintér, who propose a framework for analysing the market competitiveness of renewable energies. They organise the broad set of influential factors into four categories of "barriers": political and legal, technological, social and market. By applying their framework to renewable energy promotion policies in place in the Danube countries, they conclude that "there is no trade-off between risk and return because of the constantly changing conditions". We would add to their conclusions that their findings suggest the need for deeper analysis of the political domain and, particularly, the power structures intertwined with the energy sector in most of the Danube countries. To some extent, the paper by Sorin Cebotari complements the introductory contribution from Nikolett and Pintér, as it provides a critical analysis of the Romanian power sector. Cebotari not only presents a clear overview of the striking development of the Romanian renewable energy sector in the last decade, but his analysis also highlights the most critical issues which will determine the further development of the sector: "underdeveloped grid capacity and interconnections and the unstable/uncertain institutional arrangements". Interestingly, Cebotari's findings underline (from a country level perspective) the role that grid and market integration beyond national borders might have in a future with deeper penetration of renewables. In their contribution, Éva Szabina Somossy and Tamás Tóth consider innovative integration options, i.e "joint renewable energy support schemes". They discuss analytical models that describe the function of support schemes reaching beyond national boundaries and the expected improvements in the aggregated cost-benefit ratio. They apply those models to two potential groupings: a Central-East-Europe group including Austria, the Czech Republic, Hungary and Slovakia, and the Visegrád countries, which would combine the "Czech-Slovak-Hungarian (and perhaps Polish) market(s)". Their analysis points to "the sharing of indirect benefits (local job creation, spillover effects, local value added, etc.)" as the most difficult issue for a real application of the schemes. This, in turn, underlines the assertion that developing strong political cooperation in energy topics is a prerequisite for measures that aim to advance the integration of energy infrastructures and markets.

The part of the book dedicated to exploring the particularities of renewable energy resources in the Danube Region opens with the Istvan Szeredi's contribution on hydro energy. He initially reviews the status and potential of hydroelectric power in the Danube Region and then focuses specifically on the Hungarian case. Against a background of increasing power imports, rising demand and decreasing off-peak prices in the wholesale power market, among other factors, Szeredi's analysis provides strong arguments for allocating a significant role to hydroelectric power in the reconfiguration of the Hungarian power system, particularly for its "capability to stabilise fluctuations between demand and supply".

The section dedicated to "Wind Resources" begins with a brief overview of the penetration of wind power in the Danube countries (excluding Germany) by Ildikó Dobi Wantuch. His analysis shows that the wind power sector in most of the Danube countries is at a rather early stage, or is even, in some cases, practically non-existent – despite the fact that significant potential is recognised throughout the region. A common barrier is regulatory uncertainty for wind power investment. One prominent issue is the definition of areas available for wind power developments. Two papers in this section address this issue by applying geographical information systems and exploring the actual potential for wind power in diverse economic, technical and environmental circumstances. Nándor Csikós and Péter Szilassi propose a methodology to "locate those areas that are perfectly or moderately suitable for building wind [power capacities]". They apply their methodology to the county of Csongrád in southern Hungary. In this way, they demonstrate how the methodology is suitable for exploring how both the geographic distribution and the aggregated wind power potential are influenced when considering different definitions of buffer zones. Béla Munkácsy, Ádám Harmat and Dániel Meleg apply similar methodology in order to assess Hungary's technical wind power potential. They estimate that 19.6% of the Hungarian territory is legally available for wind power development. Moreover, Munkácsy and his colleagues propose to complement the assessment by applying a comparative analysis between Hungary and Eastern Germany in order to estimate what they call the "socio-economic" potential. Accordingly, they estimate that reaching a total wind installed capacity of 10,286 MW in Hungary by 2050 is viable. Under that scenario, only 1.1% of Hungarian territory would be used for wind power developments. Károly Tar, István Lázár and Renáta Gyarmati provide the last contribution in this section. They address the predictability issue of wind power, which is critical for the daily management of wind power capacity and ultimately for the financial performance of wind projects. Tar and his colleagues propose a statistical method to "determine the probability of increase or decrease of daily average wind speed and wind power to the next day". Their results indicate that it would be worthwhile to further develop and test the method for its application under actual operating conditions.

Annamária Nádor and Szilárd Árvay open the section dedicated to "Geothermal Resources". Based on up-to-date information they provide an overview of the potential and actual use of geothermal resources in the Danube Region. Their study clearly exemplifies the significant potential available in almost all Danube Region countries, but also illustrates the rather marginal role that geothermal energy currently plays. Nádor and Árvay also identify challenges common to most of the Danube Region countries, such as the low rate of reinjection and low thermal and utilisation efficiency (which often lead to overexploitation in the case of existing plants), but also the fragmented regulatory system, the lack of financial incentives and the need for more accurate data on geothermal resources in order to make informed decisions on the development of geothermal potentials. In the second half of their contribution, Klára Szita Tóth and Anna Vizkeleti complement this overview by discussing actual usages of geothermal resources in Hungary. Tóth and Vizkeleti describe some exemplary cases of geothermal energy applications for district heating in Hungary and provide some data on a pilot project for an enhanced geothermal power plant expected to be established in the coming years in Hungary's Southern Great Plain. In their paper, Erika Bódi, Tamás Buday, Réka Lilla Kovács, Richard William McIntosh and Miklós Kozák address the need, already mentioned, for more accurate data on interesting reservoirs. Bódi and her colleagues develop a 3D geological model for a location in Hajdúság (Eastern Hungary), which is part of the Pannonian Basin. This is a location where 24 thermal wells are used for balneological or geothermal energy extraction purposes. Their results underline the need for accurate models of the distribution of geothermal reservoirs as a prerequisite for the more efficient and more sustainable management of resources. Moreover, their observations reinforce the concern, which has already been mentioned, about the overexploitation of reservoirs in existing geothermal facilities. Examples of the utilisation of geothermal resources from the same Pannonia basin, but in this case in the Romanian Western Plain, are given by Mircea Gordan, Cristian Vancea, Cornelia Gordan, Maria Bittenbinder and Monica Costea in their contribution. They describe the main geological features and the utilisation of two fields close to Oradea, Romania. Particularly interesting is the cascade approach applied by the system installed at the University of Oradea, which contains two utilisation loops for the geothermal water. Gordan and his colleagues also report on a prototype for a thermoelectric generator that uses geothermal water and provides 30 to 50 W during operation. This micro-generation concept represents an interesting option for complementing the cascade utilisation already in place at the university. In contrast to the previous contributions, Tamás Buday, István Lázár, Gergely Csákberényi-Nagy, Erika Bódi and Tamás Tóth address the energy potentials of shallow systems. Based on meteorological data from the Renewable Energy Park in Debrecen (Eastern Hungary), which include soil temperatures at 9 different depths, Buday and his colleagues investigate the effect of solar radiation and other climatic variables on underground temperature. While the effect of solar radiation is significant in the shallow regions, the recovery effect is hardly appreciable at depths greater than one metre, which is particularly critical at the end of the cold season.

Based on their results, Buday and his colleagues suggest some practical recommendations for siting and design.

Professor Damir Šljivac opens the "Solar Resources" section by discussing the overall distribution of solar irradiation in the Danube Region. Although – in general terms – the "Danube Region lies in the area favourable for solar energy generation", Professor Šljivac emphasises that the actual usable potential depends on parameters such as "the type of technology, configuration of the energy system and the efficiency in converting the solar irradiation to electricity and/or heat". Exploring the effect of different technology types, system configurations and national regulations on the economic performance of investments in solar PV is the main aim of the contribution from Denis Pelin, Sándor Zsolt Kovács, Andrea Suvák, Damir Šljivac and Danijel Topić. They undertake a cost-benefit analysis of investment scenarios resulting from the combination of five different PV technologies, two system configurations and four countries. Not only the final figures on cost-benefit ratios, but also many of the intermediary results from their study, provide valuable data for further research and development of practical applications of PV in the countries studied: Croatia, Hungary, Serbia and Slovenia. In contrast to the techno-economic approach of Pelin and his colleagues, Lea Végh's study addresses one of the major concerns relating to large scale photovoltaic developments, i.e. the need for large areas and the potential impact on landscape fragmentation. She proposes a methodology based on geographical data in order to identify degraded areas in Hungary, where large PV developments are technically viable but would not necessarily result in negative environmental impacts. In order to refine her assessment, she proposes a definition of 'degraded sites' that considers degradation through landfill, mining and agricultural land prone to frequent inundations. The results, and particularly the methodology proposed, present promising options for further research and development in this particular field in both Hungary and the Danube Region as a whole. The section on solar resources closes with a case study on the application of solar water heating at a secondary school in Croatia. Marinko Stojkov, Krunoslav Hornung, Ante Čikić, Dražan Kozak, Damir Šljivac and Danijel Topić explore the potential reduction in natural gas consumption that can be achieved by integrating a solar water heating system with the existing central heating system. They conclude that the suggested solar thermal system could replace 23% of the school's annual gas consumption.

The section relating to "Biomass Resources" contains contributions analysing the suitability of two plants (sugar beet and reed) as primary energy sources. Laszlo Potyondi elaborates on several arguments around the suitability of sugar beet as an energy crop and discusses aspects such as the high yield of ethanol per hectare, the suitability of sub-products as animal feed and the possibility of using all or part of the plant as substrate for biogas production. Ultimately, Potyondi's analysis opens the field for further and deeper research on the role that sugar beet could play in low-carbon energy systems, i.e. the technical, economic, social and environmental aspects linked to scenarios with increasing production of sugar beet as an energy crop. Jürgen Krail, Hannes Kitzler, Georg Beckmann, Helmut Plank, Christoph Pfeifer and Doris Rixrath present a comprehensive investigation on technically viable possibilities for configuring a value-chain of reed pellets. They assert that reed pellets are suitable for domestic heating or larger district heating systems, but also note that it is preferable to use them in combination with conventional fuels. Doris Rixrath, Jürgen Krail and Arne Ragossnig complement the analysis of reed as an energy resource by analysing the market competitiveness of different value-chain configurations. To that end, they estimate the total production costs of reed-based fuels and compare them with conventional (bio)fuels. According to their estimations, the production of reed pellets can be economically competitive under current market conditions. Moreover, they note that considerable cost reductions are possible by improving the harvesting process.

If it were possible to sum up the diverse aspects and findings shared by the authors of the contributions in this book and the conference participants, the main emerging message would be that there is significant potential in the diverse conditions of the Danube Region countries and considerable knowledge about sustainable energy transitions. Many contributors agree that the main challenges are neither technical nor economic but are, in fact, institutional, due to the current status of different national energy systems which have little connection to each other. In addition, there is often limited awareness of the opportunities that the transition to sustainable energy can offer, such as improving the security and stability of national energy systems, labour markets and regional economies. Creating more opportunities to share and discuss ideas, experience and knowledge relating to common challenges will certainly help to clarify the issues and to build the knowledge base to facilitate the transition to a more sustainable energy system in the Danube Region.

Willington Ortiz Orozco, Márta Somogyvári, Viktor Varjú, Stefan Lechtenböhmer

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INTRODUCTION

The Signs of Post-Fossil Transition in the Energy Landscapes along the River Danube

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Abstract: The paper examines the differences between previous energy transitions and a possible future energy transition towards renewable energy, identifies the indicator technologies of such a transition and analyses the trends in eight Danube river countries. There are definitive signs of the transition in Germany, while Austria, with its excessive use of hydro power, is in a special situation. Some countries on the periphery have made attempts to replicate the experiences of Germany, but the same measures and structures for transition management that led to a considerable share of renewables in the central wealthy countries have not proved appropriate for the peripheral countries, due to technological, societal and political resistance.

Keywords: post-fossil energy transition, energy landscapes, energy systems, Danube river countries

1. Introduction

The driving forces of the post-fossil energy transition are unique in the history of mankind. This is the first instance of governments and groups of scientists trying to prevent not only a local and distinctly visible environmental problem, but also a future vague global climate catastrophe. The goal of this paper is to examine the energy landscapes in eight countries along the river Danube and to look for indications of this transition. The river Danube connects the core regions of Central-Eastern Europe across ten different countries. In this paper we focus on energy landscapes along the river from the source to the delta (Germany, Austria, Slovak Republic, Hungary, Croatia, Serbia and Romania), but we omit the two last border countries Ukraine and Moldova. These countries have a very short river section and it was not possible to gather reliable data for them.

2. Methods

We summarise the main points of previous energy transitions based on historic energy literature and attempt to outline the unique features of the future transition to the post-carbon era, indicating the main differences and challenges that impede the transition and highlighting technological and societal barriers related to renewable energies. With the help of statistical data we outline the energy landscapes, namely the exploitation, generation and consumption levels of fossil, nuclear and renewable energy along the river Danube, in order to find evidence of the transition.

3. Energy transitions

Previous energy transitions, i.e. the change from biomass to coal and from coal to hydrocarbon in the form of oil and natural gas, displayed certain similarities that are not evident in the suspected transition towards renewable energy. The concept of energy transition refers to the contribution of a primary energy source in the energy balance where the total energy input reaches more than 50%. This rate does not indicate the decline of former primary energy use; the data shows a continuous increase of the "old" primary energy consumption in absolute terms (Grubler 1999, Gales et al. 2007). The new primary energy source has always had a higher energy density (Smil 2008) and/or was generally applicable. The transition from firewood to coal or coal to oil entailed the change of primary energy source, new infrastructure for obtaining and transporting the primary energy source or secondary energy carrier, the development of new energy conversion technologies and the rise of new end-use technologies and appliances. The new, initially crude, imperfect and expensive technologies (Rosenberg 1994) were capable of performing particular tasks, such as water pumping via the steam engine or the delivery of an improved energy service such as lighting via gas or electricity (Fouquet 2010). The fossil-nuclear paradigm established a system with asymmetrical distribution of energy generation and energy consumption. Huge, polluting energy converting plants, which were originally established by preference outside the population centres, generate secondary energy carriers such as electricity or gasoline. The transportation infrastructure, in the form of coal and oil freight vehicles, pipelines and power transmission lines, now expand across the whole world.

The post-fossil transition displays certain unique features. The main goal is decarbonisation, i.e. the abandonment of coal, oil and natural gas in favour of primary energy sources with very low energy density. Only geothermal energy has a comparable energy density to hydrocarbons and nuclear energy, but this is the least developed renewable energy given its share in total energy input, at approximately 0.19% in 2013 (REN21). The new energy sources shaping the first steps of the transition in Europe are not always truly renewable. The classification of renewable energy accepted by the European Union includes all non-fossil and non-nuclear primary energy sources that can produce energy (EU2009). This includes primary energy sources such as various forms of biomass which are utterly unsustainable and have a significant negative impact on soil, natural ecosystems and the climate. Biomass production in large scale monocultures occupies huge areas of land and, in order to ensure high yield, fertiliser is used in massive quantities. This, combined with transportation requirements and the energy needed to convert biomass into bioenergy and biofuels, accounts for greater levels of GHG emissions in the whole biomass life cycle than in the fossil fuel combustion it replaces (Zgajewski 2014). Hydro energy satisfies the stronger definition of renewables by IEA because it is 'derived from natural processes...that are replenished at a faster rate than they are consumed' (IEA, 2014), but most of the large-scale hydro energy facilities were built as part of the fossil-nuclear paradigm and, therefore, their capacity and production cannot be classified as an indication of the transition.

The energy conversion technologies used by renewable energy facilities do not represent big changes; apart from solar cells they are mostly further developments of existing technological principles. The really new feature is electrification, i.e. the extended use of electrical energy in the cooling, heating and transportation sectors. The debate about centralised and distributed grids continues and this is one of the big issues of the transition. Grid extension plans indicate that the philosophy of centralisation is not going to change in the short term (Schaber et al. 2012).

Table 1. The main features of energy transition

	Previous energy transitions	Post-fossil energy transition
PES consumption	Old PES consumption is increasing	Decreasing and cutting old PES consumption
Density of PES	Change to higher density PES	Change to lower density PES
Infrastructure	New infrastructure (pipelines, tankers, power grid)	Keeping and extending old infrastructure (power grid, gas pipelines, transport of biomass, etc.)
Energy conversion	New energy conversion technologies (steam engine, turbines, internal combustion engine)	Partly new energy conversion technologies (solar cells, wind turbines, heat pumps)
Energy system	Centralisation	Centralisation or decentralisation, and/or distribution options
End-use appliances	New end-use appliances	Keeping old end-use appliances (electrification)
Energy services	Better, more comfortable energy services	Energy services are the same or clumsy, less comfortable
Energy price	Decreasing energy prices	Expensive

There are two factors that inhibit the penetration of the post-fossil transition. One is the quality of energy services. Previous energy transitions made everyday life and industrial production more and more comfortable by providing better energy services. This is not the case with the post-fossil transition; if we consider the universal use of electricity, there are problems not only in terms of power generation with the intermittent solar and wind energy sources, but we also face severe limitations in the transport sector by using electric vehicles. The second factor is price. Energy expenditure for a given energy service has historically followed a continuously decreasing trend (Fouquet 2010). According to the calculation methods applied to the fossil-nuclear paradigm, renewable energy is, in general, more expensive than fossil energy. In spite of this, in the power sector there are some locations where solar or wind energy exploitation has reached grid parity, even in times of low oil prices (DB, 2015).

4. Energy landscapes along the river Danube

The countries along the river Danube are heterogeneous, of different sizes and population, but there is a visible trend – as the river flows from West to East, the economic and energy indexes outline the change from the centre to the periphery. Germany and Austria have between 6 and 7 times more nominal GDP per capita than the poorest country, Bulgaria, where the GDP was 5500 EUR in 2013. The second group of three countries (Slovakia, Hungary and Croatia), led by Slovakia, produce between 1.8 and 2.5 times more GDP than Bulgaria; Romania's GDP was 30% higher and Serbia is approximately on the same level (Source: EUROSTAT). These figures represent a typical slice of Europe, with the most developed and wealthy countries at the upper river, with declining social and economic performance in the countries in the middle and poverty at the lower end of the Danube.

The trends in energy consumption show a slight decrease of 14% over the last 20 years and primary production follows the same downwards trend but with a greater decrease (28.5%) illustrating the depletion of indigenous fossil primary energy sources. The main primary energy sources are dominated in the region by the fossil-nuclear paradigm, as shown in Figure 1.

In order to establish a reliable basis for comparison between the heterogeneous countries, we will use per capita data where applicable. The differences between per capita consumption are mostly based on consumption in non-residential sectors, due to the countries' differing levels of economic and industrial development (Figure 2). The share of renewable energy in gross final consumption (including biomass and large-scale hydro) is, with the exception of Austria, very low – the average is 12%. The growth of renewable energy production between 1990 and 2013 is 359%, with a yearly average growth of 6% from the starting point in 1990 when renewable

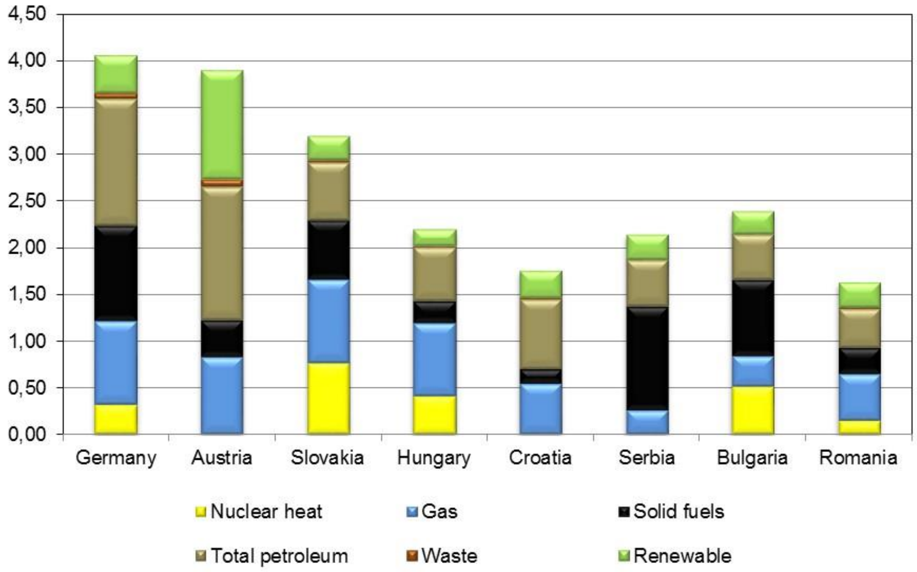

Figure 1: Gross inland energy consumption by fuel type per capita 2013

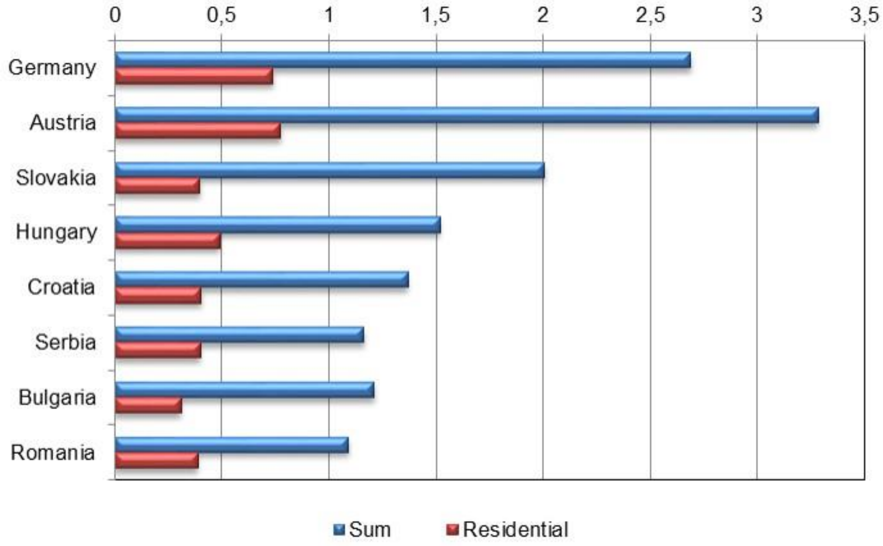

Figure 2. Final energy consumption per capita per sector

growth will not continue. Energy investments have a long-term horizon and the recent reductions in levels of support for renewable energy (Held et al., 2014) due to budget deficits following the financial crisis have had the effect of demotivating further large-scale development. The growth rate of renewables in final consumption has decreased since 2010 in all the countries in this study (Table 2).

There is a considerable gap between the 2020 target and the 2013 share of renewables in the final energy consumption in the upper river countries, i.e. Germany, Hungary and Slovakia, while the low river countries have reached their target and Bulgaria has even exceeded it.

Table 2. Share of renewable energy in gross final energy consumption and the gap to the 2020 target

Country	Average growth rate per year 2003–2013 (and 2010–2013), %		Share 2013, %	Target 2020, %	Gap in percentage points, %	Gap in thousand toe
Germany	16.0	(6)	12.4	18	5.6	15,083
Austria	4.2	(2.75)	32.6	34	1.4	429
Slovakia	6.4	(2.14)	9.8	14	4.2	603.99
Hungary	7.6	(–0.9)	9.8	14.65	4.85	935
Croatia	6.0	(6)	18.0	20	2	141
Bulgaria	8.1	(8)	19.0	16	–3	–286
Romania	6.4	(–2.14)	23.9	24	0.1	23

Source: EROSTAT

5. Electricity mix

Electricity may be the possible bridge towards the post-fossil paradigm. It is the most important energy form in modern societies. The yearly per capita consumption, as shown in Figure 3, is highest in Austria and Germany (8.9 and 7.8 MWh/a respectively) and lowest in Romania (2.97 MWh/a). The consumption in other countries varies between 4.28 and 5.38 MWh/a. The gross inland electricity consumption is based on coal and nuclear thermal power plants, with a dominance of coal in Germany, Serbia and Bulgaria, and a dominance of nuclear plants in Slovakia and Hungary. Romania has the most diversified consumption pattern with coal-nuclear-gas and large scale hydro. Croatia relies mostly on hydro energy and import. Austria's hydropower generation includes 150 large scale facilities constructed in the 1990s and the output has plateaued in recent years (Pirker 2006). The 3000 small scale hydropower facilities provide only 12.5% of the total amount of hydro electricity generated.

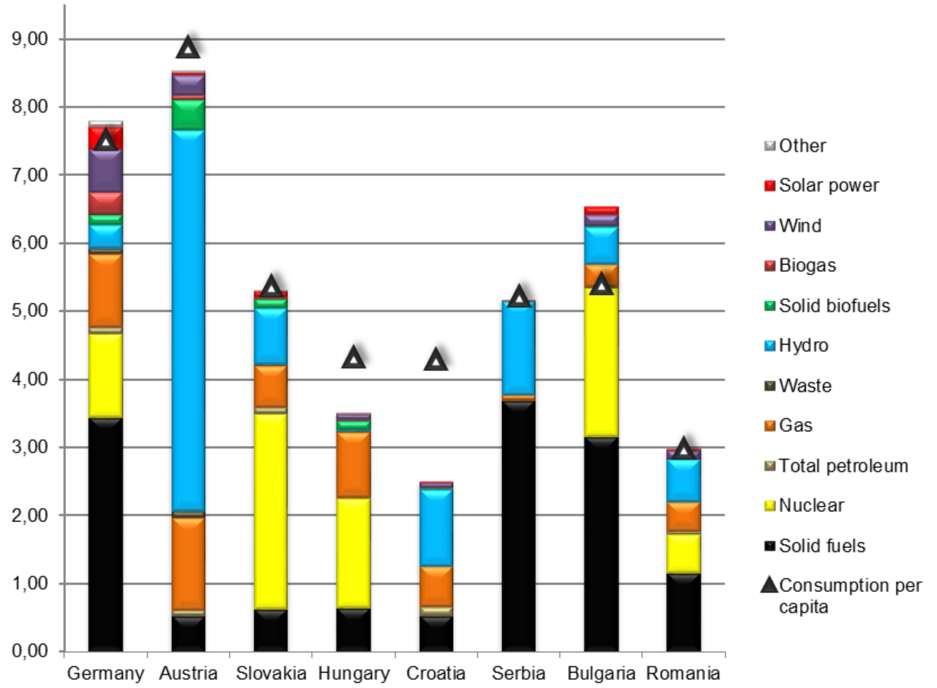

Figure 3. Gross inland electricity generation and consumption by fuel type per capita 2012
Source: EUROSTAT.

The construction of large hydropower facilities can be evaluated as part of the fossil-nuclear paradigm, as most of the hydro plants in this region were built in the last century and there are considerable barriers to installing new capacity. If we want to find the "real signs" of transition we have to focus on the new, and sometimes clumsy and inefficient, renewable technologies. Figure 4 shows the indicator technologies: solar, wind, biogas, small scale hydro and geothermal energy. This last technology can be practically ignored in these countries, although there was an installed capacity of 22.3 MW of geothermal energy in 2014 in Germany (Statista 2014). The energy efficiency measures that are incorporated in a third 2020 EU target could pave the way to using low-density energy technologies, but this will not necessarily be connected with the transition.

If we compare the share of transition indicators with the share of EU renewables, it is evident that only Germany made a considerable step towards the new energy paradigm with wind and solar power playing an important role in Germany's 18% share. The second highest is Austria, with its development of small scale hydro and wind energy. Slovakia and Hungary both have a very low share of only 2% to 3%, while in Serbia the transition technologies are non-existent. In Croatia, Romania and Bulgaria the share is between 5% and 7%. The difference between the share of EU renewables and transition indicators is considerable in countries with high hydropower generation, as shown in Table 3.

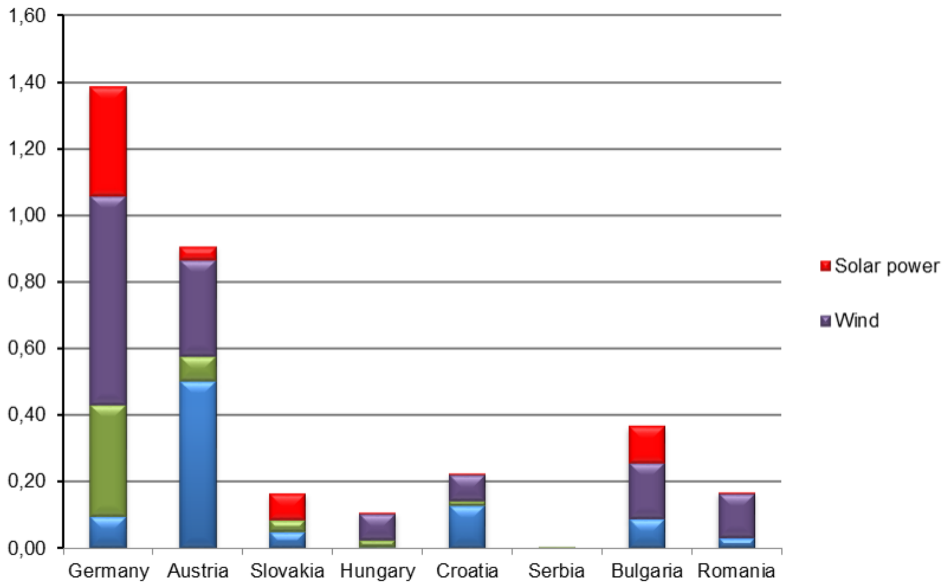

Figure 4. The production of the transition indicator renewables MWh per capita 2013
*Estimation on the base of HYDI, WSHPR 2014.
Source: EUROSTAT

Table 3. The per capita electricity consumption of EU renewables and post fossil transition indicators

	Electricity consumption per capita (MWh/a)					Difference, %
	Total	EU renewables	Transition indicator renewables	Share EU renewables, %	Share transition indicators, %	
Germany	7.52	1.85	1.39	25	18	7
Austria	8.87	6.48	0.90	73	10	63
Slovakia	5.37	1.07	0.16	20	3	17
Hungary	4.31	0.27	0.10	6	2	4
Croatia	4.28	1.23	0.22	29	5	24
Serbia	5.20	1.39	0.00	27	0	27
Bulgaria	5.38	0.8387	0.37	16	7	9
Romania	2.97	0.2621	0.16		6	3

6. Transition indicators in the heating-cooling and transport sectors

The EU 20-20-20 directive sets specific goals for the transport sector; a share of 10% is a minimum target to be achieved by all Member States (EU 2009). This is manifested mostly in the use of biodiesel and bioethanol, while the role of electricity is limited to rail transport.

The heating-cooling sector shows a huge variability. Austria uses large quantities of solid biofuel both in heat-only and in CHP plants. Heat generation is also dominated in Slovakia by solid biofuel (mostly wood). In Germany half of the renewable heat comes from renewable waste combustion. The indicator renewables in both the transport and heating-cooling sectors are negligible (Table 4).

Table 4. The share of EU renewable and indicator renewables in the transport and in the heating-cooling sector 2012, %

	Transport		Heating and Cooling		
	Total RES	There of electricity	Share of total RES heating cooling	Thereof solar heating/cooling	There of geothermal
Germany	6,30	2	11,40	0,002	0,02
Austria	7,45	3	44,90	0,68	0,07
Slovakia	5,30	2	17,33	0,22	0,004
Hungary	5,35	3	6,52	0,8	0,01
Croatia	2,15	1	1,83	–	–
Serbia	n.d.	n.d.	n.d.	n.d.	n.d.
Bulgaria	5,63	1	0,34	–	–
Romania	4,65	2	2,38	0,004	–

Source: EUROSTAT

7. Financing the transition in the electricity sector

The power sector could be the main area of transition to a post-fossil paradigm. Electricity is a universal secondary energy carrier and there is a belief that it could solve the problem of decarbonisation in most energy services. The electricity system in the river Danube countries – and across the whole of Europe – struggles with capacity and financial problems. The massive subsidies for renewable energy generation in the form of Feed-in-Tariffs expanded the power generation capacity with intermittent and highly volatile solar and wind plants. The special situation of renewables, the mandatory feed into the grid and the principle of merit order in the power exchange lowered electricity prices and decreased the profitability of the fossil-nuclear plants (Sensfuss et al. 2007). The Feed-In-Tariff loads the financial burden of the transition exclusively on the consumer, i.e. on the payer of the electricity bill. Figure 5 shows the expenditure for electricity per capita in the corresponding countries. This illustrates that the German and Austrian residential consumer spends more than double on electricity in comparison to similar consumers in other countries. The centre-periphery tendency is visible, with wealth resulting in increased electricity use, but the prices are also much higher in the frontrunner transition countries (Figure 6). The situation for companies is different, because they have the possibility to buy electricity on the liberalised market and, as shown by EUROSTAT's data, the price for medium-sized industries was in the range of 0.82-0.87 EUR/kWh in Germany, Austria and Hungary, while the highest price was identified in Slovakia (0.11 EUR/kWh) and the lowest in Serbia (0.05 EUR/kWh).

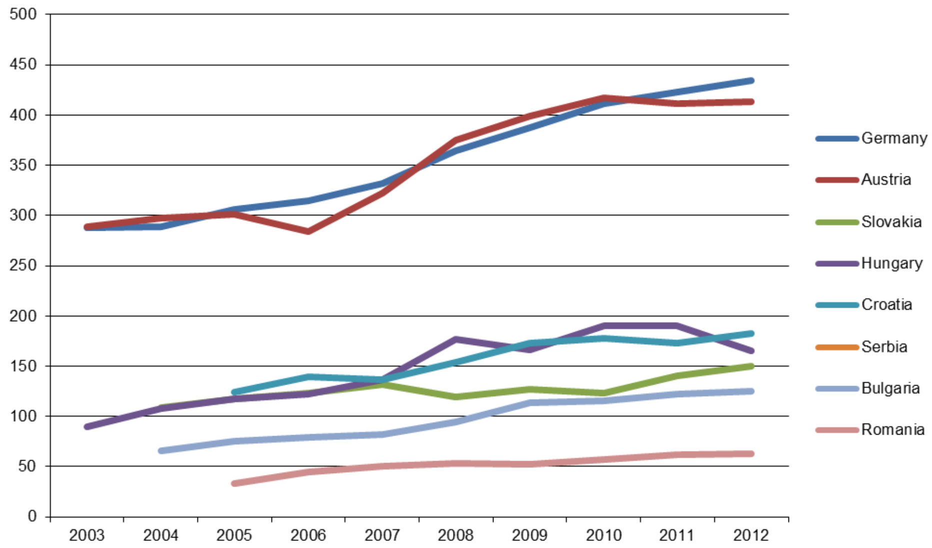

Figure 5. Expenditure for electricity
Source: EUROSTAT

At first glance it appears that it could be appropriate to raise the prices in the countries from Slovakia down to Romania in order to finance the transition by offering Feed-In-Tariffs. However, this is not a viable option in countries struggling with poverty and, additionally, the cultural heritage of socialism means cheap energy, low energy awareness, high levels of corruption and the common use of utility bill cuts as political weapons. The Bulgarian example shows that the rapid development of significant renewable energy capacity (mostly solar and wind) is possible in a country providing beneficial Feed-in-Tariffs, but the people are not willing to pay the increasing prices. This is understandable if we look at the income/expenditure data in Figure 7.

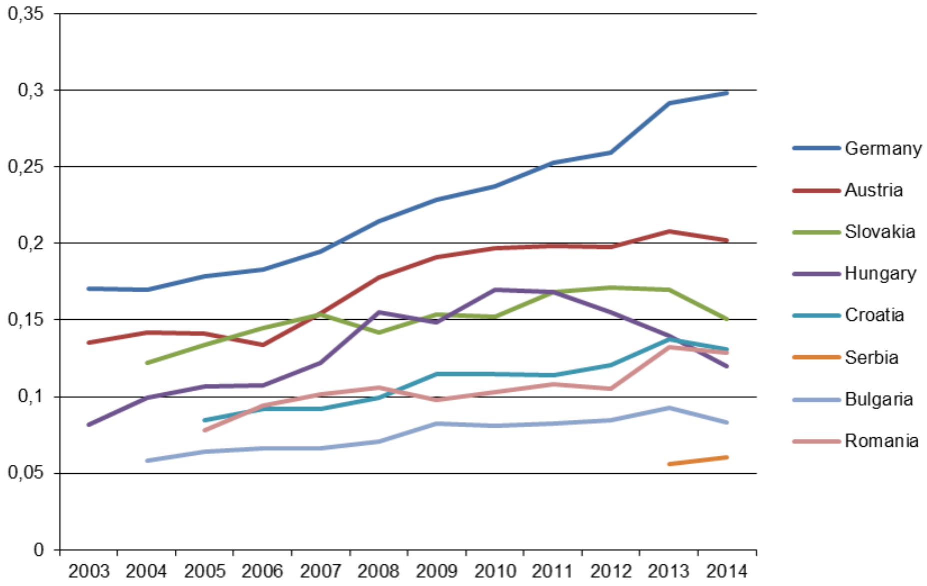

Figure 6. Electricity prices by type of user
Source: EUROSTAT

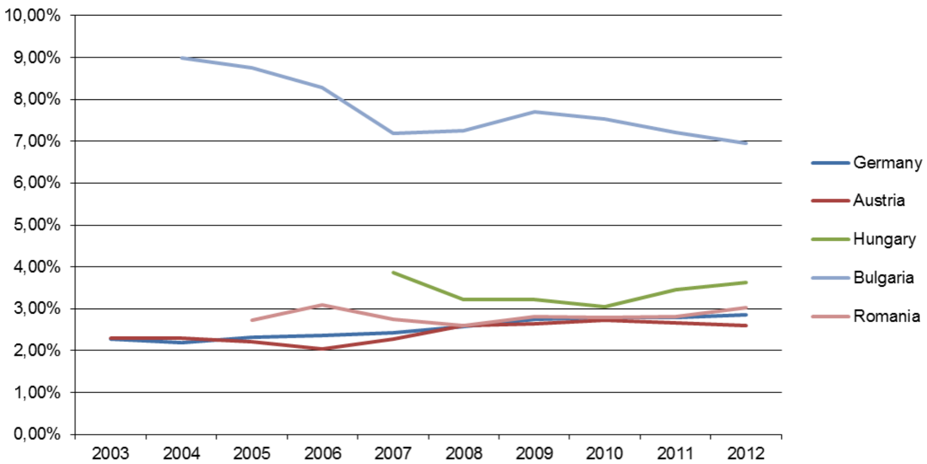

Figure 7. Ratio of expenditure for electricity and net income. Single person without children, 50% average wage
Source: EUROSTAT

The weight of electricity expenditure compared to net income falls within a similar range in Germany, Austria, Romania and Hungary, but is very high in Bulgaria. The protests against the Borisov cabinet in 2013 due to high electricity and hot water bills resulted in the government being overthrown. The automatic adoption of the Feed-in-Tariff subsidy system, combined with the mismanagement of the energy sector, affected not only the consumer but also the state-owned public power provider NEK, which was struggling with a deficit of 1.65 billion EUR in the spring of 2015 (EURACTIV, 2015). At the beginning of 2015, Bulgaria abandoned incentives for new renewable energy installations. This example shows that the methods and measures which induce the transition in developed, wealthy countries often fail in the peripheral countries.

8. Summary

Our main findings from considering the energy landscapes of the Danube river countries can be summarised as follows:

- The post-fossil energy transition is concentrated in the electricity sector; in the transport and heating sectors it is practically non-existent.
- Of all the Danube river countries, the country where we can detect definitive signs of post-fossil transition is Germany.
- The post-fossil energy transition has not yet started in the peripheral countries.
- A considerable share of nuclear energy in the electricity mix appears to be a barrier to the transition.
- The experiences of the central countries cannot be directly transferred to the peripheral countries. The technology might work, but the societal framework needs new and innovative solutions.

The challenges faced by the post-fossil transition have reached a new phase. The era of enthusiastic experimentation with new generation technology is over as, with the exception of geothermal energy, mature and reliable technology close to economic viability now exists. The outlines of new energy system designs are apparent and further innovation is mainly required in the field of energy storage. The main inhibitor to change seems to be not the technology per se, but the economic and political resistance, combined with the rigid paradigm of centralised energy systems in the minds of energy experts. In considering the Danube river countries, it should be admitted that there is considerable doubt about whether this situation can be changed in the peripheral countries in the short term as they face the joint challenges of low oil prices, increasing poverty levels and decreasing environmental awareness.

Conflict of Interest

The author declare no conflict of interest.

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SYSTEMIC COMPONENTS AND CONSTRAINS

The Role of Renewable Energy in the Energy Network System of the Danube Region

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1. Introduction

Scientists desire to decode the history. Registering what happened is not too much challenging. However, understanding why something happened is much more difficult. There are great turning points in the history, when the organisation of the societal activities and the way, how the mankind produce everything, which is needed for the life: called industrial or economic revolutions. The first total change in economic and social organization began about two hundred fifty years ago in England, when the replacement of the hand tools with power-driven machines started.

Jeremy Rifkin, one of the representatives of the technological determinism, proposed a hypothesis (see Rifkin 2005, 2011, 2012): *The great economic revolutions in history occur when new communication technologies converge with new energy systems*. Today, the Internet technology and renewable energies are beginning to merge to create a new industrial infrastructure for a Third Industrial Revolution that will change the way people will live in the twenty first century. In the coming era, hundreds of millions of people will produce their own green energy in their homes, offices, and factories and share it with each other in an "Energy Internet,"- a distributed smart grid-just like we now generate and share information online. The democratization of energy will also bring with it a fundamental reordering of human relationships, impacting the very way we conduct business, govern society, educate our children, and engage in civic life.

All human activity starts with a plan, with a vision, motivated by desire, defining what should be achieved and how. The five pillars of the Rifkin's Third Industrial Revolution are

- Shifting to renewable energy;
- Transforming the building stock of every continent smart green power plants equipped with smart appliances and smart owners, smart cities, smart countries, etc.;

– Deploying hydrogen and other storage technologies to store the intermittent energies;
– Using Internet technology to transform the power grid of every continent into an energy Internet; and
– Transitioning the transport fleet to electric plug-in and fuel cell vehicles.

Unfortunately, Europe is still lacking the infrastructure to enable renewable energy to develop in a way dreamed. The existing infrastructure is hindering the development of the integration of renewable energy sources into energy system and development of a more sustainable economy, and honest implementation of the "three-times twenty" strategy.

Here we have also to take into the account the existing differences in Europe. Part of the European countries consumes moderate amount of energy per capita. These countries need more energy for their economical development even if they will try to save every Joules of energy and use it in a rational way. Especially the electric energy consumption has to be raised in these countries (see Fig 1), since the per capita electric energy consumption is some indicator of the development. The majority of the countries in the Danube region are quite behind of Germany and Austria.

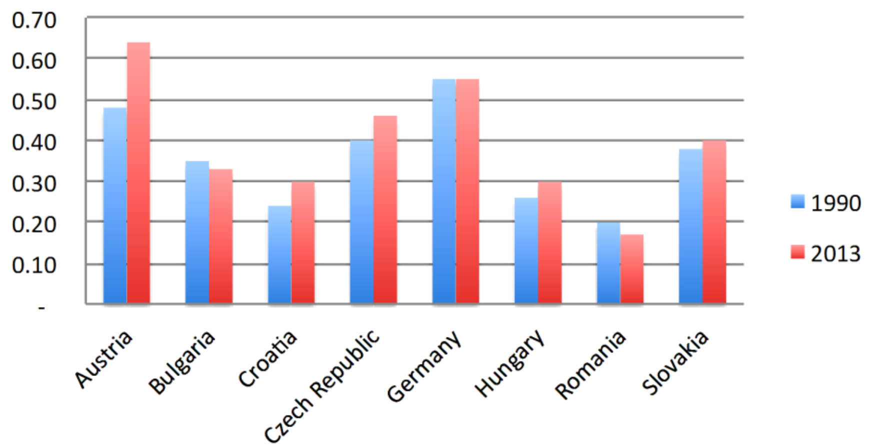

Figure 1. Comparison of the energy consumption per capita in Danube Region countries
Source: http://www.pordata.pt/en/Europe/Search+Environment/Chart

2. What kind of energy system do we need?

The energy should be affordable, the production and consumption have to be sustainable and the system has to be reliable. In this paper, the reliability of the system, mainly the reliability electrical systems will be discussed. The system is reliable, when:

- There are sufficient generation and transmission resources installed and available to meet projected electrical demand plus reserves for contingencies,
- The system will remain in operation even after outages or other equipment failure or geopolitical crises.

There are three subsystems in the existing power systems: generation, consumption and the transmission, distribution in between. The consumption is variable in time and the consumer behaviour is volatile. Reliable supply is achieved in the existing systems via controlling the generation. Disturbances in the generation, transmission and distribution systems as well as the variability and volatility of consumption are managed by reserves, redundancy and diversity. The basic tool for the control of the system is the dispatching the generation that is composed by base load plants, load-follow and peak-load generators. The consumers are little motivated. The tariff/price-system slightly influences the consumer behaviour. If this system fails, total blackout can happen, like in the US and Canada in 1965 and repeated later in 2003. The largest blackout in Europe happened in 2006.

The "good" system should have certain attributes:

1) The infrastructure has to be robust.
2) The system has to be
   a) Redundant – several parallel solutions for one function
   b) Diverse
      i) The markets/sources have to be diverse;
      ii) Different and independent technologies have to be integrated into the system;
3) The system has to be has developed internal connections as well as developed interconnections to the neighbour countries that allow regional cooperation and balancing the disturbances.
4) Reliable and strong storage capacity.

Obviously intense cooperation and solidarity among neighbouring states contribute very much to the reliable power supply. Regional integration and cooperation of the system operators is an achievement of the European Union, ensuring stable "50 Hz" power supply for 532 million of customers, operating more than three-hundred thousand kilometres of power lines and 1000 GW generating capacities. The integration increases the reliability of particular systems, since the structure of the particular national systems is different and this appears as some kind of diversity. From this point of view the countries of the Danube Region have real divers power generation systems and plans for the future development.

During last years the European Union focused mostly on the strengthening the interconnections mainly for ensuring the free trade. The increased reliability due to interconnections was only some kind of side effect.

Figure 2 is showing the actual electricity flow across Hungarian border (the plot is published online at http://www.mavir.hu/web/mavir/ adatpublikacio). It seems the countries of the Danube region are well interconnected.

Although the interconnections between national grids improve the reliability of supply, the interconnections of the power systems transmit electricity generated by burning coal. Consequently, the recent integration of the countries in Danube region shows the features of the past, rather than the features of the future.

It can be expected that the integration of the renewable energy sources into the system will also increase the system reliability, since the renewable sources appear as internal source independent from the market. The positive effect of integration of

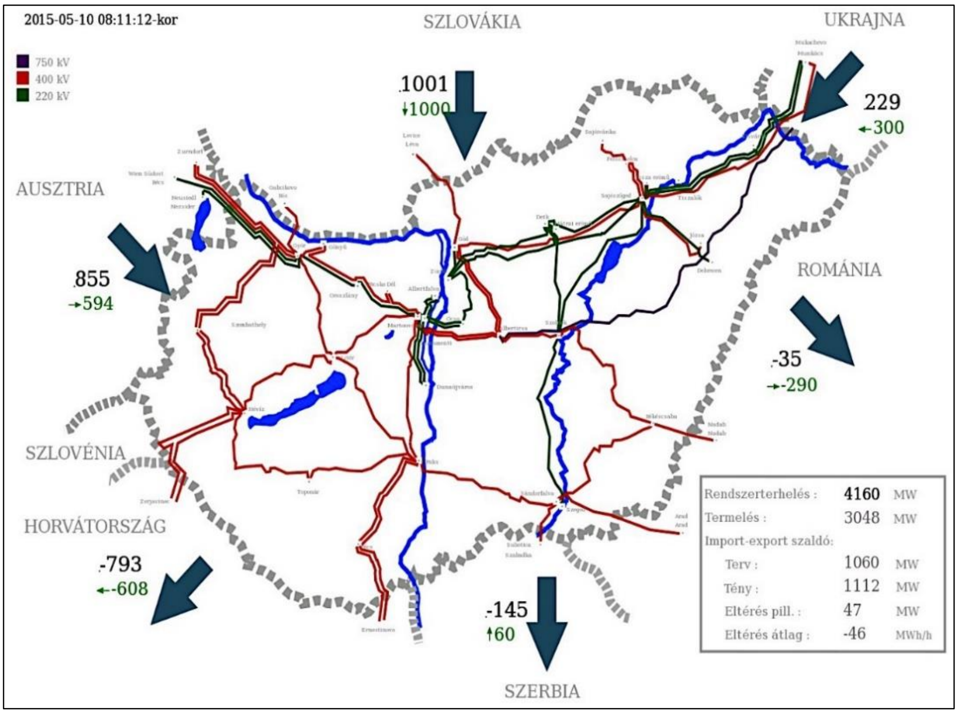

Figure 2. Electricity flow across Hungarian border (the plot is published online at http://www.mavir.hu/web/mavir/adatpublikacio)

the renewables will be amplified if we consider integration larger scale, covering whole.

However, the integration of renewables into the system has rather controversial effect under recent technical level of electrical grid. Due to the integration of renewables the production is becoming more volatile. Consequently the system operator has to deal with volatile consumption and intermittent generation.

Increasing share of renewables generates new problems to be solved:

– System stability problems related to the intermittency of renewable generation. New paradigm of system operation needed. There is a burning need of grid development. However, the industry is not really motivated.
– Need of replacement of obsolete base-load generation capacities. The utilities are not interested and motivated to invest into construction of new capacities. Financing of long-run projects is rather difficult.
– Technologies for the storage of electric energy have to be developed.
– Need of developed regional cooperation regarding reserves and storage.

Obviously, integration of more renewable generation capacities into the existing electricity systems requires enormous effort in grid development.

Let's see on the example Germany. In Germany the installed capacity of solar is over 38,500 MW and wind capacity is over 39,165 MW. The peak load capacity is below 60,000 MW. This means that the solar and wind covers the peak-load capacity. It means also that the German power system is already theoretically green, practically not at al. In spite of large share of renewables, the production of base-load coal fired plants remains nearly constant. Between 2012–2014 production of the base load plants in the system was slightly decreasing 59.3–60.3% (±1%), although the production by renewables increased by 3.2%. There is an international effect of the situation in Germany. When the wind is blowing and the sun is shining, Germany is selling the excess electric power generated by the base-load coal fired plants, which could not be stopped because of the system stability. This is seen in Fig 3 that is showing the load-curve of different capacities on the triumphal day of renewables, 17th of August 2014, when the country's renewable generation capacity peaked at 41 GW while demand was around 53.5 GW – meaning that renewables accounted for roughly 75% of generation capacity, a new record for Europe's biggest economy. At the time of the peak, wind capacity stood at 18.6 GW, solar at 13.5, hydro at 4 with approx. 4.9 from biomass. The Fig 3 shows that the excess energy has been sold (for cheap!) hence the base-load plants are needed in the system for ensuring the relia bility of supply. Consequently, emission of power system of Germany was not significantly lower this time as in an average day.

What is needed for better utilisation of the renewables? For example, decentralisation of the system is required. That is the opposite of the tendency up-to now, since the recent system is a product of strong centralization). Intelligent control of all participants has to be implemented, not only the control of generation, except renewables. Further we need the following:

- Smart appliances
- Smart users, households
- Smart communities and cities
- Smart metering
- Smart grid
- Smart market

As it shown by Goulden et al. (2014) the success depends on smart users. Practically, for the new age of energy supply and consumption a new smarter mankind is needed. Looking around in our recent world, there are serious doubts that we will turn soon in-to this new type of mankind.

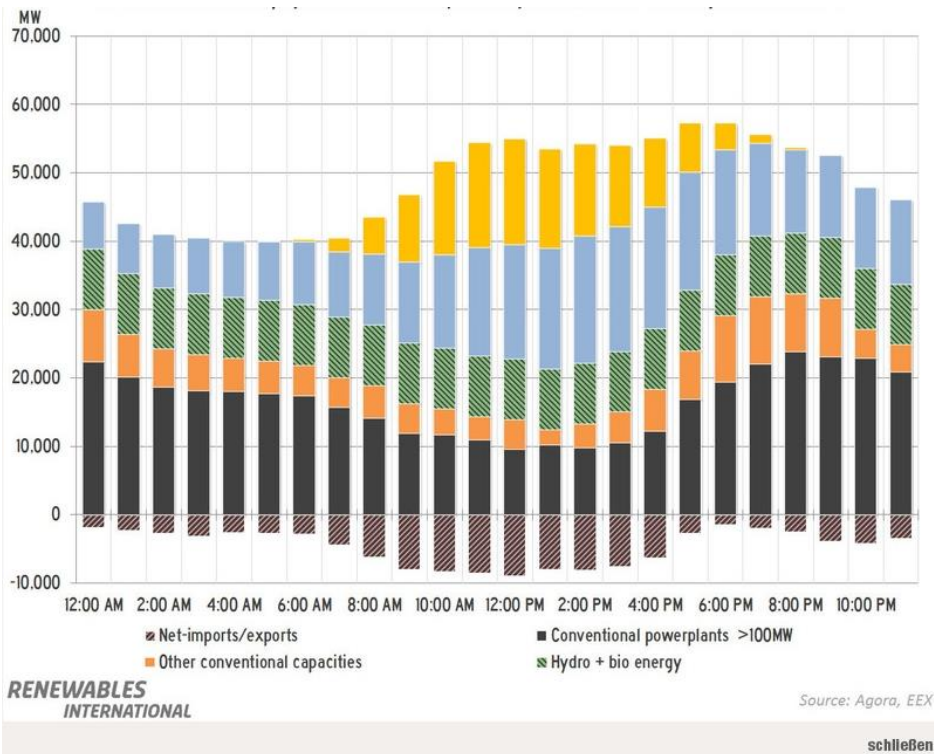

Figure 3. Load-curves for different generators in Germany 17th of August 2014 (http://www.renewablesinternational.net/germany-meets-75-of-the-domestic-electricity-demand-with-renewables/150/407/81057/)

3. Smart-grid – the solution

The smart grid functional characteristics are:

– Self-healing from power disturbance events
– Enabling active participation by consumers in demand response
– Operating resiliently against physical and cyber attack
– Providing power quality for 21st century needs
– Accommodating all generation and storage options
– Enabling new products, services, and markets
– Optimizing assets and operating efficiently

Smart grid requires the use of digital technology to ensure reliability, resiliency, flexibility, and efficiency (both economic and energy) of the electric delivery system.

The legal framework for the smart grid development is compiled in the European Union (see, e.g., COM(2011)202 on Smart Grid). From policy point of view the development is ensured.

The intention of this paper was not to discuss matters related to money. Unfortunately these aspects can't be ignored. Questions about the reliability, affordability and sustainability of our energy future often boil down to questions about investment, especially, investment into research and development. Representative study of the International Energy Agency (IAEA 2014) shows that huge amount of money has to be invested into power sector, in the transmission as well as generation part. The investments are driven by the governments and not by the market. Obviously, the governments of the countries in the Danube region have rather limited means (except of some!) to finance this development. There are several other important findings in the IAE Special Report on World Energy Investment Outlook:

– Europe needs to invest 2.2 trillion USD to 2035 to replace ageing infrastructure and meet the decarbonisation goals.
– 100 GW of new thermal plants is needed before 2025 to ensure the reliability of supply.
– This investment won't happen with current market rules, since the wholesale power prices are 20% below cost-recovery levels.
– Returning back to the Danube region, we can see in Fig 5 that the distribution of the founding for research projects in the energy sector is very asymmetric.

It seems different countries develop the power system in different way. Unfortunately, the Danube region is behind the average, except of Germany and Austria.

A few words about storage options: In the Rifkin's vision transitioning the transport fleet to electric plug-in and fuel cell vehicles was mentioned. It is really the future, but the recent situation is completely different. Figure 4 shows the existing and planned energy storage capacities in the US. As it is seen in Fig 4, there are many options for energy storage, but the really practicable solution for today is the pumping hydro-storage. This is a real option for some countries in the Danube Region, first of all for Austria. This type of storage is completely unacceptable in Hungary because of socio-psychological reason. The recent business conditions are also unfavourable for building new pumped hydro storage capacities.

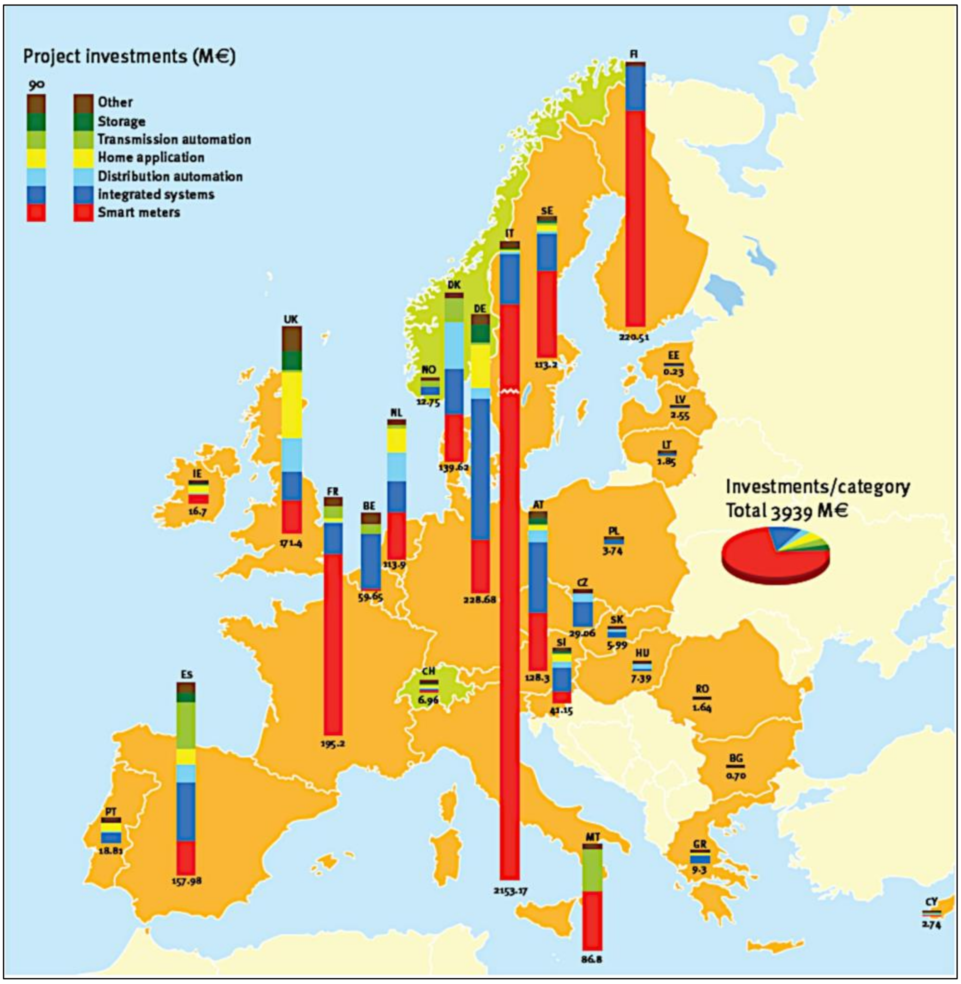

Figure 5. Project investments into development of power system in European Union
Source: Giordano et al. 2011.

Figure 4. Existing and planned US energy storage capacities

Storage technology	MW	%
Open-loop Pumped Hydro Storage	22 545	78.9
Closed-loop Pumped Hydro Storage	4 100	14.4
Molten Salt Thermal Storage	541	1.9
Compressed Air Storage	426	1.5
Lithium-ion Battery	209	0.7
Lead-acid Battery	133	0.5
Chilled Water Thermal Stroge	130	0.5
Electro-chemical	104	0.4
Flywheel	98	0.3
Thermal Storage	72	0.3
Ice Thermal Storage	64	0.2
Gravitational Storage	50	0.2
Flow Battery	39	0.1
Nickel Based Battery	27	0.1
Sodium based Batttery	23	0.1
Other/unspecified	13	0.1

Source: US Energy Storage Technology Outlook. www.energystorageupdate.com/usa

4. Research and development

Hence the founding of the research projects in the countries of Danube region is limited, the cooperation in the R&D between the countries in the region could be a tool for better use of national founds.

The JRC analysed the cooperation between the EU countries in the area of smart-grid R&D. For each pair of countries, each common project has been multiplied with its corresponding budget and added together for obtaining an aggregated weight for the relationship between the pair. Thus, the matrix representing the cooperation links among the countries in European multinational projects has been obtained. The resulting matrix is represented as a heat map (the higher the budget, the stronger the links); see Fig 6. Cells corresponding to country pairings represent the strength of the link between two countries. Figure 6 shows that the Danube region countries have rather limited means for smart grid R&D (except Germany and Austria), and the countries are cooperating more with developed partners rather than with each other. Considering this matrix, the Danube Region seems to be a geographic term only.

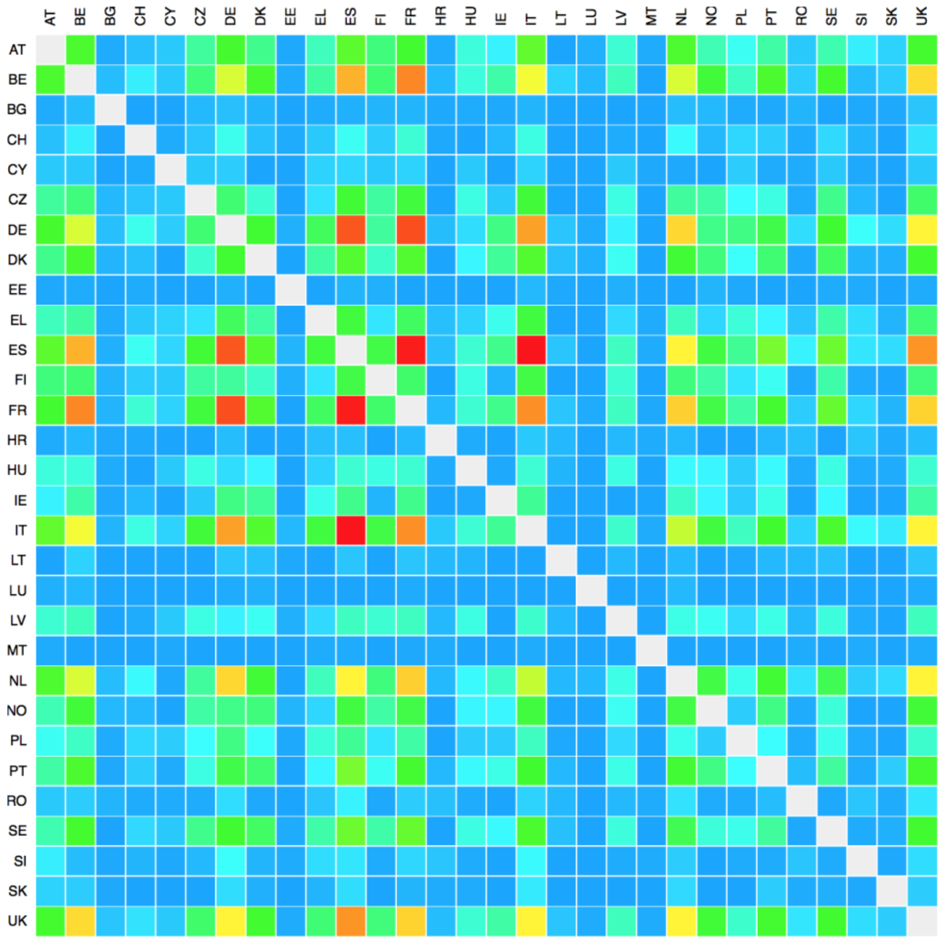

Figure 6. Matrix of smart-grid R&D cooperation between the countries in European Union

5. Conclusion

The energy system in Europe as well as in the Danube region requires urgent actions. The recent market situation and the current overcapacity are temporary. Europe needs mega-investments to generation and transmission industry to 2035. More urgent, hundred thousand MW of thermal plants (base-load) has to be built up-to 2025 for ensuring the reliable supply. This is quite shocking, since we may think the investments have to go to increase the shear of renewables. The reason is the retirement of base-load generators and delay of expected deployment of a computer based new generation and transmission system. The new system has to ensure the reliable supply, respond to new challenges (cyber-attacks) and it has to be accepted by the users, too. For the stabilizing the system, which is now transitioning from old to smart, the base-load generation has to be developed otherwise the reliability of the power system can't be ensured, moreover no more renewables can be integrated into the system otherwise. The countries in the Danube Region have to enforce the cooperation in R&D and in developing their power systems. Otherwise the Danube Region will be a pure geographic designation.

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Modelling the Integration of Large Energy Storage in the Alpine Region

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Abstract: Energy systems with high shares of renewable electricity are feasible, but require balancing measures such as storage, grid exchange or demand side management (DSM) to maintain system stability. The demand for single balancing options cannot be assessed separately since they influence each other. The interdependencies between these measures are addressed with an integrated model of the European energy system in 2050. The model architecture allows for a detailed analysis of multiple parameters, which makes it possible to determine interrelations in the highly complex electricity system and to understand interdependencies between different balancing technologies. This enables to identify the possible contributions of different technologies in single countries to the highly integrated European electricity system and to develop transnational strategies for implementing balancing options. To illustrate the possible applications of this model, a case study concerning pumped hydro storage (PHS) and the balancing demand in the Danube region has been conducted. Potentials for large storage facilities mainly depend on geographical conditions, whereas the potential for DSM is closely connected to a country's industrial and economic structure. By applying the model, the effects of large seasonal storage facilities in the alpine region (Austria and Switzerland) and the effects on balancing needs in neighboring countries of the Danube region are investigated. The model is also used to determine the effect of increased grid transfer capacity on the utilization of these large alpine hydro storages in a European grid.

Keywords: Energy System Modeling, Europe, Storage, demand side management, transmission grid

1. Introduction

By now, several studies are showing that high shares of renewable energy (RE) in the electricity sector are feasible [Feursch et al. 2008, Sensfuß et al. 2011, Teske et al. 2012). But how much balancing options such as grid extension, demand side management (DSM) and storage capacities are needed to enable high shares of RE? Grid extension will decrease the need for storage and DSM to some extent – but how much grid extension is reasonable? Energy storage and DSM are both suitable for a temporal shift of energy demand – but how does the implementation of DSM influence patterns of storage usage? These and further questions are addressed in the RESTORE2050 project[1] by implementing an integrated model of the European electricity system for the year 2050. This is a multinode dispatch model, consisting of one node for each European country. With this model, the effects of different states of development of storages, cross-border-capacities, and DSM on the temporal (hourly) and spatial energy balance can be investigated.

To introduce this model and illustrate its application possibilities, a case study is conducted here which aims at answering the following questions:

1. How does the increase of grid transfer capacity influence the residual energy demand in Europe?
2. Can the degree of utilization of large energy storage within the Danube region be increased by the extension of grid connection within Europe?
3. How does the utilization of DSM by electric vehicles in the Danube region influence patterns of storage use?

2. Methods

2.1. The model and its basic architecture

The Restore model has been developed to analyze the mutual interdependencies between different balancing options such as grid capacities, storage and DSM in energy systems with high shares of renewable electricity infeed. Therefore spatially and temporally resolved input datasets are provided. For each European country, time series, covering ten years in hourly resolution, were developed for renewable feed-in (provided by the University of Oldenburg) and for electricity demand. The long time period of ten years was chosen to cover both, exceptional and unexceptional weather phenomena in the data set. These time series are then scaled according to an existing third party scenario. In the RESTORE2050 project, scenarios of (Sensfuß et al. 2011) and (Teske et al. 2012) were chosen as consistent baseline scenarios. These scenarios describe possible technical pathways and are meant to be a desirable system configuration in 2050, but not a prediction. In addition, the potential for different kinds of storage and for sectoral DSM is analyzed for each country and prepared as model input by Next Energy (Kleinhans 2014).

The task of the model is to deploy the balancing options in order to match energy demand and renewable energy supply spatially and temporally, thereby decreasing

[1] RESTORE2050 – Regenerative Stromversorgung & Speicherbedarf in 2050, conducted by Next Energy, Universität Oldenburg and Wuppertal Institute, funded by the German Federal Ministry of Education and Research (BMBF) within the "Förderinitiative Energiespeicher"

the need for fossil-fuelled electricity generation. Since the modeled European energy system is highly complex and diverse interactions are possible, an optimization is necessary in order to determine the best interplay between the balancing measures. The target function of this optimization aims at the minimization of the sum of positive residual load in all regions and time steps. The residual load is the remaining load after utilization of all fluctuating and controllable RE as well as available balancing options in all regions. The remaining residual load, that cannot be covered by renewables, is assumed to be provided by fossil power plants. Here no further subcategorisation is made within the model since both analyzed third party scenarios assume solely gas fired power plants. Their energy generation in this study is part of an ex-post analysis. The annual maximum power of the remaining residual load in each country defines the necessary backup capacity.

2.2. Depicting Europe, and the Danube region in the model

The energy system analyzed in this case study, includes nearly all Entso-e[2] member states (excluding Iceland, Cyprus, Malta). By applying the model, the effects of increased interconnections and the application of DSM on storage facilities (PHS and Seasonal Storage in Austria and Switzerland and PHS in the Danube region) are investigated. Therefore these countries are modeled as single nodes, the remaining European countries are implemented in lower spatial resolution. This results in the following regions (see also Figure 1): Germany, Austria, Switzerland, Hungary, Czech Republic and Slovakia as single countries, the Baltic countries, Scandinavia, UK (including Ireland), Western Europe and Southeastern Europe as aggregated regions. Within each region, no transmission restrictions are considered.

For each of these regions, renewable infeed and electricity consumption is modeled according to the capacities and demand in (Sensfuß et al. 2011) based on weather data of 2004. The following Table 1 shows the relevant characteristics of the regions. Since the potential for DSM of electric vehicles is part of this case study, the numbers of electric vehicles is assumed for 2050, on base of (*EEA 2009, EUROSTAT data*).

2.3. Simulation configurations to answer the research questions

In order to answer the research questions, a series of simulations is performed, in which the dispatch of flexibility options in the European energy system is optimized for a time period of one year in hourly resolution. Each of the simulations represents a different system setup regarding the installed interconnection capacities between regions and the implementation of DSM measures.

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[2] Enstso-e: European Network of Transmission System Operators for Electricity

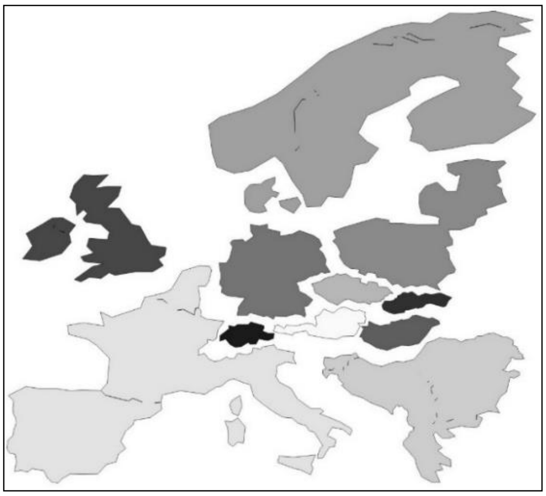

Figure 1. Spatial resolution of the European energy system in the case study (11 regions)

Table 1. System configuration of future energy system in 2050

No.	Country / Region	PV Power [2] [GW]	Wind Power (onshore & offshore) [2] [GW]	Electricity demand [2] [TWh]	Number of Electric Vehicles [6,7,8] [Mio.](not considered)
1	Germany	69.0	544 / 50.2	567.8	34.62
2	Austria	6.3	6.3 / 0	63.2	4.486
3	Switzerland	8.6	0.9 / 0	54.2	4.12
4	Hungary	7.9	2.1 / 0	44.8	4.58
5	Czech Republic	11.4	15.6 / 0	65.3	4.05
6	Slovakia	5.4	1.1 / 0	29.3	2.42
7	Baltic countries	7.6	66.4 / 1.4	196.9	(30.01)
8	Scandinavia	0.0	54.2 / 23.4	327.6	(9.61)
9	UK (including IE)	2.9	121.5 / 50.2	415.3	(32.96)
10	Western Europe	172.4	242 / 62.7	1 594.0	(80.73)
11	Southeast Europe	47.7	29.2 / 3.1	251.1	(19.01)

The first simulation (Sim-1) is the baseline scenario for this case study. Here, interconnections between regions are limited according to the data provided by the Ten-Year Network Development Plan 2014 (ENSTO-E 2014), including all mentioned projects, regardless of their actual development status. Losses of the transmission lines are not considered in the model. As flexibility options, PHS and seasonal hydro storage plants are being considered in all scenarios.

In simulation 2 (Sim-2), the system is optimized with unlimited interconnection capacity between all regions.

In a third simulation (Sim-3), the basic interconnection capacities are considered (as in Sim-1), but in addition DSM of electric vehicles (EVs) is assumed to be utilized only in the Danube region. It is assumed that 50% of the EVs in these countries can be utilized for DSM. For all simulations (Sim-1: Baseline, Sim-2: Grid capacity increase and Sim-3: DSM utilization) performance indicators of balancing options as well as the residual load and necessary backup capacity are analyzed.

Table 2. Configurations of simulation runs for the performed case study

Simulation Parameter	1: Baseline 2050	2: Increased Grid	3: DSM
Grid capacity	TYNDP 2014	copper plate	TYNDP 2014
DSM	No DSM	No DSM	E- Mobility DSM 50%

3. Results and discussion

3.1. Residual load and excess energy in the Danube region

The results of Sim 1 show the potential situation in Europe 2050 with the foreseeable minimum grid extension. Installed PHS capacity in this scenario does not differ significantly from today. However, the development of renewable technologies shows a strong increase of generation capacities (Table 1). In the overall system 2970 TWh of renewable electricity is generated. In this base scenario, 2694 TWh of the overall production is used to cover the demand resulting in 276 TWh of excess energy (8% of generation) and leaving a residual demand of 903 TWh (25% of the total energy demand) to be covered by backup capacities. Here the resolution of the modeled regions is important. Since no transmission restrictions exist within the aggregated regions (Baltic countries, Scandinavia, UK [including Ireland], Western Europe and Southeastern Europe), shares of residual load and excess energy tend to be even higher in a highly resolved system. For the Danube region and its overall demand of 825 TWh, the simulation results in 268 TWh (32%) of residual energy demand and 16 TWh (2%) of excess energy. This above average share can partly be ascribed to the absence of offshore windpower in these countries. The mainly solar and hydro based energy systems show increased fluctuation in comparison to countries with a high a share of near shore and offshore windpower.

The increased grid transfer capacity in Sim 2 leads to a reduced residual energy demand in Europe of 766 TWh (–15.2% vs. Sim 1). The excess energy is reduced by 138.5 TWh (–49.8%). The absolute reductions of residual energy and excess energy are almost identical with around 137 TWh each, since the high grid connections allow to transport energy from excess regions into demand regions when both phenomena occur simultaneously. With a reduction of 49.8% of the excess energy demand, Sim 2 shows the maximum possible impact of grid extension for the European energy system leaving another 50.2% for the remaining balancing options storage and DSM respectively. Only storages and DSM are able to make this excess energy available by shifting the feed in of this energy (or load in case of DSM) in time.

By implementing the demand side management of EVs in Sim 3, another balancing option is analyzed. Results show that the potential to reduce residual energy demand is very low on a European scale (reductions for overall System <1%) and only small in the Danube region (–1.8% vs. Sim 1). In Sim 3, DSM is only considered in the countries of the Danube region. A reduction can be seen for single countries (ranging from 0.2% to –3.3%). The reason for this limited potential of DSM can be identified by observing the charging times of EVs. The potential is temporally varying, providing high load shifting capacities when many cars are connected to the grid at the same time. In times of high demand (eg. early evening time), when cars have just been connected to the grid, the option to bring demand forward in time is not available. Later at night, flexibilization is possible in both temporal directions. Thus, the potential increases while the amount of cars is constant. Unfortunately, a time overlap of peak demand and low balancing potential leads to a limited effect on maximum residual load reduction. In contrast to that, applying the EVs DSM only in the Danube region results in a reduction of the excess energy of 18.9%. Here the potential of this DSM application can be shown, since the ability of a temporal shift of the charging process is very flexible with EVs, especially at night time, when excess energy is mainly produced.

Table 3. Model results for residual energy, excess energy and residual load in base scenario (Sim 1) (Source: own calculations)

	Unit	Overall System	Danube Region	AT	CH	GER	HU	CZ	SK
Electricity demand	TWh	3,609.0	824.6	63.2	54.2	567.8	44.8	65.3	29.3
Residual demand	TWh	903.4	267.7	18.7	27.9	162.0	20.8	26.4	11.8
% of demand	%	25.0	32.0	30.0	52.0	29.0	46.0	40.0	40.0
Excess energy	TWh	276.0	15.7	0.5	0.7	12.6	0.3	1.5	0.2
% of demand	%	8.0	2.0	1.0	1.0	2.0	1.0	2.0	1.0
Max. residual load	GW	327.6	109.5	15.2	18.8	77.8	8.5	13.1	5.6

3.2. Utilization of storage within the Danube region

The installed capacity of PHS within the Danube region adds up to a power P of 14.2 GW (12.6 GW) for generation mode (pumping mode) with an overall capacity C of 544 GWh. In addition to that, seasonal hydro storage plants (no pumping mode) are considered in Austria (P=3.7 GW, C=3201 GWh) and Switzerland (P=8.1GW, C=8800 GWh). As performance indicators the number of equivalent full load cycles N and the number of load changes (change from charging mode to discharging mode) are assessed from simulation results. To compare storage units of different size, the capacity factor c of the storage units is calculated according to equation 1.

$$c = \frac{N * 2 * C}{8760 * P} \tag{1}$$

Table 4 shows the results for PHS. Results of Sim 2 show that the utilization of storage units decreases only very slightly (change of c from +0.2% (GER) up to –4.9% (SK)) when grid capacity is increased. This corresponds to the results of the analysis of residual energy demand. The patterns of spatial energy distribution of the grid and the temporal shift of energy demand do not influence each other significantly. Only in regions with low transmission capacity (eg. SK), storage utilization decreases because in Sim 1 situations of excess energy occur, that are caused by limited grid capacity. In Sim 2 these cases are not existed, due to unlimited capacity of the grid.

With the implementation of DSM in the Danube region (Sim 3), another balancing option is introduced, that also makes temporal energy demand shift possible. With their high balancing power but relatively small storage capacity, DSM applications act preferably as short term storage in the range of hours. All PHS show a number of load changes between roughly 1300 and 1650 per year, resulting in an average charging/ discharging time of 5.3 to 6.7 hours. The results show that the utilization of all PHS decreases by 5% to 7%, in case of DSM use. For future energy systems with increased storage capacity it can be expected that this effect will become stronger, as DSM in other sectors (such as heating and cooling) may emerge and a pan European application of EVs DSM will lead to less balancing need outside the Danube region.

To analyse the impact of changes on the utilization of seasonal storage, the produced energy and the equivalent full load cycles are used. Since all seasonal hydro storage plants are implemented, charging only via a predefined natural influx, these power plants are treated like controllable renewable energy units. The results show that neither the grid extension in Sim 2 nor the utilization of additional DSM in Sim 3 have any noticeable impact on the seasonal storage units. Looking at a scenario with less than 100% of RE, all energy that flows into the seasonal reservoirs, is used to cover the energy demand.

Table 4. Performance indicators for PHS in Danube region and results of simulations

Performance indicator	AT	CH	GER	HU	CZ	SK
C/P ratio	32.9	184.5	5.8	–	10.3	4.3
equiv. load cycles (Sim 1)	48.4	9.9	287.5	–	193.3	425.0
load changes (Sim 1)	1416	1428	1415	–	1328	1445
load changes (Sim 2)	1439	1391	1539	–	1370	1651
load changes (Sim 3)	1511	1393	1554	–	1415	1516
Cap. factor c (Sim 1)	36.3%	41.6%	37.8%	–	45.4%	42.2%
Cap. factor c (Sim 2)	36.2%	41.0%	38.0%	–	42.8%	37.3%
Cap. factor c (Sim 3)	30.6%	36.6%	31.5%	–	38.5%	36.8%

4. Summary and Conclusions

In an integrated, future European energy system with a high share of renewable energies, the role of countries within the Danube region will change significantly in comparison to today. The foreseeable grid extensions up to the year 2050 support the reduction of residual demand within the region. Results of the performed simulations show that further grid extension helps for a better integration of the region without having a strong influence on the utilization of local storage units. Due to the fairly low resolution of grid interconnections, effects of grid extension could be shown on a qualitative level. To quantify these effects, simulations with much higher resolution are necessary.

The contribution of DSM in the sector of electric vehicles to the reduction of maximum residual load peaks is poor, since the match of temporal patterns of peak load demand and availability of battery power is disadvantageous. At the same time, sectoral DSM proves to be suitable to reduce excess power and thus decrease the overall residual energy demand. As applications in different load sectors enter the market of DSM (eg. Heating and Cooling applications), this could enhance system stability within the region. A simultaneous development of intersectoral DSM and technical storage potentials may lead to a competitive situation of these balancing options, decreasing operation time of each technology. Therefore the development of technical diversity, covering short term as well as long term storage systems appears reasonable for the Danube region.

The central position on the European continent and the absence of less fluctuating infeed from near shore or offshore windpower (compared to solar power) makes a good grid infrastructure crucial for the Danube region in a system with high shares of RES. This effect is decreased to a certain extend by the steady availability of hydro power in the alpine countries and relatively high storage capacities. By utilizing the available balancing options, this region will play a key role as link between large solar capacities in southern Europe and wind power in the northern part of the continent, making an integrated European energy system possible at last.

Acknowledgments

The authors thank the members of the Restore 2050 project at Next Energy and the University of Oldenburg for contributing in form of theoretical support and providing RE infeed datasets.

Conflict of Interest

The authors declare no conflict of interest.

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Ideas of the Renewable Energy in Climate-Strategies of Medium-Size Hungarian Cities

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Abstract: In our paper we would like to give a short insight to the circumstances, possibilities and alternatives, which can promote or hinder the application of renewable energies in Hungarian medium size cities. As a first step we analysed and compared the climate strategies of Hungarian settlements to European examples. The results show that the examined interior strategies contain almost the same adaptation and mitigation topics what we have found in the climate strategies of the European cities. However we still feel the differences! That is why we tried to unfold the main factors which are necessary for successful switchover processes on the selected settlement level, and explore how the decision makers thinking about the role of renewables, mitigation and adaptation in local space. With the help of local experts and case studies we faced with several positive and negative (optimistic and pessimistic) factors, we identified basic problems but also good practices and we tried to outline (and emphasize) the usability of renewable energies for smaller populations. We hope that our specific results can help the local intentions, and give useful information and pointers for environmentally-conscious municipalities.

Keywords: climate strategies, renewable energies, medium size cities

1. Introduction

Adaptation to the expected impacts of climate change becomes a central question in Hungary as well, which can be seen in different research projects, documents and institutions such as VAHAVA (2003–2006), National Climate Change Strategy (I. II.) or foundation of National Adaptation Centre. We can found several provisions and specific pledges in this theme among the objectives of the European Union until 2020: from elaboration of adaptation strategies and increase of energy efficiency until decrease of greenhouse gases emission or increase of renewable energy's ratio. Hungary wants to achieve the EU expectations with operative programmes and tenders which connect to the 2014–2020 financial planning period. Together with this, Hungary is promoting struggle against climate change, wherein renewable energy sources come to the front. In the last decades our knowledge about climate change has expanded, and nowadays changes of climatic elements and its consequences are considered as facts by most people. Mankind has realised that it must face these changes (Stern 2006, Csete et al. 2007).

Similarly to many countries of the word, Hungary recognized the importance of mitigation and adaptation to climate change. The National Climate Change Strategy, or other documents and initiatives, like Climate Friendly Municipalities Association or Energy Efficient Settlements Association help to achieve this. All these are integral parts of the process to prepare the society for the challenges of climate change, and lead to energy efficiency, environmental urban planning and application of renewable energies. Therefore in our research we focused on the local answers for the challenges of climate change, climate strategies of European and Hungarian cities and focuses for renewable energy.

2. Methods

We used the following methods in our study: first, we reviewed the significant international results of climate protection, the main principles of climate policy in the European Union and Hungary, the existing research papers about the climate strategies of European cities and we analysed the climate strategies of the Hungarian medium size cities. After that, we prepared experts interviews with the prominent persons who participated in the preparation of strategies or working in local climate associations. They have appropriate insight on the effectiveness of the local climate protection programs.

The main aim of our work is to compare the climate strategies of medium size cities[3] in the EU and Hungary and to investigate the possibilities of Hungarian climate protection, in particular with regard to renewable energies. Since climate strategy is not a mandatory urban planning document, in the case of many cities it is only exist as a part of other larger urban document (Integrated Urban Development Strategy, Environment Protection Programme etc.). These „hidden strategies" show that concerns about environment still play a significant role in development planning, although there are no separate climate documents. According to our experience, these strategies are not adequate documents, but sometimes more detailed than the earlier strategies; and in some cases concrete climate protection plans can be found in these programmes. However, we used only separate climate or energy strategies, partly because of their international comparability, and partly because – according our preconception – these separate strategies may show stronger commitment towards adaptation.

[3] In the Hungarian settlement geography, medium size cities usually defined as cities with 20–100 thousand inhabitants. We used different categories and defined medium size cities as cities with 10–110 thousand inhabitants.

3. Result and discussion

3.1. Climate strategies in European cities

The sustainability (or its absence) of the European cities has been in the focus of the attention, especially in the case of those cities which were affected by extreme weather events linked to climate change. The first extensive European survey with consistent methodology has been made by Reckien and colleagues (2014). In this survey they investigated 200 cities from 11 countries. They examined whether these cities have climate strategies or not, the content of these strategies (whether they only include mitigation plan or contain elements of adaptation too), what measures are mentioned and what commitments are present in these documents in order to reduce GHG emission. The investigated cities comprised 16.8 % of the population of the EU27 in 2008, and they involved in the Eurostat 'Urban Audit' monitoring programme. The examined cities had more than 50 000 inhabitants.

According to our results, 65 % among these 200 cities had mitigation plan, but only 28 % of them had adaptation documents, and a significant part of the examined cities had no concept about climate change at all. There are significant differences between the countries. For example, 93 % of settlements in the UK had at least a risk management plan, but this ratio in Belgium and France only 43 and 42 %. Adaptation plans exist only in connection to mitigation documents in every case. These plans can be found in the UK in highest proportion (80 %), while second and third places are Finland and Germany with 50 and 33 %. However, these two documents appeared integrated in only 22 % of the cases, so there may be significant reserves in this area, according to the authors of the survey.

In both type of planning documents, the frequency of mentioned measurement were analysed (Fig. 1.).

The results of Reckien and colleagues (2014) show that there are significant shortcomings in the planning and preparedness of the European cities in relation to the climate change, and mostly only the larger cities targeted specific goals of climate protection. This highlights that settlement size is an important differentiating factor in this regard, the medium size cities of Europe with a population between 50 000 and 250 000 are less dynamic and innovative in the climate protection than the larger ones. According to Dormois (without year) the reasons are the following:

- These settlements are very closely located to the idyllic rural landscapes so it is hard to sell the additional costs of “green developments” for the potential urban buyers.
- The typical settlement-environmental conflicts like traffic jams are not so dramatic to force the people to choose more environmentally friendly ways of travelling, which undermines the financial support of green development.

– In the era of globalisation, the headquarters of the international companies are located in the large urban centres, so the available financial support for green development are generally more limited in the medium size cities.

Since the financial background and the attitudes for eco-friendly green developments are controversial, the medium sized cities have to implement a more innovative communication to generate climate-friendly local economy and lifestyle, and they have to integrate the new ideas into the city's development, documents and daily routine.

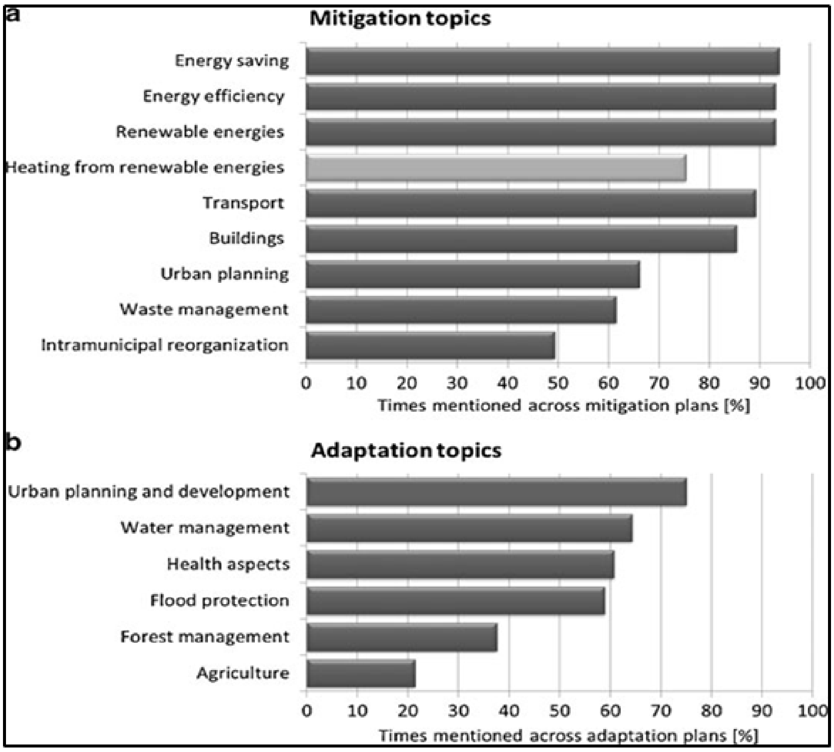

Figure 1. Topics of the mitigation and adaptation plans across Europe (%)
Source: Reckien et.al. (2014)

3.2. Climate strategies and issues of renewable energy in Hungarian cities

The local climate protection efforts in Hungary are mainly embodied in the climate protection organizations. According to our research we must mention those recently active organizations which are able to mobilize both local governments and civil society. These include the Climate Friendly Municipalities Association (with 18 members) and the Energy Efficient Governments Association (has 24 members) (http://klimabarat.hu; http://ehosz.hu/szovetseg), as well as the Hungarian Climate Alliance whose members include 13 NGO's and 7 municipalities (http://www.eghaj latvedelmiszovetseg.hu). It is worth pointing out that although the areas of climate protection and energy efficiency are very close to each other, the overlapping between these organizations is minimal. We found only two cities – Gödöllő and Tatabánya – who are members both of the Climate Friendly Municipalities Association and of the Energy Efficient Settlements Association. The number of Hungarian cities which have climate strategy is very low in international comparison. Until this time, only 10 medium size cities prepared publicly available climate strategy, but some of these documents are only „water management climate strategies" (such as in the case of Vác and Pomáz). These documents only focus on water management issues like flood protection and rainwater management. Some of the other strategies put the focus on energy management and efficiency.

Nowadays we have found several background materials, scientific and policy documents – like the Climateguide edited by Fülöp (2009) – that can be useful for the Hungarian settlements to prepare an elaborate climate strategy. According to the aforementioned Climateguide, the first (and most important) steps are revolving around energy, like founding local energy committees, creating an energetic database and preparing local energy-conceptions. Almost all of the climate concepts contain the land-, water-, and forest- management, flood protection, heat and UV action plans, but the recommendations of the Climateguide also point out that in Hungary, local energy management and the increased use of renewable energy is considered as the most effective way to mitigate the effects of climate change. We also carried out an analysis of the targets of these documents to compare them to the international results (Fig. 2).

It can be seen that most of the local climate strategies contain almost every topics with the exception of the need for restructuring of the public services (intermunicipal reorganization). This feature is an important difference between domestic and international climate strategies, which shows, domestic strategies consider every topics important in theory, but the realization is weak in practice in many cases. However, the presence of the topics does not reflect to the different emphasis each strategy has. The analysed climate strategies pay particular attention to the question of energetics which supports our hypothesis that energy management is one of the most important topics for the settlements. These goals and objectives are related to the topic of mitigation, so it shows us that the current documents are emphasising the prevention of climate change instead of adaptation. This is similar to the European experience. However there is a significant difference, because the integrated approach is common in Hungarian documents, and every strategy includes both mitigation and adaptation topics.

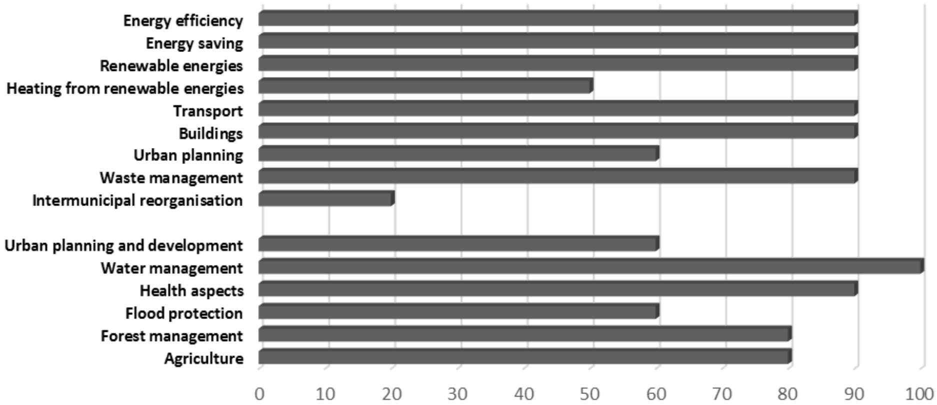

Figure 2. Topics of mitigation and adaptation (%) in the examined Hungarian climate strategies
Source: Own elaboration from Hungarian climate strategies.

In addition to mitigation topics in European cities, Hungarian possibilities mentioned in the city strategies are the following:

- reducing emissions, CO_2 sequestration
- development of monitoring network (e.g. air pollution)
- increasing green areas and green roofs
- landscape rehabilitation
- awareness for mitigation

According to national documents it can be concluded, that the first starting point is the energy efficiency. The use of renewable energies is the second step, but it should be incorporated into the local development if we would like to achieve visible results.

Based on the above mentioned experiences we examined the possibilities and hindrances of increasing the use of renewables.

We have selected six settlements, where we analysed the local climate strategies and conducted interviews with the prominent experts on the subject. The experts also agreed on that energetics will have the most important role in climate protection in the future. These experts work in local governments in cities with climate strategies. They were contributors in creation of climate strategies and they are the responsible of realization in it. They opinion not only a subjective opinion but represents a wider community.

We need to understand that one of the key main causes of the climate change is the emission, which related to the use of fossil energy sources. There are two different ways to cut down the amount of energy: reduce the use of energy or increase the efficiency. In this approach it does not matter that the energy is come from fossils or renewable, because the reducing of emissions will be realised. The possibility – that we decrease the emission with the use of renewable sources – is definitely positive, but currently this idea is not a priority for most municipalities. However there are some exceptions as good practises. There are among the municipalities who have been invested work and attention to create their own climate strategies. These settlements have confirmed the importance of responsibility, climate-consciousness and behaviour both in individual and municipal level. With shaping attitudes the popularity of renewables can be enhanced. Following the climate-conscious comments; in our opinion the local governments, (in partnership with the civil society) can invest for green goals even though there is not enough governmental support or funding sources. This is supported by economical calculations (e.g. Eger) which demonstrate the advantageous effects of energy investment (opposite of investments such as other infrastructure). So the renewable energies probably have local benefits in long term consumption.

According to the experts, the alternative technologies which are necessary for the change of attitude – are already available for Hungarian cities, moreover, the „hardware background" of renewable energies has become more affordable in recent years. In relation to economic sustainability, there is no consensus yet; the dilemma of solar energy use is a good example of it. Some experts predict a rapid spread of solar energy, while others believe that solar energy use is only a marginal, „prestige item" of energy production. It would mean that the use of solar energy would not take a break in Hungarian medium size cities. This view is supported by the fact – which is a sceptical opinion of specialists –, that these energy sources would be used in a much larger volume, if climate protection and use of renewable energies would also mean significant economic savings and not only an environmental benefit. They add: "Only a few municipalities, institutions, enterprises, urban residential communities or individuals can afford long-term profitability developments on the base of renewable energies."

Despite some disagreements all experts agree on that „not used energy is the safest, cheapest and most environmentally friendly energy". Taking this into account, and on the basis of the climate strategies, the greatest possibility for energy saving is reducing urban electricity consumption in medium size cities. The existence of a modern, efficient district heating system is an important issue in energetics of surveyed cities. Development of district heating is a possibility not only as a saving solution, but possible transition to renewable energy, which means geothermal energy and biomass mainly. Use of biomass – as renewable energy – for district heating is beneficial only in that case, if mining, primary processing and utilization are local. Also, biomass production requires an extremely complex care in landscape and environment.

4. Conclusions

Sustainability, climate protection, energy management, renewable energy sources are closely related concepts. During our research we have tried to outline some important aspects of climate protection focused on renewable energy. For this reason we analysed local climate strategies, possibilities, limits and other circumstances using the example of medium size cities (with climate strategy) in Hungary.

Climate strategies assign an important role in the renewable energies. Despite, this way has too much difficulties, for example the policy about energetics. We should realize the fact: nowadays the nuclear power is the main factor in the energy management of Hungary. It seems that the use of renewable energy sources (next to the conservative methods of energetics) is limited to a rather narrow circle. The environmental acts and the lack of financial resources are also make difficulties to transition for a new environmental paradigm. The current national practices have strong influence on local considerations. The current price level of fossils is still lower, so the renewables are suffering from a competitive disadvantage, and the rate of investment are below than in other European countries with best practices (e.g. Austria, Germany). In contrast to these facts some local social community and decision maker have realised, that energy saving may lead to financial savings and able to bring direct benefits to local governments. This recognition put the energy efficiency, the improvement and modernization to the focus in this sector. The renewables can play an important role in this process, but the settlements have to keep in their mind that the use of renewable depends on local conditions, because the opportunities are spatial-specific.

Therefore the current reality is that renewable energy use is ranked behind energy savings and efficiency in the examined settlements (and in the similar cities). However we are witnessing the transition to a new kind of energy thinking and management and the increasing popularity of renewables in several domestic settlements. Many people have already strong confidence that the reduction of emissions and use of renewables can contribute to climate protection, and also lead to economic benefits in local scale.

Conflict of Interest

The authors declare no conflict of interest.

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Overview and Perspectives of Renewable Energy Sources in the Danube Region in Croatia

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Abstract: In this paper, potential of renewable energy sources for Danube region in Croatia will be presented. Croatian Danube region consists of two counties, Vukovar-Sriem County and Osijek-Baranya County. Potential of solar energy, wind energy, geothermal energy, hydro energy and biomass energy for Danube region in Croatia will be shown in detail. Overview of current state of renewable energy sources usage for electricity and heat production in Croatian Danube region will be presented. Usage of solar energy, wind energy, geothermal energy, hydro energy and biomass energy for electricity generation in Croatian Danube region will be shown in detail. Also, perspectives for further development in these two counties will be presented.

Key words: Danube region, renewable energy sources, potential, usage, perspectives.

1. Introduction

Renewable energy sources (RES) are very important part of energy balances in almost every country. They provide electric and thermal energy with reduced pollution and they exclude the use of fossil fuels. Also, unlike conventional technologies, RES use many dispersed sources of energy, and they are compatible with "smart grid" implementation in distribution system. Danube Region in Croatia consists of Vukovar-Sriem County and Osijek-Baranya County. Both Counties show interest in increasing the use of RES, which is visible in comparison of Figure 1. and Figure 2. Wind and waterpower energy potentials are insignificant in these two Counties, but biomass and solar energy potentials are clearly expressed, especially biomass, while geothermal energy mostly needs further researches. Current state of RES and perspectives with potentials are given in following chapters.

2. Overview of Renewable Energy installations in Danube Region in Croatia

Energy generated form renewable sources in Danube region in Croatia, like in the whole country, is paid by a tariff system given in following table. The prices of energy produced by any renewable source are determined with this system.s

It is important to note that the construction of solar power plants whose energy is paid by this tariff system is limited to 5 MW per year, and that every plant built beyond that limit is paid by regular prices for energy from conventional energy sources and not by this tariff system. Figure 1. shows built power plants in Danube Region in Croatia.

Table 1. Tariff system for renewable energy sources in Croatia

Group	Type of plant	Incentive price C (kn/kWh[4])
	The plant with installed capacity ≤ 5MW	
1.a.1	Solar power plants with installed capacity up to and including 10 kW.	1,91
1.a.2	Solar power plants with installed capacity exceeding 10 kW up to and including 30 kW.	1,70
1.a.3	Solar power plants with installed capacity exceeding 30 kW and up to and including 300 kW.	1,54
1.a.4	Ground – mounted solar power plants	RC
1. b. 1	Hydro power plants with installed capacity up to and including 300 kW.	1,07
1. b. 2	Hydro power plants with installed capacity exceeding 300 kW up to and including 2 MW.	0,93
1. b. 3	Hydro power plants with installed capacity exceeding 2 MW.	0,88
1. c.	Wind power plants.	RC
1. d. 1.	Solid biomass plants including biodegradable ind. and municipal waste with installed capacity up to and including 300 kW.	1,30
1. d. 2.	Solid biomass plants including biodegradable ind. and municipal waste with installed capacity exceeding 300 kW up to and including 2 MW.	1,25
1. d. 3.	Solid biomass plants including biodegradable ind. and municipal waste with installed capacity exceeding 2 MW.	1,20
1. e.	Geothermal power plants.	1,20

[4] 1 EUR = 7,578 kn

Group	Type of plant	Incentive price C (kn/kWh[4])
1. f. 1.	Biogas power plants from agricultural plants and organic remains and waste from agriculture and food processing industry, landfill gas power plants and power plants using gas from water treatment plants with installed capacity up to and including 300 kW.	1,34
1. f. 2.	Biogas power plants from agricultural plants and organic remains and waste from agriculture and food processing industry, landfill gas power plants and power plants using gas from water treatment plants with installed capacity exceeding 300 kW up to and including 2 MW.	1,26
1. f. 3.	Biogas power plants from agricultural plants and organic remains and waste from agriculture and food processing industry, landfill gas power plants and power plants using gas from water treatment plants with installed capacity exceeding 2 MW.	1,18
1. g.	Liquid biofuel power plants.	RC

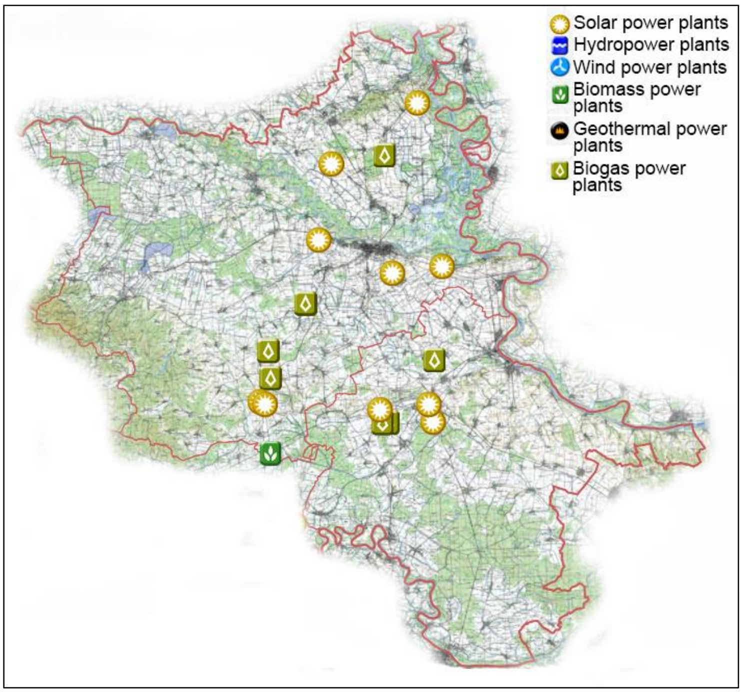

Figure 1. Built power plants on renewable energy sources (Ministry of Economics)

2.1. Photovoltaics

Overview of operating photovoltaic power plants in Danube region in Croatia is given in Table 2. for Osijek-Baranya County and in Table 3. for Vukovar-Sriem County.

Table 2. Overview of photovoltaic power plants in Osijek-Baranya County (HROTE)

Project	Plant type*	Location	Electrical capacity (kW)
ZMAJEVAC-1	1.a.1	Kneževi vinogradi	10.0
SEG1	1.a.2	Osijek	30.0
SEG3	1.a.1	Jagodnjak	9.8
SEG5	1.a.1	Osijek	10.0
TENJA1	1.a.1	Osijek	10.0
Mijakić – 1	1.a.1	Đakovo	10.0
Knežević – 1	1.a.1	Đakovo	10.0
Hrastović – 1	1.a.1	Đakovo	10.0
Total			99.8

*According to tariff system by HROTE: 1.a.1 – solar power plants <10 kW;
1.a.2 – solar power plants from 10 kW to 30 kW.

Table 3. Overview of photovoltaic power plants in Vukovar-Sriem County (HROTE)

Project	Plant type*	Location	Electrical capacity (kW)
Suhomont	1.a.2	Vinkovci	29.0
Krmek	1.a.1	Vinkovci	4.1
Patričar 2	1.a.2	Ivankovo	30.0
Total			63,1

*According to tariff system by HROTE: 1.a.1 – solar power plants <10 kW,
1.a.2 – solar power plants from 10 kW to 30 kW.

2.2. Biomass Power Plants

Overview of operating biomass power plants in Danube region in Croatia is given in Table 4.

Table 4. Overview of biomass power plants in Osijek-Baranya County (HROTE)

Project	Plant type*	Location	Electrical capacity (kW)	Thermal capacity (MW/h)
Hrast	1.d.3	Strizivojna	3	3,5

*According to tariff system by HROTE: 1.d.3 – biomass power plant on solid biomass > 2 MW.

2.3. Biogas Power Plants

Overview of operating biogas power plants in Osijek-Baranya County is given in Table 5. and Table 6. for Vukovar-Sriem County.

Table 5. Overview of biogas power plants in Osijek-Baranya County (HROTE, Osatina group)

Project	Plant type*	Location	Electrical capacity (kW)	Thermal capacity (MW/h)
Mitrovac	1.f.2	Čeminac	2	–
Slašćak	1.f.2	Viškovci	1	–
Mala branjevina – 1	1.f.2	Vuka	1	–
Mala branjevina – 2	1.f.2	Vuka	1	–
Tomašanci	1.f.2	Gorjani	1	1,3
Tomašanci – 2	1.f.2	Gorjani	1	1,3
Total			7	2,6

*According to tariff system by HROTE: 1.f.2 – biogas power plants from 300 kW to 2 MW.

Table 6. Overview of biogas power plants in Vukovar-Sriem County (HROTE, Osatina group, Novko et al. 2014)

Project	Plant type*	Location	Electrical capacity (kW)	Thermal capacity (MW/h)
Ivankovo	1.f.2	Ivankovo	1	1.30
Ivankovo 2	1.f.2	Ivankovo	1	1.30
Landia	1.f.2	Tordinci	1	1.07
Total				3,67

*According to tariff system by HROTE: 1.f.2 – biogas power plants from 300 kW to 2 MW.

3. Perspectives of Renewable Energy Sources in Danube Region in Croatia

Danube Region in Croatia has very good potentials for solar and biomass energy exploitation. Both Counties are rich with forests, fields, livestock and sun. Figure 2. shows planned power plants on renewable energy sources in this region and it is obvious how much biomass and sun come to expression.

In this chapter terms theoretical and technical potential will be used very often. Theoretical potential is potential of area in case of complete utilization of resources (without losses) and technical potential is potential of area which takes in consideration inability of complete utilization in some areas, energy and raw material losses, exploitation efficiency and similar impacts. Distribution of projects and their power output in Osijek-Baranya County by type of renewable energy sources is shown in Figure 3. and Figure 4. shows same for Vukovar-Sriem County (Ministry of Economics n.d.).

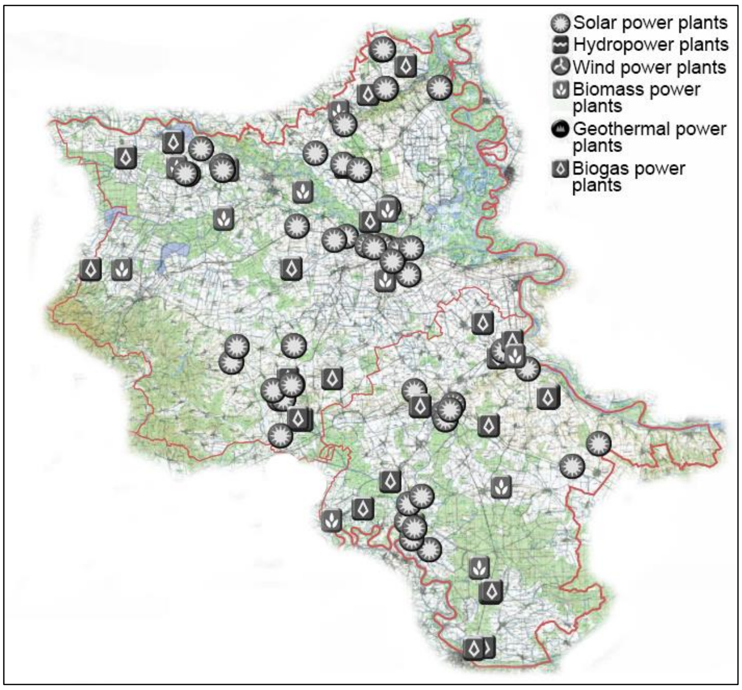

Figure 2. Planned power plants on renewable energy sources [mingo]

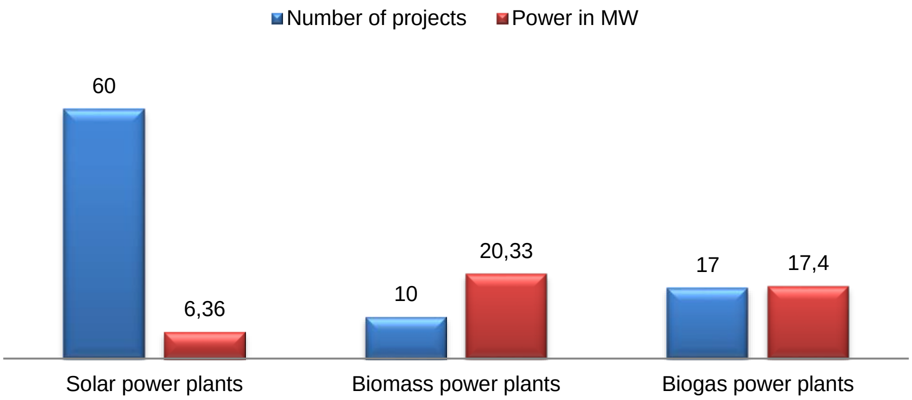

Figure 3. Distribution of projects and their power output by type of renewable energy sources in Osijek-Baranya County

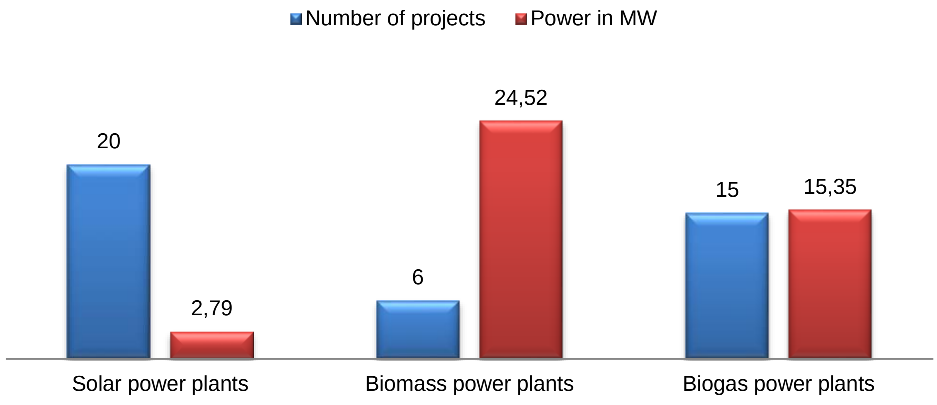

Figure 4. Distribution of projects and their power output by type of renewable energy sources in Vukovar-Sriem County

4. Wind Energy

Characteristic winds for Osijek-Baranya County are northwest wind in warmer months and southeast wind during colder months with quiet times mostly during summer and autumn. The intensity of wind is stronger in winter, but there are no outstandingly strong winds on the annual level which could be used for production of energy. Average annual speed of wind in this County doesn't exceed 5.6 m/s on altitude of 80m. Preliminary available technical wind potential in Osijek-Baranya County is estimated at about 20 MW, while satisfying the necessary technical conditions. In Osijek-Baranya County on the exposed mountain tops of Diljska gora and Krndija, the loess plains in Baranya and some clearings are probably some locations that would have justified use wind energy from the standpoint of available resources. However, identifying potential locations would require a closer investigation, which in this time is not done (Bačan et al. 2012).

Northwest wind in warmer months and southeast wind during colder months are characteristic for Vukovar-Sriem County. The intensity of wind is stronger in winter; however, on annual level there are no particularly prominent winds which could be used for production of energy. Average annual speed of wind in this County doesn't exceed 5.6 m/s on altitude of 80m. Preliminary available technical potential in Vukovar-Sriem County is estimated at about 30 MW, while satisfying the necessary technical conditions. North and more eastern parts of County have best wind energy potential. Determining the potential sites would require a thoroughly research, which at this time hasn't been done (Bačan et al. 2012).

5. Solar Energy

Natural potential of solar energy is estimated by the annual irradiance on horizontal plane (Bačan et al. 2012). Annual solar irradiation and potential power production by photovoltaic installations for Osijek-Baranya and Vukovar-Sriem County with three angles (horizontal, vertical and optimal – 33°) are presented in following tables.

According to data from register of renewable energy sources by Croatian Ministry of Economy, 60 solar power plants are planned to be built in this County with installed power capacity of 6.36 MW (Ministry of Economics). In comparison with current state of installed solar power (99.8 kW) that is tremendous growth.

According to data from register of renewable energy sources by Croatian Ministry of Economy, 17 solar power plants are planned to be built in this County with installed power capacity of 2.72 MW (Ministry of Economics). In comparison with current state of installed solar power (64 kW) that is tremendous growth. Thermal energy is second type of energy obtained from solar irradiance. Solar thermal system can satisfy up to 75% of energy needs for heating domestic hot water in case of a household of four members (solar collectors ~4 m^2 and DHW cylinder volume ~300 l). Both Counties have big potential for solar thermal energy but it requires more researches to obtain concrete numbers.

Table 7. Annual solar irradiation and potential power production by photovoltaic (PV) installations for Osijek-Baranya County (Huld–Suri, n.d.)

	Yearly global irradiation (kWh/m²)			Yearly PV power (kWh/1kWp)		
	Horizontal	Vertical	Optimal	Horizontal	Vertical	Optimal
Minimum	1,192	888	1,342	890	669	998
Average	1,219	909	1,374	909	684	1,020
Maximum	1,236	925	1,395	921	696	1,035

Table 8. Annual solar irradiation and potential power production by photovoltaic (PV) installations for Vukovar-Sriem County (Huld–Suri, n.d.)

	Yearly global irradiation (kWh/m²)			Yearly PV power (kWh/1kWp)		
	Horizontal	Vertical	Optimal	Horizontal	Vertical	Optimal
Minimum	1,236	923	1,394	921	694	1,034
Average	1,254	940	1,417	934	706	1,050
Maximum	1,280	966	1,451	954	726	1,075

6. Biomass Energy

According to the Spatial plan of Osijek-Baranya County, agricultural land covers 266,245 ha or 64% of total area and about 114,257 ha is covered by forest (Grigić et al. 2002).

Biogas is a product of anaerobic decomposition of organic matter; it was assumed utilization of the total amount of manure generated on farms in the County for calculation of biogas production. The amount of waste from animal husbandry is calculated on the basis of data on the number of livestock units of cattle, pigs and poultry. The theoretical energy potential of biogas production in Osijek-Baranya County on an annual basis is presented in following table (Bačan et al. 2012).

Table 9. Energy potential of biogas production in Osijek-Baranya County on an annual basis

Raw material	Availability of manure	Theoretical energy potential (MWh/year)	Theoretical energy potential (TJ/year)
Biogas production in monodigestion			
Cattle manure	344 764	189 620	683
Pig manure	251 901	41 967	151
Poultry manure	16 972	16 758	60
Raw material	Area required for growing maize silage (ha)	Theoretical energy potential (MWh/year)	Theoretical energy potential (TJ/year)
Biogas production in digestion with maize silage (silage mass portion ~30%)			
Cattle manure + silage	4 395	342 814	1 234
Pig manure + silage	3 211	153 897	553
Poultry manure + silage	216	24 279	87

According to the Spatial plan of Vukovar-Sriem County, agricultural land covers 150,856 ha or 62% of total area and about 72,000 ha is covered by forest Premuž – Štajcer et al. 2002). Approximately 40,000 ha of cultivable land is currently used by agricultural companies and livestock farms so there is a lot of potential for growth of biomass energy business, along with Osijek-Baranya County, this County has highest biomass potential in Croatia (Šljivac et al. 2008).

The theoretical energy potential of biogas production in Vukovar-Sriem County on an annual basis is presented in following table (Bačan et al. 2012).

Taking into consideration the existing practice in agriculture, assuming consolidation of livestock production and in accordance with the Energy Development Strategy of the Republic of Croatia can be estimated that about 20% of the theoretical potential could be used to produce renewable energy.

Table 10. Energy potential of biogas production in Vukovar-Sriem County on an annual basis

Raw material	Availability of manure	Theoretical energy potential (MWh/year)	Theoretical energy potential (TJ/year)
Biogas production in monodigestion			
Cattle manure	252 050	138 628	499
Pig manure	100 319	16 713	60
Poultry manure	9 535	9 440	34
Raw material	Area required for growing maize silage (ha)	Theoretical energy potential (MWh/year)	Theoretical energy potential (TJ/year)
Biogas production in digestion with maize silage (silage mass portion ~30%)			
Cattle manure + silage	3 213	250 624	902
Pig manure + silage	1 279	61 289	221
Poultry manure + silage	122	13 676	49

6.1. Biomass from forestry

The most common forms of forest biomass used for energy purposes are firewood, chips, bark, sawdust, shavings, briquettes and pellets. Wood biomass can be converted into heat and electricity as well as in liquid and gaseous fuels using various thermochemical and biochemical technologies. Table 11. presents theoretical energy potential from forest biomass, and Figure 5. shows distribution of total wood stock in Osijek-Baranya County.

Distribution of total wood stock in Vukovar-Sriem County is shown in following figure and theoretical energy potential of forest biomass is shown in Table 12.

Table 11. Theoretical energy potential from forest biomass in Osijek-Baranya County (Bačan et al. 2012)

Total timber stock (m^3)	Total annual growth (m^3)	Annual allowable cut of the stacked wood (including conifers) (m^3)		Theoretical energy potential of annual cut of stacked wood (including conifers)			
				Planned logging		Realized logging	
		Planned logging	Realized logging	GWh	TJ	GWh	TJ
22 291 528	758 689	274 143	186 370	479	1 724	344	1 239

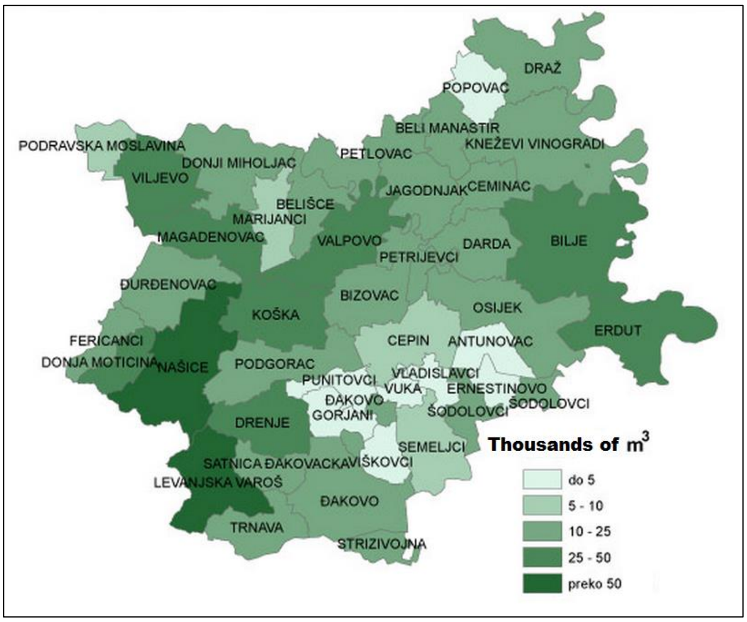

Figure 5. Total wood stock of economic forests in Osijek-Baranya County (Šumska biomasa)

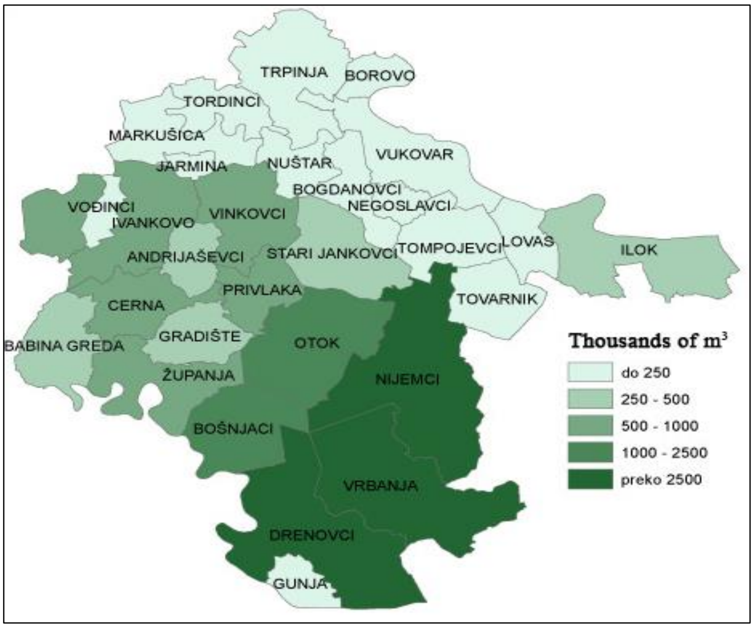

Figure 6. Total wood stock of economic forests in Vukovar-Sriem County (Šumska biomasa)

Table 12. Theoretical energy potential from forest biomass in Vukovar-Sriem County (Bačan et al. 2012)

Total timber stock (m³)	Total annual growth (m³)	Annual allowable cut of the stacked wood (including conifers) (m³)		Theoretical energy potential of annual cut of stacked wood (including conifers)			
				Planned logging		Realized logging	
		Planned logging	Realized logging	GWh	TJ	GWh	TJ
19 602 016	533 733	164 037	163 571	389	1 399	387	1392

It should be noted that the energy potentials shown in tables represent the theoretical potentials. The technical potentials will depend on the efficiency of facilities for production of useful energy (stoves, heating plants, power plants, or cogeneration plants) (Bačan et al. 2012).

6.2. Geothermal Energy

In Osijek-Baranya County the value of geothermal gradients ranges from 40 to 50 °C/km. Thermal water is already found in several deep research wells like:

- Slavonka-1 – 75 °C (1667 m), water is used for spa therapy and for energy purposes (heating);
- Mandarinci-1 – 96 °C (1970–2630 m);
- Bokšić-3 and Obradovci-2 – 41°C (300–850 m);
- Ernestinovo-1 – 74 °C (1600–2100 m).

In Vukovar-Sriem County the value of geothermal gradients are little larger and ranges from 50 to 65 °C/km. Thermal water is already found in several deep research wells like:

- Babina Greda – 110 °C (1571–1585 m) and 121°C (1767–2266 m), geothermal power plant is planned to be built on this location;
- Domaljevac – 70–80 °C (1212 m), water is used for heating of greenhouses;
- Sikirevci – water of technological quality (655–665 m);
- Otok – 130 °C (2635 m) – water flow and quality still not tested;
- Ranisavlje – 130 °C (3000 and 3063–3078 m) – water flow and quality still not tested;
- Lešić – 70 °C (1063–1275 m) – water flow and quality still not tested.

With deep sources of geothermal energy in this region there is also a possibility of using geothermal energy via heat pumps that are suitable for low – temperature heating and / or cooling, and domestic hot water. Mostly their application is for small and large objects. Heat pumps use the constant temperature of the soil at a depth of about 2 m or ground water and use it for reheating during winter and cooling during summer and / or for domestic hot water (Bačan et al. 2012).

6.3. Hydropower Energy

Hydropower potential is not recognized in this area. There is no hydropower plant under 10 MW of nominal power, and there are no plans for the construction of the same (Bačan et al. 2012).

7. Conclusions

Danube Region of Croatia, Osijek-Baranya County and Vukovar-Sriem County, has significant interest in the increasing of use of RES which is shown in this paper. Most of installed capacities of biomass and biogas power are in these two Counties and it will grow even more which is shown in chapter 3. Geothermal energy is still in process of research for whole Croatia not only for this region, but several locations have good potential for energy exploitation, it is used for spa treatments and heat. Waterpower in terms of RES is insignificant in this region, because there are no small and fast rivers. Wind power is also still unexplored area, but few locations show potential for small wind parks.

Conflict of Interest

The authors declare no conflict of interest.

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SOCIAL DOMAIN

Social Aspects and Challenges of Renewable Energy Usage

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Abstract: Increase in usage of renewable energy has many premises and impacts. Of course, technological issues are determinative, beside those there are many social and economic aspects to consider. Awareness of the users, knowledge about the possibilities, legal regulation, reliability of supply chain, cultural and religious traditions are just a few examples that should be considered in a project initiative. A special problem is that most of the social impacts is difficult to measure. Some factors are represented in statistics e.g. personal thinking can only be analysed by soft methods. Conference presentation of the Social Domain draw up a picture about the macro-effects. This paper shows the frames by highlighting a possible list of the factors and it gives additions to the state of personal aspects.

Keywords: social issues, social domain, social evaluation, personal factors

1. Introduction

Sustainable development is a common challenge of the mankind and the science. The theory of zero growth worked out by the Meadows-team led to general resistance in 1972. This means that the economic factors are more important than the environmental problems. Further researches tried to find a complex and generally acceptable viewpoint, the possibilities of harmonisation between the environmental, social and economic interest. The basic concept of sustainability was first published by Lester Brown in 1981 but the complex model of sustainable development was worked out by the Bruntland-Committee (Brundtland 1987) later. It seems the general solution, but the highlighting of the economic pillar often gives escape from the actions and development.

Nowadays, the corporate social responsibility (CSR) boosted up the topic because it defines the fight against environmental and social problems openly as a business category (Schwartz 2011, Simpson and Taylor 2013). Of course the basic question remains whether the efforts lead to true responsibility. Tóth (2007) points out that it needs changes and a new approach in business strategy, or it is only a spectacular mask for influencing the consumer behaviour.

Beside the general development of the concept of corporate social responsibility there are industrial solutions, methods and tools necessary. The technical approach forces the development of efficiency, including finding new ways and sources. Using renewable energy sources is one of the most important part of achieving sustainability. Of course, plant reality depends on economic and financial possibilities (Somogyvári 2011). It should be seen that support background is inevitable. There are some voluntary corporate programs and regional initiations, but the experiences show that the profit-orientation can be overwritten mainly by legal requirements.

2. Methods

Economic assessment is usually a part of feasibility studies. It also may represent the social domain but it cannot cover all challenges because it deals only with aspects that are to express in monetary terms. Handling public goods, social welfare, individual preferences and consumer behaviour needs both quantification and expert methods. Most difficulties emerge because of the time-effect and the interrelations: social impacts of e.g. a new technology reflects in the long run (discovering the diffusion progress is inevitable) and permeated of other technical, social and economic results. Social inclusion has a slow and complex progress (Deutsch 2014)

Deustch (2011) deals with the assessment possibilities related to a given technology. The followings must be investigated before starting a new technology, including the case of planting a known technology to new users:

- Space need per capacity
- Aesthetics of plants and the related infrastructure
- Noise effects of utilisation
- Expected social conflicts and resistance
- Need and state for risk-taking of the population
- Participation need and possibility
- Need for personal control of utilisation and usage
- Need for education
- Potential disasters

In a wider approach there is a need for a wider criteria system that allows both the assessment of the current state and the impacts of development action. A comprehensive list of aspects can be as follows:

- Personal thinking: personal factors, level of knowledge
- Technological availably
- Institutional frames
- Health impacts
- Labour market impacts.

The personal factors include awareness, consciousness, living conditions, personal financial-economic factors and the expected changes in those. National and local cultural impacts must be also considered. Level of knowledge about the technologies and the impacts is worth to be separated. Of course, the level of knowledge has a significant influence on decision but a limited and deformed information base can be expected. The wider approach pays attention to education, corporate training, structure and content of education, and information about the availability best practices.

Analysis of technological availability must involve the social impacts of exploitation, investment and continuous use of RES. Institutional frames completes the analysis with legal requirements and possibilities, bureaucracy, centralisation of decision making, ethical issues, CSR, analysis of stakeholders etc.

The log run social effects can be measured by health status of the society (impacts of technology on people and communities, mortality and morbidity). Considering the welfare and the personal aspects of economic impacts can be represented by the labour market impacts (impact on employment structure, job creation, level of wages and salaries).

3. Results and discussion

In my opinion the level of knowledge and personal attitudes has a determinant role on consumer decisions and eventually on the diffusion patterns of RES/RET. Of course, legal actions and support can hijack the current development, but the true and basic breakthrough requires the consideration of personal behaviour.

I can illustrate the distortions with some results of an empiric research (Berényi 2014). The figures below show the opinions of 104 higher education students who are the future decision makers (data collection period: autumn of 2013). The used questionnaire specifies a list of global problems and asks the respondents to mark on a 1..6 scale the opinion about the level of them. There are separated lists for marking the level for local environment, the European Union and the world. Local performance was considered better in most cases but feeling safety is a bit worse. It is interesting to note that factors of everyday problems show nearly the same value on both levels (crime, food healthy, household waste, degradation of nature and built environment). Among the listed factors the respondents felt cultural changes less problematic what is interesting in the mirror of the professional opinion that social problems induce environmental ones (Figure 1).

The evaluation of global level uses different method: maximum 3 elements of the list could be marked as important problems. This method helps to moderate the deformation of the answers by the social shared expectations. The most problematic issue is the depletion of energy resources on global level (Figure 2). Starvation (social problems) was the third important problem but the environmental factor dominate visibly. It can be concluded that the respondents considered the distant problems more serious or they push the problems away and do not assume that they were living in them.

It can be expected that the formal opinions and the content of the activities sharply differ from each other because the need for meeting the social expectations or group pressure can influence both (Smith & Mackie, 2007). Considering the lack of knowledge and the popularity of the topic this distortion shall be managed. The questionnaire contains 6 topics. Respondents can mark pairwise which one would be sacrificed by a company. I used the Guilford method (see Kindler & Papp 1977) for checking the consistency level of the answers. 49 of the 104 respondents reached 100% what means that they have absolutely clear order of preferences about sustainability. The factors and the relative positions are summarized in Figure 3 for the sample and grouped by bachelor/master respondents (the results of the part-samples are not directly comparable, only relative position can be drawn on interval-scale).

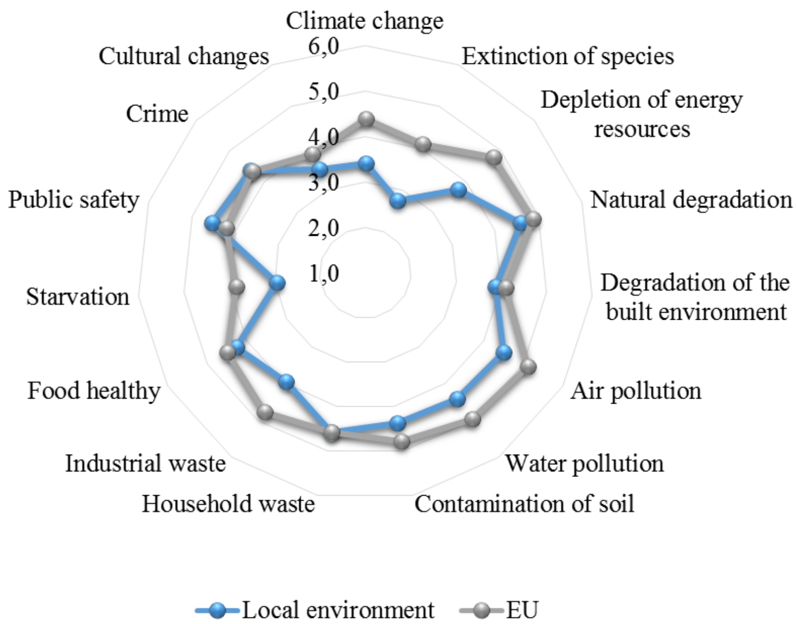

Figure 1. Evaluation results on local and EU level (measured on 1.6 scale).

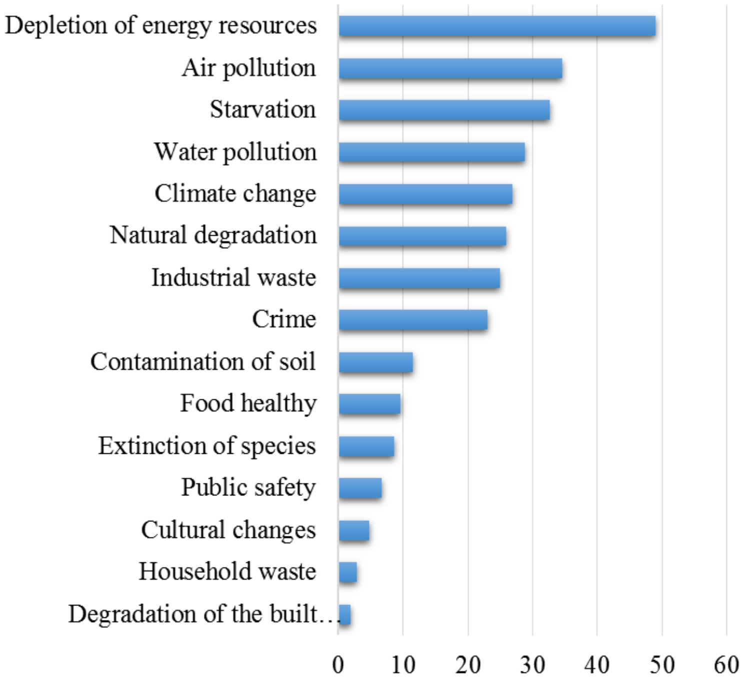

Figure 2. The most important global problems (on worldwide level, % of the respondents).

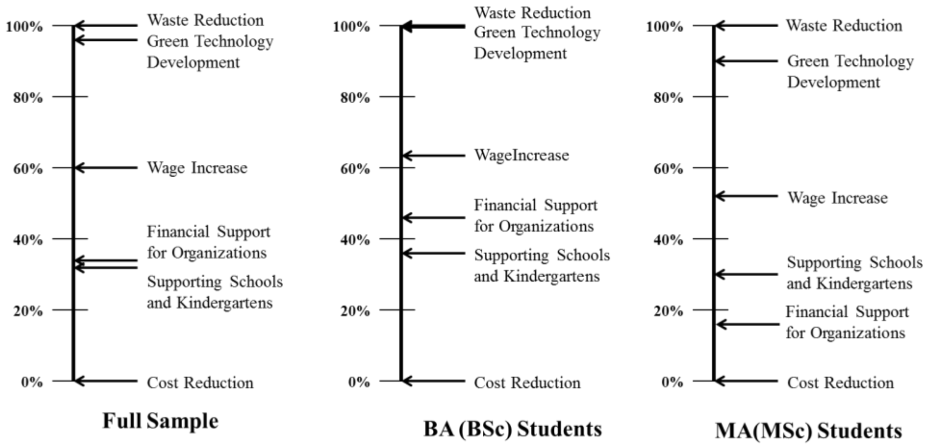

Figure 3. Preferences in the sample and part-samples. Source: own construction

The prioritization order of the factors is similar in the samples but comparing the results of the bachelor and master students it can be seen that master students have more sophisticated opinions. An interesting finding of the analysis was that the order of waste reduction and green technology development is reserved grouped by gender. While women prefer waste reduction, men see the solution of sustainability problems in green technologies. The women's approach highlights the directly visible result; encourage greening needs an integrated approach. Both are important but there are basically different approaches.

4. Conclusions

Assessment of social impacts is complex issue that requires a multidisciplinary approach and toolset. It seems obvious to express the problems and the solutions in monetary terms but it is not possible. Differences in individual needs, local possibilities or cultural background makes the social impacts difficult to measurable. Using expert methods can expand the possibilities and justify usefulness of development actions.

It is further complicated to evaluate social impacts because individual and social interest may be in conflict with each other. The impacts are represented in social statistics and in performance indicators (see e.g. Varjú 2014) but discovering the causality of other influencing factors and time-effects is difficult. Individual attitudes and opinions may be divers. It seems to be appropriate to represent the people with an average value of the characteristics but as consumers they must be convinced individually. In my opinion one of the most important barriers is to overcome the problems of misunderstandings and lack of knowledge.

Solving the problems and achieving a general agreement on the assessment criteria of social issues of RES/RET topic go far beyond the limits of one publication. The aim of this paper was to draw attention to key possibilities.

Conflict of Interest

The authors declare no conflict of interest.

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The Theory of Environmental Modernization and its Feasibility Application in Capitalist Economy. The Case of Renewable Energy Diffusion in Romania

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Abstract: Addressing major environmental challenges (global warming, ozone rarefaction, fading biodiversity, rampant deforestation and large urban areas living conditions deterioration) requires international concerted efforts, national public policies and strategies, developed and implemented in a proactive and intelligent manner, and sharpening the civic responsibility. Within environmental sociology field there is a continuing debate focused on the causes, consequences and future steps for the society in terms of various environmental issues, including global climate change, which appears to be the most important of them. Large corporations are increasingly turning to renewable energy to power their operations. Companies are investing in renewable energy because it makes good business sense: renewable energy helps reduce long-term operating costs, diversify energy supply and hedge against market volatility in traditional fuel markets. Even if companies and institutions must undergo transformations of all levels to survive in a future of limited resources, the feasibility of ecological modernization remains a serious problem in the capitalist economy because a very rapid change would have major implications on the stability of existing social systems. The aim of this paper is to perform a diagnostic analysis regarding the development the RES from wind and photovoltaic sources in the Danube region, with a focus on the energy diffusion in Romania.

Keywords: feasibility, renewable energy, Romania

1. Introduction

Even though global climate change is not the only challenge of our times, environmental issues seem to be the most pressing ones. There is an almost unanimous recognition among scientists that environmental issues will have serious implications during the 21st century. Starting with Peter Drucker (1999), the father of modern management, it has become already a truism that economic performance should depend now by new determinant vectors for ensuring economic growth. This "new idea of economic growth" is mandatory to be smart, sustainable and socially inclusive in order to be placed in a new dominant logic. Although the acknowledgment of the need for a new paradigm is welcomed, environmental organizations continue to be dominated by natural and physical scientists, with little training in social sciences. More than 30 years after William Catton and Riley Dunlap (1978) called for a "new environmental paradigm", some things seem to have been clarified: 1) social scientists have greeted this optimistic signal and have spawned "environmental sociology", a viable sub-discipline; 2) a "new environmental paradigm" still remains as a challenge currently unfulfilled; 3) environmental technical issues such as global climate change remain largely isolated in physical and natural sciences field, indicating the need for trans-disciplinary research. Based on some aspects of important qualitative studies performed in the field of "environmental sociology", the aim of this paper is to make a critique analysis about feasibility application of ecological modernization theory in capitalist economies of Danube Region, the case of Romania.

2. Theoretical Background. An economic perspective on feasibility of Ecological Modernization Theory

In the spectrum of environmental sociology, there is a continuing debate focused on the causes, consequences and future ways for society in terms of various environmental issues, including global climate change, which appears to be the most important. However, there are two angles from which the reference to this problem can be started. The first line of reasoning is placed into the logic of capitalist economic development theory and imposing a lesser concern in relation to ecological modernization. From this perspective, ecological modernization is marginal because overlapping economic action is centered on continued economic expansion, accompanied by capital accumulation. The latter should be done by changing priorities resulting from the creation of new renewable energy systems and a coherent state action on environmental development (Mol 1995, Mol and Spaargaren 2000, Mol, Spaargaren and Sommemfeld 2009). Focusing on this line of research, basically means that in the future, companies must change their attitude towards environment to become sustainable and to be considered reformed, from environmental point of view. The second line of reasoning seems a more radical approach, and is based on a very critical perspective of the current economic system, which is currently held responsible for the magnitude of environmental problems. Arguments to support ecological unsustainability of the current economic system were found in field literature (Clark and York 2005, Dietz, Rosa and York 2007, Foster 1995, Gould, Pellow and Schnaiberg, 2008, O 'Connor, 1998, Schnaiberg and Gould 2000, York, Rosa and Dietz 2009). Guidelines according to which environmental programs should be focused on, so as to minimize the number of existing unsustainable areas in the current economic system, created a lot of controversy among specialists and still generates disputes among them. According to York and Rosa (2003) and York (2008), reformed ecosystem can provide a path to a better future, but there are not compelling evidence yet, that this process has as vector the current model of sustainable development. In conclusion, all ideas making up the reform process architecture were generalized, definitely have been introduced on the agenda of public debate on regional and global response in the face of such challenges, and can favorably contribute to profound changes at the institutional and regulatory level. For such reasons, for both the entire international community, and the highly industrialized states, the problem is just a matter of "when and by whom it will be made" (Friedman, 2008). Addressing economic and environmental systems, from this transition perspective, revealed an optimistic assumption of modernization theory called Ecological modernization, very well epistemological and methodological structured, because it combines economic development ideas in close relation to environmental sustainability. Although most environmental reform theories consider the functional market economy, and especially neo-liberal subcomponent, incompatible with this type of companies' ecological modernization, modernization followers argue that the transition from traditional resources exploitation to redesigned sources can occur within existing structures, under the circumstances of providing new future industrial development, through technological paradigm shift, ensuring a high environmental level (Mol 1995, Mol and Spaargaren 2000, Mol, Spaargaren and Sonnenfeld 2009). I have identified, in the literature field, a set of counter theories, having in common the belief that the current capitalist system, an environmental unfriendly one, and intensive energy consumer, cannot be ecological sustainable. Foster (1995) explained the idea through the annual growth of 3% in industrial production, which would basically mean that industrial production would double every quarter century.

3. Global situation of investments and policies

In terms of economics, global renewable energy can be conceived, not only as an energy source in itself, but as a way to reduce transaction costs in companies, at the same time solving other pressing issues, where we can include: employment by creating new jobs in the "green companies" sector, health costs reduction, by limiting the harmful effects on health and environment, associated with fossil and nuclear energy, improved educational opportunities and poverty reduction by increasing the quality of life. Moreover, in the European Union, the positive effects of investments in renewable energy sources can be enhanced by ensuring energy security. A close look on specialized reports that include global progress, can reveal an optimistic policy trend linked to funding alternative energy sources that somehow seems to have been passed to states' mainstream. According to 2014 REN21 report, the renewable energy investments value has increased to over 84% globally and reached

USD 220 Billion, from 2004 to 2013. Thus, renewable energy at the end of 2012 represented 19% of total consumption and continued to grow strongly during 2013. Modern Renewable Energy was being increasingly used in four distinct markets: power generation, cooling and heating, transport fuels and rural/ off-grid energy services. Also, according to a global top 5, which includes end of 2013 data, China ranks first by dividing the total value of investments in renewable energy sources development, followed by US. Among the European Economic Area's countries, this ranking contains also data for United Kingdom and Germany, as last positions. The report also provides optimistic data regarding the growing number of states adopting governmental policies in terms of environmental reform. Their values, significantly increased from 48 in 2004 to 144 in 2013.

4. Development of renewable energy from wind and photovoltaic sources in Danube Region. Case of Romania

The European Union has developed an ambitious energy policy that covers all renewable energy sources (solar, wind, geothermal, hydro) in an attempt to trigger a new industrial revolution, leading to low energy consumption economy and climate change limitation, assuring that the energy we consume will be cleaner, safer, more competitive and sustainable. EU directives aimed at combating climate change and promoting the use of renewable energy sources had as initial target the reduction with 20% compared to 1990 of greenhouse gas emissions, increasing by 20% the energy from renewable energy sources (RES), by total EU energy consumption and a target of 10% bio-fuels in transport energy consumption. Nationally, in order to meet environmental targets set by EU2020 strategy, the Romanian government set up more ambitious environmental policies regarding energy production from renewable sources, so that the gross consumption of total produced electricity to be at the level of 33% in 2010, 35% in 2015 and 38% in 2020. According to Romanian Wind Energy Association (2011), the number of companies and business units that conducts research and development operations associated renewable energy is increasing. The most important progresses was obtained in development of energy from wind and photovoltaic sources because its have the highest potential for exploitation. According to the National Action Plan for Renewable Sources Energy, until 2020, approximately 12,589 MW of energy should come from renewable sources, out of which 4000 MW from wind energy. Economically, the wind power has faced increased levels in recent years in Romania, especially in Dobrogea, on the Black Sea coast. The most important centers in this area are represented by Tulcea and Constanta counties. According to Society of Power Engineers (2014), evolution of Romanian installed capacity in wind plants has known a significant upward trend from

2005 according to Table 1. By end of March 2014, the total installed capacity, according to green certificates policy, was produced in 97 wind plants.

Also, the same report reveals that the 2013 total electricity nationwide produced in power plants based on renewable energy, sustained by green certificates policy, was 6279 THW, approximately 10.55% of the total energy produced in Romania, out of which 67.07% in wind power farms and 17.86% in PV plants. The maximum power produced by wind farms in Romania was 2,294 MW, recorded at 08.05 a.m. on 03.10.2014, being the main source at that moment, according to Table 2.

Table 1. Evolution of wind-energy development in Romania during 2004–2014

No.	Year	Power/ MW
1	2005	0.9
2	2006	2.6
3	2007	6.7
4	2008	6.9
5	2009	14,2
6	2010	370,3
7	2011	826
8	2012	1822
9	2013	2782.5
10	01.04.2014	2901,2

Source: Society of Power Engineers, 2014.

Table 2. Situation of electric energy consumption from wind source

1	Total electric energy production in National Energy System	8591 MW
2	Wind electric energy	2294 MW
3	Coal electric energy	1969 MW
4	Hydro electric energy	1774 MW
5	Nuclear electric energy	1431 MW
6	Gas electric energy	1020 MW

Source: Society of Power Engineers, 2014.

The second type of renewable resource enjoying a large development potential for exploitation due to land in agricultural areas, is the photovoltaic energy. Expansion of green energy was achieved largely in the south of Romania. According to the European Photovoltaic Industry Association report (2014), Romania ranked the 4th in the total 2013 EU market, with a 10% produced photovoltaic energy, being surpassed only by Germany (30%), United Kingdom (14 %) and Italy (13%). In Romania, the evolution of total photovoltaic capacity installed was developed in a fast pace during 2010–2014. Table 3 is showing a spectacular evolution of the photovoltaic plants number, according to the SPE Report (2014).

Table 3. Evolution of photovoltaic energy in Romania

No.	Year	Number of photovoltaic centrals	Electric power generated in MW
1	2010	1	0,009
2	2011	4	1,011
3	2012	32	44,329
4	2013	348	1.022, 04
5	April 2014	411	1.171,81

Source: Society of Power Engineers, 2014.

5. Methods

The theoretical part of this paper follows a critical literature review from the economic perspective of environmental reform such as ecological environment modernization theory, trying to explain the economic conditions for its feasibility and to show the reality in terms of global investments and adopted policies. The information was collected using international data bases such as: ISI, Web of Knowledge, Science Direct, Scopus, Jstore and ProQuest. The global investments findings and related trends in this area were obtained from REN21 and EPIA reports in 2014. Renewable Energy Policy Network for the 21st Century and European Photovoltaic Industry Association could be considered the most important sources in the field of renewable energy due to their annual reports, for the strongest economies of the world. This analysis offers a prospective assessment of how and at what scale states are committed to invest in and procure renewable energy. This report findings are based on publicly available information. The data provided in tables was collected from Romanian Society of Power Engineers 2014 report.

6. Conclusions

Ecological economy reformation has already known an important development, and seems to keep growing, beyond the budgetary problems occurred by the global financial crisis, members configuring their public agendas to adopt environmental policies and establish specialized institutions to guard the fulfillment of ambitious targets. Availability of the largest global economies for future investment in reducing the consumption of non-renewable energy, greenhouse gas emissions, wind and solar energy production and increased consumption of renewable energy, make us optimistic and confident. Globally, after analyzing data on environmental investments, the first important conclusions can be drawn. First, we can look confident to reformed future of Europe, by the fact that Britain and Germany, the two most important economies in the European Economic Area, rank a Global Top 5. Secondly, it can be surprisingly the 1st rank of China, because it demonstrates, to some extent, the fact that emerging economies can quickly transit to ecologically sustainable systems. Further on, as a member of European Union, Romania has set ambitious environmental targets, higher than EU2020 goals. In this respect, the reports provided by the Romanian Association of Power Engineers, shows great progress in the field of wind and Photovoltaic sources. Although the rate of exploitation of these renewable sources is alert, we detach however the idea that complete shutdown of traditional sources and ensuring energy security, still remain as goal stage. First, a rapid transformation can have major economic implications for fragile economies, on the stability of the existing social systems, in most of ex-communist countries. However, this gap can be filled by applying alternative government policies, much needed in transition period systems. From the jobs' sustainability perspective, companies producing wind and photovoltaic energy, could provide jobs not only for installing parks or other services, but also in research needed to develop other types of renewable sources. From this economic perspective, the feasibility application of environmental reform seem to be transition dependent.

Acknowledgment

This work was co-financed from the European Social Fund through Sectorial Operational program Human Resources Development 2007–2013, project number POSDRU/159/1.5/S/142115 "Performance and excellence in doctoral and postdoctoral research in Romanian economics science domain".

Conflict of Interest

"The author declares no conflict of interest".

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An analysis of Social Effects of Climate and Energy Usage Modernization: Romanian Green Labor Market

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Abstract: One of the key factors differentiating countries performance, considering the tight competitive climate, is the attitude towards environmental issues. Besides positive environmental outcomes of sustainable energy usage and climate change, national economies face positive, but also negative social results. In this logical thinking of sustainability, European countries' strategic thinking thrives to increase quality and life standard of individuals, through social and economic integration, for which concerted actions of governments, businesses and communities are imperious necessary. Smart and proactive attitudes towards environmental issues are carefully underpinned by national policies, under the close surveillance of European Union, in order to reach targeted objectives of becoming an example of smart, sustainable and inclusive integration mechanism. In this limited resources economy, the paper discusses the sustainable social actions taken in the light of EU 2020 strategy, by map drawing the corresponding effects of greenhouse gas emissions reduction, renewable energy sources used in final energy consumption and energy efficiency indicators, on social outcomes such as employment, at the level of the Danube Region. At the mid-term for the 10 years strategic timeline, the paper performs an exhaustive evaluation for the "green" jobs labor market, emphasizing the environmental sustainability at the level of the EU countries around the Danube River.

Keywords: sustainability; greenjob

1. Introduction

The environmental issue is a subject frequently brought into any discussion and nowadays it is considered, both by researchers, as well as decision makers, as an emblematic matter of the century. In this respect, the social effects of eco-friendly actions have a large amount of literature to reveal a two dimensional approach, one where ecology impacts differentially the society, and one where the economy benefits from environmental moves both economically, through patterns of production and consumption (Pye et al. 2008), as well as socially. Therefore, there is a need for concerted efforts from both policy makers, and social actors, to take an integrated approach regarding this matter. The aim of the paper is to perform an exhaustive evaluation of the environmental accounts at the level of the Danube Region countries, in order to outline the potential impact in the green sector's labor market. The elected case study is the Romanian employment in the environmental areas.

There are several years since the European policies are focusing, to a greater extent, on how to make a sustainable and inclusive European economy using smart means. It has become a usual comparison for the amount of pollution produced by industry and households and the value of output produced by these sectors or the production of eco-friendly products, which may be weighted in the employed population purchasing power and life satisfaction index, thus the environmental accounts serving as important gateways towards a more inclusive Europe. Accordingly, the environmental modernization theory, simply associated with the consequences and future steps of the society in terms of ecologic actions, plays an important role for reaching a sustainable Europe.

2. Environmental sustainability and the importance of social response in Europe

The great need of social gains in such an effervescent economic environment, fueled by austere budgets, explain the rise of importance of the ecological modernization theory. The dominant approach of the EU's sustainability lies on the fundamentals of ecological modernization theory. It has gained a lot of attention during the last decades due to its large contribution to the economic growth. At a first look, ecology and economy have no positive effect on welfare, but deeply analyzing the matter, like its substantial contributors have (Mol and Spaargaren 2000), economy and ecology can be favorably combined. Environment, in the form of air, water, soil, ecosystems, and industry means of production, as future incentives of growth, can be compared with the same amount of development in labor productivity and capital productivity. In other words, potential innovations that reduce the natural resource usage in terms of quantity, structure and quality, thus transforming the production mechanism in terms of people's input, can bring new patterns in social value orientations, skills and knowledge.

It has already become a truism that ecological modernization is now a subject of great importance between social scientists and decision makers. Today's economy is highly stumble through by two dominant directive lines, one that strands for the ecologic modernization theory which focuses on social-ecological decisions and continued expansion of economies, with a shift in priorities, resulting in new energy systems, and another one looking at the economic systems that are ecologically unsustainable (Smith et al. 2011). For some scientist, the environmental reforms are frequently part of any political decision due to the fact that economic expansion, growth and changing patterns of consumption, and change in technological capital use, compromise the ability of states to ensure a quality environment (Hajer 1995).

Both main lines of thought, although similar, differ, one due to positive attitude towards the future and social status, the other due to a focus on the limitations of the economic system.

Ecologic modernization represent one of the mainstream environmental – sociological perspectives, according to Buttel (2000), which tends to give significant importance to private eco-efficiencies and overall environmental reforms, due to the fact that its involvement is highly approached by social scientists (Schnaiberg et al. 1999, Redclift and Woodgate 1997, Mol and Spaargaren 2000, Mol 1999, Cohen 1997). The line of unsustainable economic system shapes, in a distinctive way, the idea of environmental destruction, basically because of existing capitalist systems, although such a theory does not bring enough arguments to overcome these actions. On the other hand, ecological modernization is viewed as a possible solution to prolong life and avoid the environment degradation and global climate change, thus making the economic system more sustainable. From this perspective, academic research and large public debates, bring lots of pros for this approach (Mol 1995), as a response to ecological crisis. The main principles of ecologic modernization intend to severely reduce the burden of industrial growth without alternatives. Using smart incentives in order to reduce the environmental pressure and increase innovation capacity, often being motivated by potential competitive advantages, notable economic value and lower business risks, the ecological modernization becomes a strategic approach for environmentally intensive companies (Janicke 2007).

Although it is believed that capitalism is the evil hand damaging the environment (Spaargaren and Mol 1992, 2000), instead it is perhaps only one viable means of economic production, permanently reengineered in order to meet the needs of an ever changing world. The consequences of all forms of production are continuously damaging the ecological systems by an increased level of natural resource extraction and pollution (Schnaiberg 1980, Schnaiberg, Gould 2000, Gould, Pellow, chnaiberg 2008). Moreover, even if the capital accumulation is expected to grow under the capitalist ideology, it does not solve the problem of wealth distribution around the globe, and green jobs are one mean of transfer of such earnings. According to Oxfam report (2014), the world's 85 wealthiest people have as much money as the 3.5 billion poorest people on the planet, representing a significant threat to inclusive political and economic systems.

3. A strategy for smart, sustainable and inclusive European growth

Initiated from an irrepressible desire of continuously emerging new sets of instruments for becoming an example of unification, constantly overcoming the colossal effects of the global crisis, in 2010, the European Union Council launched the 2020 strategy, intended to shape the transition towards a smart, sustainable and inclusive growth. Considered as a transformation path for the Member countries, the strategy defines five headline targets, covering a wide areas like education, poverty and social inclusion, employment, R&D and, nonetheless, environmental targets represented by the trinomial 20 - 20 - 20 indicator - greenhouse gas emissions reduced by 20% compared to 1990 values, increased share of renewables on total energy consumption to 20%, and increased energy efficiency by 20%. The Europe 2020 strategy, contributes to Europe's industrial innovation and technological leadership in a smart, inclusive and sustainable way, the latter being a transversal objective to reduce the burden of implementation of environmental accounts.

The concept of "green jobs" among field vocabulary has reached great notoriety due to its positive responsiveness to the global challenges of environmental protection, economic development and social inclusion. It is a dynamic concept and relatively new, referring to those jobs that protect ecosystems and biodiversity, which, according to the Green Jobs Country Report (2014), through high efficiency and reengineering, reduce energy, materials, and water consumption, minimize the burden of waste and pollution. Thus, it is a mean of transition towards „new skills and new jobs" (European Commission, 2010).

The EU 2020 strategy is currently under the loop for its implementation phase, and benefits, to a large extent, from a great criticism effervescence regarding its potential for full or partial fulfillment of the targeted objectives. Starting from the premises that, in the absence of an agreed standard for measuring yield, EU encounters significant difficulty in monitoring the output of such ambitious targets, more like pseudo-indicators. The awareness of its great importance has raised several risks associated with the negative effects that the accomplishment of some indicators may be linked to others' failure, like the reducing of greenhouse gas emissions with 20% by closing effects from the chemical industry, especially in the Eastern part of the Europe, including the Danube region countries, may lead to increased unemployment ratios in industry and imbalance the poverty reduction goals. An East European country, Romania is the case where a lot of such production systems were closed, encountered great problems with unemployment in affected areas, but still registers slight increases in the area of employed persons in environmental systems. Andrea Renda (2014) completes the critiques and rises important feasibility questions for the strategy, assessing the European Commission evaluation as "euphemistic" because of the "mixed results" that have been achieved so far. According to his appreciation, the educational target and the environmental one are the most reachable ones, the latter being on its track due to a significant industrial production slowdown, accompanied by the economic crisis. In counterbalance, "the new skills and new jobs" flagship is appreciated as being the one target with no chances of success. In a personal opinion, the flagship can be partially reached, in a specific, yet not exclusive, from the green sector.

4. Methodology

Following a critical and quantitative literature analysis, the paper applies a systematic analysis of the relevant qualitative and quantitative environmental indicators with respect to sustainability and employment rates in environmental areas, with a focus on the Danube region countries and the case of Romania. The article attempts to provide a holistic understanding of the environmental and human consequences of the widespread adoption of "green" efficiencies objectives.

Accompanied by a concentrated literature based on the ecological environmental theory, the comparative analysis was performed based on the most relevant data for EU28, selected Danube region countries and Romania, based on Eurostat and national offices statistics. The illustrative analysis is expressed through statistical and graphical data management (dynamics and intensity), using Excel features in order to reveal the performance of selected countries.

5. A trend towards the "green" labor market in the Danube region. The case of Romania

The European labor market appears to be in a transition towards more green jobs. This is caused by the business opportunities dynamics of services and energy market transformation. The Eurostat report on employment in the environmental goods and services sector (2014) reveals optimistic data concerning the increasing number of green jobs in this field, as we can observe from figure 1.

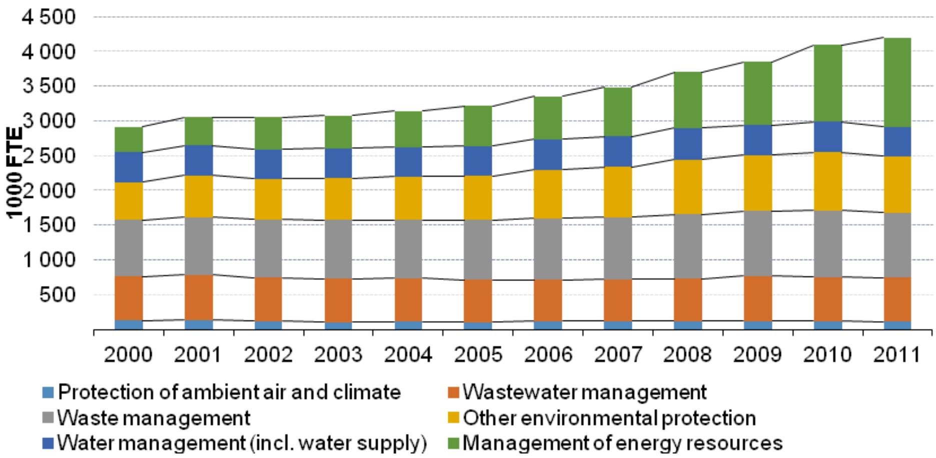

Figure 1. EU28 Employment in the environmental goods and services sector

Source: Eurostat, http://ec.europa.eu/statistics_explained/index.php/Environmental_goods_and_services_sector

The request for developing a green labor market in the European Danube region countries has been one of the most difficult ones, involving them in complying with environment as of EU2020 indicators. In their continuous move towards reaching ambitious targets for CO_2 gas emissions and smart increase of employment rate, including the field of "green" jobs, are created with significant social costs, destabilizing the old systems. Most of the Danube countries, in order to make a smooth transition process from communism to capitalism, have passed through major economic changes at all levels. From large fossil fuels consumer systems and alarming CO_2 gas emissions, but with an impressing number of jobs, the transition seem to have been done in a great proportion. Table 1 presents a status of the employment levels in green sector for the selected countries.

Table 1. Employment (FTE) in environmental goods and services sector selected Danube region countries

Country	Green jobs (Full Time Equivalent)				
	2009	2010	2011	2012	% over 2009–2012
EU28	3,934,000	4,068,000	4,181,000	4,282,000	108.85
DE	347,973	385,576	421,006	421,006	120.99
AT	169,589	170,192	171,245	173,702	102.43
RO	127,859	118,000	130,266	146,026	114.21

Sources: Eurostat, 2014, http://www.statistik.at/, https://www.destatis.de/EN/Homepage.html and http://www.insse.ro/cms

According to the latest available trends on Eurostat database, Europe had a 42% rate of employed persons, working in environmental productive output in 2013. Although is passing great difficult transition times, Romania is a key player in the Danube region, struggling to temperate the crisis effects for reaching the full benefits from a cohesion economy. The Romanian labor market has been tightened by the repressive effects of the economic crisis, but still allocates significant effort to build a smart, sustainable and inclusive economy. We can observe in Figure 2 that, according to the National Statistics Office, the number of "green" jobs in the environmental sector, although little (approximately 1.5% of the total employed population), is continuing to grow, due to important efforts in constantly increasing the number of productive systems of renewable energy and resource efficiencies. Many of the "green" jobs are found in economies that produce eco goods and services or in environmental protection and resource management activities.

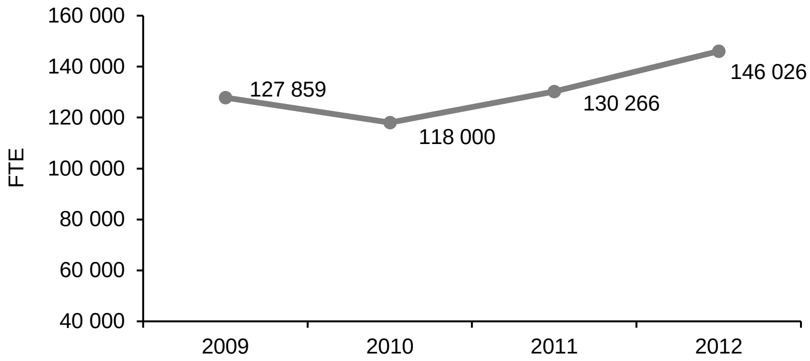

Figure 2. Employed FTE in environmental goods and services sector in Romania
Source: National Statistics Office, Romania, author's own computation

6. Conclusions

In order to continue building a dynamic framework to reinforce green initiatives and instruments for performing competitively worldwide, in terms of energy and environmental policy, the EU pays important efforts to stimulate the green sector. Slight, but sure, the green jobs market is moving forward and shows an upward trend, constantly adapting to the practices of sustainable economy. Among EU countries, comparing western to central and eastern ones, there are significant differences in terms of green jobs market, mostly influenced by their economic performance. The Danube region countries seem to register lower levels of employment rates in environmental sector, compared to the western part of EU, the differentiating factor appearing to be the same. The Romanian case, considered for the paper, shows a slow growth of green jobs field, instead the trend appears to have lower levels compared to European performers. The evolutions in the green labor market seem to have small, but continuous tendency, showing that the socio – ecological transition to smart sustainability and inclusiveness is moving on, according to the strategic plan.

Acknowledgments

This work was co-financed from the European Social Fund through sectorial Operational Program Human Resources Development 2007–2013, project number POSDRU/159/1.5/S/142115 "Performance and excellence in doctoral and postdoctoral research in Romanian economics science domain".

Conflict of Interest

The author declares no conflict of interest.

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ECONOMIC DOMAIN

Note on the Economics of Renewable Energy Technologies in the Danube region

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The European Union is committed to a substantial increase in renewable energy over the next decade as a major part of its programme to reduce carbon emissions. In order to achieve the ambitious goals determined in the EU's energy strategy, fast diffusion of renewable based energy generation technologies is needed. This is especially true for the countries of the Carpathian Basin and the Danube region. However extensive proliferation of these technologies is inhibited by numerous economic and social obstacles, which can only be overtook by systematic and continuous efforts and knowledge transfer. To identify the effective measures abolishing the barriers against the use of renewable based energy technologies, not only the economic profiles of technologies, but economic aspects of macro, mezzo and micro level affecting the diffusion of these technologies, and their relationship should also be examined.

As Figure 1 shows, the determinants of the competitiveness of RETs can be classified into two main groups, i.e. macro and technology-specific aspects can be distinguished. From macro point of view the development, use and diffusion of RETs depend on the current and expected states of political and legal, industrial or market, technological or engineering and also social issues, which can represent potential opportunities or threats, barriers for RETs in total or for the different technology groups. If we make a closer look at the *market barriers*, we can conclude that the state of liberalisation is quite different for the counties of the Danube region. However it can also be identified, that these markets are quite concentrated which means, that vertically integrated or quasi integrated dominant actors with their existing, mostly fossil-based technology portfolio are in a good position, who are poorly motivated to invest in new, RETs, which can be inconsistent with their asset, knowledge bases, and the high amortization value of the existing stations. As entry barriers are quite high in this sector new entrants are in a hard position. This is further strengthened by the different market risks, the different conditions and fees of network and market

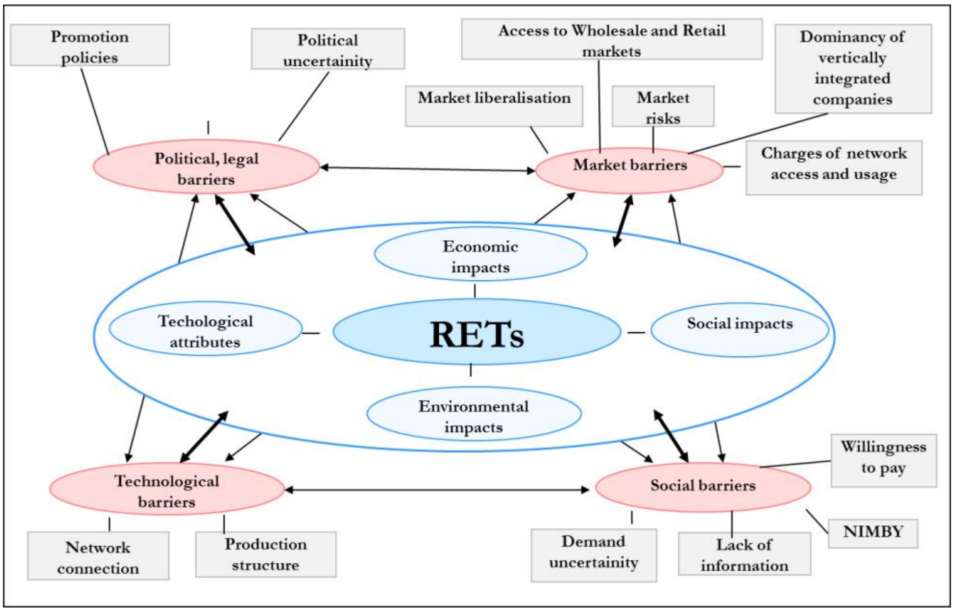

Figure 1. Determinants of RETs' competitiveness
Source: Own model.

access for RETs, especially for the smaller, distributed ones. Regarding the *legal, political issues* we could stress that the numbers of administrative procedures, and there continuous changes represent the most important barriers for RETs in the Danube regions. This also holds for promotion policies too. Traditionally we can distinguish regulatory, fiscal policies and public financing policies, however some of them promotes the operation phase – such as Feed-in tariffs, or quota-based systems, or special tax systems, while others – like loans and public commissions target to initiate the investment phase of RET utilization. Regarding the electricity sector In the Danube region, for operational promotion Feed-in tariffs, for investment promotion loan and subsidies are used, with priority access to grid as well. In the transportation sector quota and tax systems are preferred, while in the heating and cooling sector the situation is quite different among the countries, however mostly the installation of RETs are promoted (see Table 1 and 2).

From *a technological viewpoint,* network connection, the state and structure of generation, transmission and distribution assets and subsystems determine the potential installations of RETs.

Table 1. Promotion policies in the electricity sector- Danube region

Country	Quota	Feed-In Tariff	Premiums	Subsidies, Loans, Taxes	Access to Grid
Austria		X		PV, Hydro	Granted
Bosnia-Herzegovina		X	N.A.	N..A	N.A.
Bulgaria		X			No priority
Croatia		X	Special provision Wind	Loans	
Czech Republic		X (Granted)	Green bonus on market price	Hydro	Priority
Germany		X	Market and Flexibility	Low interest loans	
Hungary		X		Households: net metering	Priority
Moldova		X	N.A.	N.A.	N.A.
Montenegro		X			Priority
Romania	X			Subsidies, loans	Priority
Slovakia		X			Priority
Slovenia		X		Subsidies, loan	Priority
Serbia		X			Priority
Ukraine		X	N.A.	N.A.	No priority

Source: own model based on http://www.res-legal.eu/

Table 2. Promotion Policies in the heating-cooling and transportation sectors – Danube region

Country	Heating – cooling	Heating technologies	Transport (biofuels only)
Austria	Subsidies	Solar thermal, Heat pumps, Biomass, Geothermics	Quota, tax regulation
Bosnia-Herzegovina	N.A.	N.A.	N.A.
Bulgaria	Loans, tax regulation	All	Quota, tax regulation
Croatia	Not Promoted By The State		Quota, tax regulation, subsidies
Czech Rep.	Quota and tax regulation	All	Quota and tax regulation
Germany	Subsidies, loan	Biogas, biomass, geothermal energy, solar thermal	Quota and tax regulation

Country	Heating – cooling	Heating technologies	Transport (biofuels only)
Hungary	Subsidies	All	Quota
Moldova	N.A.	N.A.	N.A.
Montenegro	N.A.	N.A.	N.A.
Slovakia	Financial support	All	Quota and tax regulation
Slovenia	Soft loan	All (Solar, Heat pumps, biomass)	Quota and tax regulation
Serbia	n.a.	n.a.	n.a.
Romania	Subsidies	All	Quota
Ukraine	N.A.	N.A.	N.A.

Source: own model, based on http://www.res-legal.eu/

Our other focus point is the *risk exposure* of the investments. The variety of risk resources have to be taken into account by every stakeholders. Dealing with risk is the most important element when we decide about a renewable energy investment.

Table 3. Risk sources of a company

	Producer of green energy	Buyer of green energy
Operational risk	– prediction capability of load and grid imbalance is crucial – for less mature technology performance is a risk factor	– depends on banking strategy of certificates, otherwise possibly relatively low risk
Product market risk	– demand expected to rise, but at same time competition may increase strongly as well	– demand expected to rise, but at same time competition may increase strongly as well
Input risk	– bio-energy options: fuel costs important – wind and hydro: varies with climate	– large profits at risk when long-term contracts are closed and prices change
Regulatory risk	– profit strongly depends on price support – import protection	– profit and sales strongly depends on price support/tax breaks
Financial risk	– in particular relevant without long-term contracts and for sources where capital costs dominate (wind, hydro)	– depends on inventory size (banking) and portfolio of contracts

Source: http://www.green-x.at

The most important source of uncertainty for the long-term is the government policy, because it is difficult to predict how it will change.

The risk depends on the stage of the project development. Some of the risk factors can be removed during the operation but there are factors remaining – eg. expected price for power sales, actual power production level, inflation rate – that influence the project cash-flow for long term. Combining and integrating these risk factors with the investment decision methodologies – like NPV and IRR – we can outline a lot of barriers. Most important is, based on the hidden costs, that energy project investments would require a relative high rate of return.

A European study evaluate the renewable energy projects from the point of view risk-return profile.

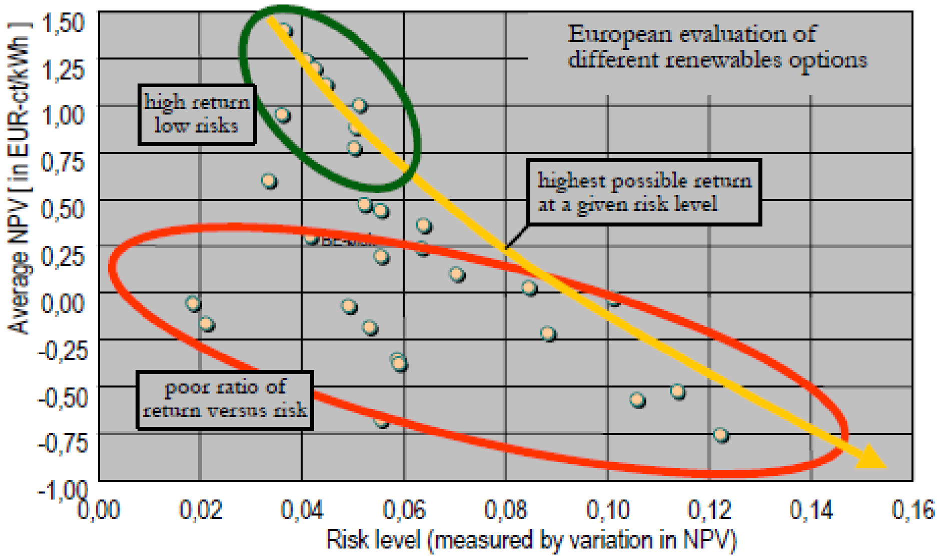

Figure 2. Risk-return profile of renewable energy projects in Europe
Source: http://www.green-x.at

This figure shows us the risk-return relation or profile of the European renewable energy projects, where the biggest cluster means that most projects are relative risky to the returns. It means that it is hard to treat the uncertainties like changing legal background, supporting system or lower energy prices. In terms of energy projects returns are decreasing at higher risk level so there is no trade-off between risks and returns. So in energy project investments have to be chosen the highest possible returns, because the initial investment cost and the risk factors during the operation cannot be backed easily by the future cash flows.

Risks are in close relation with the financial value of an investment, but it is hard to quantify how they affect the value of a project. The common policies and support mechanisms aims to reduce the renewable energy project risks, but it is a long term development process, which have initial needs and offerings. In our paper we explored and analysed the determinant of RET's competitiveness and risk factors influencing the investments. In this special sector we found that there is no trade-off between risk and return because of the constantly changing conditions.

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Romanian Electricity Market in the Light of Fast Development of Renewable Energies: General Presentation and Critical Assessment

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Abstract: Romania witnesses one of the fastest increase in renewable energy[5] generation in south-eastern Europe. Starting from less than 1% in 2010, renewable energy accounts for more than 10% of total energy generation in 2014. A tenfold increase in such a short period of time had serious impact not only on the renewable energy sector, but also on the general electricity sector. In this context, the current paper intends to analyze the general electricity sector in Romania and evaluate critically the impact renewable energies development had on it. Moreover, the paper goes into details analyzing the support scheme for renewable energies and evaluating the success of the program and possible future issues with the model. In the last part, the paper will discuss the available development paths of Romanian energy sector and the role renewable energies can play in this process.

Keywords: Renewable energies, Energy Sector, Electricity, Energy Reforms

1. Introduction

According to the latest evaluation of the interim goal of the application of the directive 2009/28/CE (Directive 2009/28/CE, 2009), Romania is one of the leaders in the implementation of the 20-20-20 goal. While as such this is a good news it is very important to look beyond the rough numbers and assess the impact of RES on the energy market structure in Romania. That will allow to understand also the challenges and opportunities behind this achievement. Even though the energy sector in Romania was previously analyzed by Diaconu et al. (2009), Popovici (2011) Raneti (2009), Haar and Marinescu (2011), Maxim (2013) or Videanu (2009) it

[5] According to Romanian legislation only hydro-power plants with a maximum installed capacity of 10MW can be entitled to renewable energy support scheme. In this context, renewable energies in this paper will refer to all types of renewable energy sources, excluding hydro-power plants with an installed capacity bigger than 10MW unless otherwise stated.

requires a new understanding due to numerous changes that occurred in the last 4 years, the most important of which is the new energy law from 2012 and the increased share of renewable energies from approximately 1% in 2010 (Popovici 2011, p. 1848) to 10.66 % in 2014 (Transelectrica n.d.).

Drawing on previous' research findings, this paper presents shortly each segment of the energy market in Romania looking closely into the renewable energy sector. Within this sector, present research aims to asses critically the current state of affair, present the support scheme for green energies and discuss the main challenges faced currently by the renewable energies in Romania.

Romanian power sector is comprised of 4 big sub-sectors: energy generation, transmission and distribution, supply and consumption. Relying on the general overview of these sub-sectors, the present paper will also discuss possible evolution paths of the energy sector in Romania and the regional implication of this evolution.

2. Power generation

Romanian generation capacity is characterized by a balanced portfolio of generation facilities comprising solid, hydro, nuclear, gas and green power generation units. Mostly because of the types of generation units (especially hydro and renewables) Romanian electricity market is exposed to environmental variables which may influence the energy generation capacities and costs (Maxim 2013). Generally, Romania is a net exporter of energy, according to the ANRE in 2013 Romania had a positive commercial balance for energy, with a net total export of 2.47 TWh (ANRE, 2013)

As presented in Figure 1, Romanian power generation mix is quite balanced and therefore allow for a large flexibility in usage of different types of resources to balance the consumption with the production on pick/off-pick cycles. However if we compare Figure 1 with figure 2, we can see that power generation in Romania changed dramatically. According to ANRE and Transelectrica, over the last 5 years, generation from coal fired power plants decreased by approximately 9%, while generation from renewable sources increased from 0 to approximately 11% (ANRE 2009, Transelectrica, n.d.). With the increase share of RES generation Romanian government had to reconsider its energy policy approach as well. In order to balance RES production effectively two important energy projects were supported – the building of the 3rd and 4th units of the Cernavoda nuclear power plant and the building of the hydro-power plant CHEAP Tarnita-Lapustesti. Generation from this pumped storage hydro-power plant can help to integrate better electricity produced from renewable energy sources (Destouni and Frank 2010). Nuclear power plant at the same time will ensure the required base-load production.

Figure 3 shows clearly how generation from hydro-power plants and RES can be used effectively in order to balance production and consumption. We can see that the decrease in generation from hydro power plants which occurs between 9am and 3pm and from 8 pm further is complemented with generation coming from wind and solar power plants.

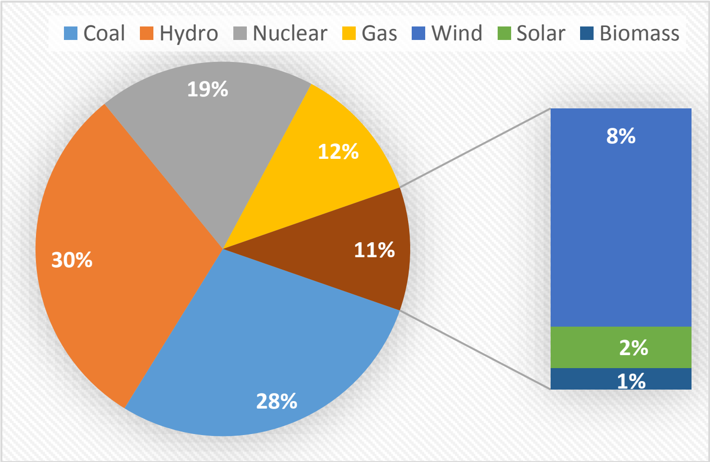

Figure 1. The structure of the power delivered to the grid in the period Jan-2014 – Oct-2014. Romania (Transelectrica, n.d.)

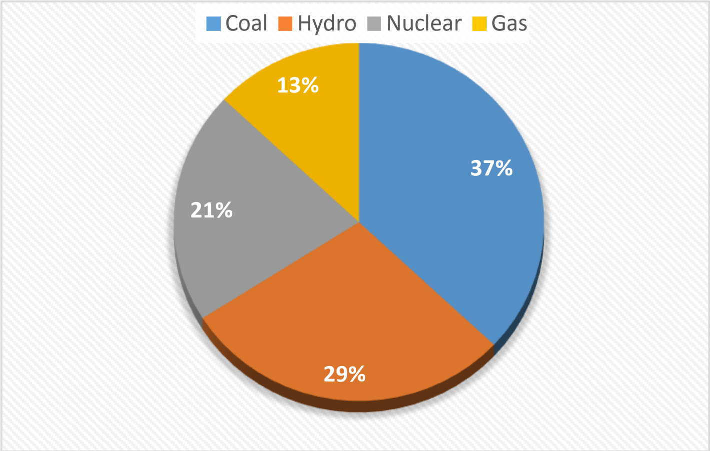

Figure 2. The structure of power delivered to the grid in 2009. Romania (ANRE, 2009)

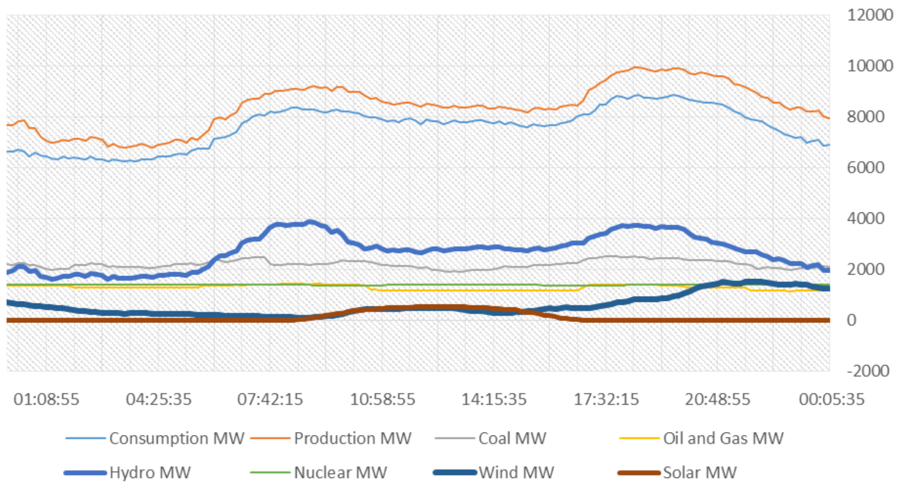

Figure 3. Daily Electricity Generation Diagram (Transelectrica, N.D.)

In this context we can argue that further development of hydro power plants in Romania will help to a better integration of renewables as well. This solution can be also combined with decentralized generation which is often presented as a part of multilevel governance of energy sector (Goldthau 2014). Ensuring generation at the local level from available energy resources, usually RES, can lead to a reconsideration of the centralized model under which energy production is balanced at the national level. As Goldthau (2014) remarks, we can produce and consume energy at the local level reducing the transmission costs, therefore reducing the costs for electricity. This type of production model can also have a series of positive externalities, such as the economic developments of rural areas rich in renewable energy resources (del Rio and Burguillo 2008, Hanley and Nevin 1999).

3. Power transportation and distribution

The role of transmission networks is often disregarded. And while disregarded, the role of infrastructure networks is crucial for the further transition to low carbon, sustainable energy system since "the role of infrastructure networks in enabling or constraining broader sustainability transitions will be crucial" (Bolton and Foxon, 2014, p. 1). Moreover, in the context of fast development of renewables, good physical interconnectors with the neighbouring countries are crucially important for balancing peak and off-peak production.

Romanian power grid is characterized by two main problems: aging electricity infrastructure and poorly developed interconnections with neighbouring countries as a result of the "energy independence" policy promoted by socialist governments

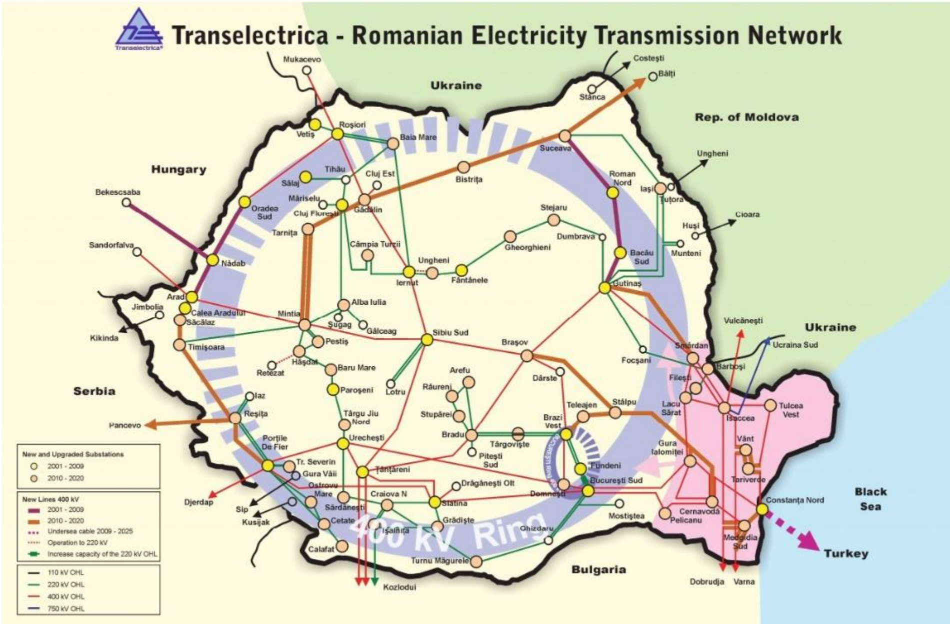

Figure 4. Electricity Transmission Network. Transelectrica
Source: http://www.transelectrica.ro/documents/10179/25146/ Harta+ RET_EN.pdf/37ef 2 da-8490-4504-b6f5-81baf0a68542

(Popovici 2011, p. 1845). Improving connections could allows for energy exports of excess energy and decreasing the pressure on the national electricity system by coupling the power balancing with other countries (Kennedy 2005).

The increased electricity generation from renewable energy, combined with the unstable character of generation of the hydro power plants[6] put a lot of pressure on the balancing system operator. In order to balance effectively the production with the consumption on peak and off-peak periods the balancing operator has to import needed quantity or export the excess. The presence of grid connection and the market coupling will certainly make easy the task of balancing, thus decreasing the costs of balancing and the congestion risks.

Important steps in this direction were already made by ANRE who started the procedure of day-ahead market coupling with Hungarian HUPX, Slovakian OKTE, Czech OTE and Polish TGE (OPCOM, 2014). Market Coupling allows the optimization of the allocation process of cross-border capacities thanks to a coordinated price

[6] In 2011–2012 Romanian energy generation system suffered from severe fall in the water level which produced a significant decrease of the energy share produced by Hydro power plants. During this period Hidroelectrica invoked twice force major clause.

formation mechanism, taking into account orders placed by the members of different Exchanges. The active phase of the project started only in March 2014, therefore it would be too early to evaluate the progresses in this area, however even now we can say that a day-ahead coupling will certainly help the balancing of power peak and off-peaks on the intra-day or day ahead markets. While of crucial importance, Romania failed to access significant founding from Trans-European Energy Networks program (TEN-E). According to the report on financed projects for the period 1995-2013, Romania accessed financing only for two studies for 400,000 Euro and 651,000 respectively (European Commission, 2014).

In order to accommodate the raising generation from renewables Transelectrica has to develop and improve the cross-border grid connectors, to implement market coupling with neighbouring countries and to improve the national transmission system. While the mentioned reforms seem quite clear and straight forward, those can be very hard to accomplish in a system which is regulated by 11 different legal provisions (Benedek, Cristea and Bartok, 2013).

4. Renewable energies, regulation and support scheme

The promotion and support for renewable energy sources is defined and regulated by the energy laws from 2008 (Legea 220 din 27/10/2008, 2008) and from 2012 (LEGEA Nr. 123/2012 energiei electrice şi a gazelor naturale, 2012). Renewable energy sources are comprised of wind, solar, wave and tidal, geothermal, hydro-electric, biomass and biogas products, and other, yet unexploited renewable energy sources.

4.1. How are the certificates allocated?

For the period of 2008–2020 ANRE established a yearly share of green certificates that are to be allocated to green energy producers through annual, mandatory quotas. The amount of renewable energy which suppliers are obliged to deliver to the final consumers coincides with the allocated quotas of green certificates which are presented in figure 5.

Within the annually allocated share for renewables which is subsidized by green certificates, the law defines different number of green certificates for different types of generations (ex: solar, wind, biomass, etc.). The numbers of green certificates allocated per MWh of produced and delivered energy for the period 2008–2020 are represented in Table 1.

It worth highlighting that the number of allocated certificates per/MWh was changed in 2013 at the recommendation of ANRE. The reason, as argued in ANRE's report is overcompensation of some producers of green energy. In order to prove the origin of the green energy, suppliers should buy the energy certificates either on the green certificates market established by OPCOM, or directly from generators who hold them. The minimum and maximum price for a green certificate is established by law between 27 snf 55 Eur/Certificate. Within this range, the price is freely formed by market.

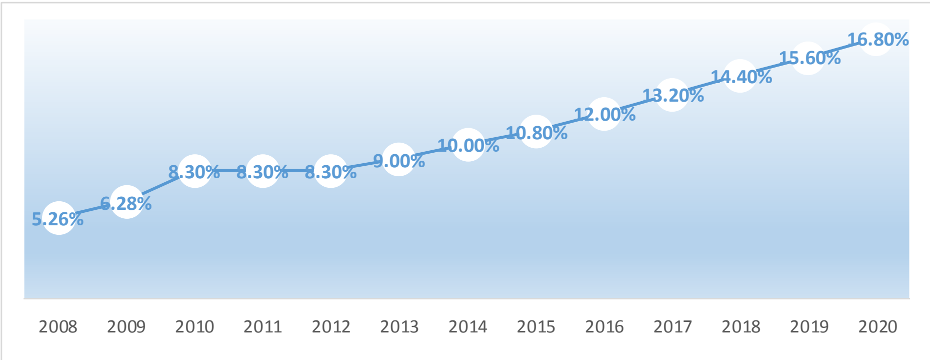

Figure 5. Mandatory Quotas for Green Certificates, 2008–2020
Source: Legea Nr. 123/2012 energiei electrice şi a gazelor naturale, 2012.

Table 1. Number of allocate green certificates per generation type (HG 994/2013, 2014)

<table>
<tr><th>Type of renewable generation</th><th>2008–2013</th><th>2014–2017</th><th>2018–2020</th></tr>
<tr><td rowspan="2">Hydro-power plants*</td><td>3 certificates/MWh for new plants</td><td colspan="2">2.3 certificates/MWh for new plants</td></tr>
<tr><td colspan="3">2 certificates/MWh for refurbished plants</td></tr>
<tr><td>Wind</td><td>2 certificates/MWh</td><td>1.5 certificates/MWh</td><td>0.75 certificates/MWh</td></tr>
<tr><td>Biomass and Biogas</td><td colspan="3">3 certificates/MWh</td></tr>
<tr><td>Solar</td><td>6 certificates/MWh</td><td colspan="2">3 certificates/MWh</td></tr>
</table>

* Only hydro-power plants with a maximum installed capacity of 10 MW are considered for the support scheme.

5. Main issues with the current support scheme

5.1. Fixed price range for the "green" certificates

One of the main critics that can be raised regarding the existing support scheme is the locked price range "covered" under a free market arrangement. In other words, market participants are encouraged to perform buy-sell activities in a free market environment and therefore form a price which reflects the "real" value of green certificates but this value is locked within the price range of 27 to 55 Eur/Certificate. By locking the price in a specific price range the regulative authority tries to make sure that neither the producers of green energy will be under-subsidized, nor the end consumers will have to over-pay for certificates.

This type of arrangement leaves however place for further distortion of the price formation mechanisms. Given the fact the only a limited amount of green certificates are available for a calendar year and the price range is pre-established we can have an artificial price formation. This can happen since both variables, the price and the quantity are predetermined thus the competition is limited.

This arrangement is criticized by energy suppliers who are supposed to buy green certificates for the contracted quantity for a yearly energy delivery. If the contracted quantity changes over the year, they need to sell or buy more green certificates. In conditions of a complete free market and free price formation this would be a problem of supply and demand, however the current regulations it create possibilities for speculations and therefore losses for the consumers on one side and low revenue for green energy producers on the other side. The problem can be addressed by liberalizing completely the price formation mechanism which will ensure a more flexible market and a higher market activity. This change should also be accompanied by complete market transparency in order to prevent any possible monopolistic moves from big market energy players.

5.2. Industry pressure and special exemptions

According to the governmental decision from July 2014, the industrial actors who have an energy intensive consumption profile can be partially exempted from paying the green certificates contribution (HG 495/2014, 2014). The exemption varies between 15% and 60% depending on the electro-intensity of the industrial process. This decision came as a response to the pressure coming from the big industrial factories having significant energy consumption. The main argument for the change was the fact that with the increase of the mandatory share of the green certificates, end consumers will have to pay more for their energy consumption and as a result of that, the competitiveness of the energy intensive industrial actors declined significantly. Due to high social and political pressure exercised by these actors, the government had to intervene and apply a partial exemption. The difference will be recovered however from the bills of remaining consumers, including households. We can expect even further pressure on the energy system from political factors since Alro (big aluminium producer) already declared their intention to support the decrease in the number of allocation of green certificates since they consider it to be hurtful to the development of the industries and social well-being (Ionascu 2013).

While this last issue presented here might seem less related to the development of the renewable energy sources, it does in fact put great pressure on the RES in

Romania. For a further development and use of renewable energies technical development is not enough. A wide public, industry and political support is needed as well. In case when big industrial producers opt clearly against RES development, society has to pay more for the energy because of the government decision to reallocate costs for green certificates, the support for further development of RES in Romania becomes more questionable.

6. Conclusions

There is no perfect model of energy management, especially when we introduce the raising pressure from the development of renewable energy sources. Romanian market is not an exemption in this situation. Regardless of this complexity, a clear understanding of the energy sector and the developments within the field can assist in forming the best solutions to the existing problems. Summarizing the discussion from the previous chapters we can highlight some of the most important directions which need to be addressed in the energy sector:

Power Generation. Romania has a diverse generation mix which allows for a safe and reliable energy supply. The fast development of renewables however brought to light some important challenges in this sector. A possible temporary solution can be further development of Hydro power plants, which was argued to assist in balancing generation from renewable energy sources. However, the main challenge still remain toward the way to accommodate raising generation from intermittent, renewable energy sources. In order to answer this challenge, a more revolutionary approach, such as decentralized generation and a change of the energy governance model.

Transportation. The importance of the transportation grid cannot be overestimated, it can generate lower costs for electricity, possibility to increase profitability of power generators, decrease the pressure on the national electricity system and ensure a permanent and safe delivery of power. Due to lack of capital investments however Romanian power transportation system is aging and poorly connected with the neighbouring countries. Further increase of the generation from the RES also increases the pressure on the grid given the limited capacity of export and balancing on the internal market. In this context immediate investments in the major infrastructure projects are needed. Also, development of a regional market would decrease the pressure on the national system because it will allow for a more flexible balancing across the region. This measures need to be combined also with a complete liberalization of energy sector, with the state privatizing remaining DSOs and liberalizing electricity prices for household costumers.

Support scheme for RES. Certainly the fast growth of RES in Romania pose a lot of pressure on the energy system, nevertheless it should be treated as a positive development. As presented earlier Romanian RES sector is characterized by a lot of changes, ambiguities and incomplete market mechanisms. All these variables create a lot of uncertainty regarding the further development path of renewable energy sources in Romania.

There is no silver bullet for all of the system's issues highlighted above, however we should pay close attention to at least two important, over-arching issues which might slow down the development of RES and of the entire energy system in Romania: under-developed grid capacity and interconnections and the unstable/uncertain institutional arrangements. Important steps toward improvement of grid and market infrastructure were made with the regional market coupling, however further investments are needed in building physical interconnectors in order to support the needed export of excess capacity. Political and institutional changes are however much harder to operate and address. Given the high importance of the energy sector it is also highly politicized and therefore effective decisions are also matter of public approval and discussion.

Acknowledgements

I would like to express my gratitude and sincere appreciation to PhD Joszef Benedek and PhD Bartok Blanca of Babes-Bolyai University for their valuable comments and suggestions.

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Joint Renewable Energy Support Schemes in the Visegrád Countries

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Abstract: This paper aims to examine the theoretical and practical background of joint renewable energy support schemes and tries to outline a concept of a new joint RES support scheme in the Visegrád countries (Czech Republic, Hungary, Poland and Slovakia). The vision of flexibility between Member States started with the idea of a common guarantees of origin system, which has been softened to non-binding so called cooperation mechanisms (statistical transfers, joint projects or common support schemes) in the RES Directive of 2009. Theoretical works underline rather the positive effects of such cooperation like easier and less costly RES target fulfillment, though we find hardly any evidence in practice. That's the reason why the European Commission gave particular guidance on RES cooperation mechanisms and stated in its new Guidelines that it will consider positively schemes open to other countries. The EU is also narrowing the range of support options of renewable electricity production (see premium and tender schemes in the Guidelines), while main characteristics remain determined by MS. In this context, the paper tries to outline a regional RES support scheme in the Visegrád countries, based on theoretical works and own assumptions.

Keywords: renewable energies, renewable cooperation mechanisms, renewable support schemes

1. Introduction

The European Union has set an objective of 20% renewable energy consumption in gross final energy consumption by 2020. To reach this goal, every Member State (MS) of the EU has to fulfil binding national RES targets until 2020 (for Hungary, this target is 13%) but Member States can also opt for higher RES shares in their National Renewable Energy Action Plans (NREAPs). Hungary has committed itself to reach a 14.65% RES target until 2020.

In order to reach targets more easily and cost effectively, the EU made it possible for Member States to cooperate in RES target fulfilment. These so called cooperation mechanisms can be statistical transfers, joint projects or joint renewable support schemes as well. According to theoretical works, these flexibility options help to use

RES potentials more efficiently across Member States as renewable projects will realize at the most cost optimal sites in the EU, which in turn makes RES target fulfilment less expensive at EU level.

There is, however, little evidence for benefits in practice as only few countries have used such cooperation mechanisms so far. Taking joint renewable support schemes as an example, only one joint green certificate scheme has been introduced so far in 2012 between Sweden and Norway.

A reason for this relatively passive behaviour of Member States can be the difficult design of such cooperation agreements, mainly in conjunction with joint support schemes and the lack of best practices in this respective field. Secondly, it can be observed that in the first phase of target fulfilment, Member States rather want to rely on own renewable resources and are only willing to enter into cooperation when the 2020 target fulfilment deadline is approaching because at that time they will know whether there will be a surplus or a lack of renewable energy production. Furthermore, cooperation can bring also hardly quantifiable benefits like spillover effects on other sectors, which can be difficult to share between member countries and can bring about political conflicts. In the case of regional RES support schemes, the question of national sovereignty can come to forefront: there is no evidence that benefits of cooperation can outweigh the loss of sovereignty and that benefits appear in the country itself though renewable energy production abroad has to be co-financed in this case.

However, the European Commission wants to see Member States reaping the benefits of such cooperation and thus considers positively new or modified RES support schemes open to other countries in the notification procedure. This doesn't necessarily mean a joint support scheme.

The aim of this work is to first examine the theoretical background of joint renewable support schemes and also examine their practical experiences. Finally, a possible joint premium system in the Central-East European Region and the Visegrád countries will be outlined.

2. Forms of renewable cooperation

The 2009/28/EC directive on RES support (EUR-Lex 2009) states that Member States have to foster all kinds of cooperation in order to reach 2020 RES targets. Cooperation can have various forms and can occur between two or more countries. In order to decrease costs of RES target fulfilment, it can be reasonable to support renewable energy consumption which has been produced abroad and make it possible for Member States to count this renewable energy into their own statistics.

This requires the introduction of so called cooperation mechanisms which can be freely chosen by Member States. The Directive mentions four types of such flexibility options:

- Statistical transfers between Member States
- Joint projects of Member States
- Joint projects of Member States and countries outside the EU
- Joint renewable support schemes

The statistical transfer between Member States is the loosest form of cooperation. Member States can enter into an agreement on the statistical transfer of a certain amount of renewable energy from one to another MS. This means that the transferred amount of green energy is subtracted from RES statistics of the transferring country and added to the one of the host country. The Directive doesn't state the nature of the transferred renewable energy, whether it should be electricity, heat or renewable fuel. Agreements on statistical transfers can be valid for one or more years.

According to the Directive, two or more MS can cooperate also in the form of a joint project, which can comprise renewable electricity, heating or cooling (renewable fuel production cannot be the subject of a joint project between MS). In this case one MS can assume the financial support of a renewable project in another MS, in turn the country can count one part of renewable energy produced into its own target compliance.

Member States may also cooperate with countries outside the EU via joint projects for the production of renewable electricity, which has to be physically imported into the EU (a statistical transfer is not enough). In these joint projects, private parties can also be involved.

The highest form of cooperation mechanisms is the joint (or partly joint) renewable support system. This can comprise renewable electricity and/or renewable heating/cooling. Two or more countries can voluntarily combine or partly harmonize their national renewable support schemes. Renewable energy produced can be shared with a statistical transfer, physical electricity flow or via swap contracts. Joint support funds can also be formed. Renewable projects generally realize in those member countries where production costs are the lowest and resources are abundant, which can contribute to lower support expenditures at an aggregate level. In the next chapters, we will focus on this aspect of renewable cooperation mechanisms.

3. Theory of regional renewable support systems

Jensen and Morthorst (2006) examined regional support clusters if joint electricity markets exist and also in the case of separate national electricity markets.

They investigated two theoretical countries which have different electricity systems and there are distinct conditions for RES technologies. The following presumptions apply:

Country A: Good conditions for renewable energy and also wind energy production. Efficient fossil power plants with low production costs and CO_2 emissions.

Country B: Moderate conditions for renewable energy and also wind energy production. Rather inefficient fossil power plants with high production costs and CO_2 emissions.

In the first theoretical case, the two countries have already a joint electricity market and they decide to combine their national renewable support schemes into a regional one. A good example could be Finland and Denmark as now they are both part of the Nordpool electricity market and this theoretical model shows what would happen if they would have also a joint renewable support scheme.

In this case, both renewable and fossil power plants would be built in that country where production is the most efficient. The situation can be thought of as it would be one country with the difference that renewable and fossil power is exported and imported between the two countries.

We assume that the joint renewable support system is a feed-in tariff system where renewable support is financed from a joint fund (see Fig. 1.).

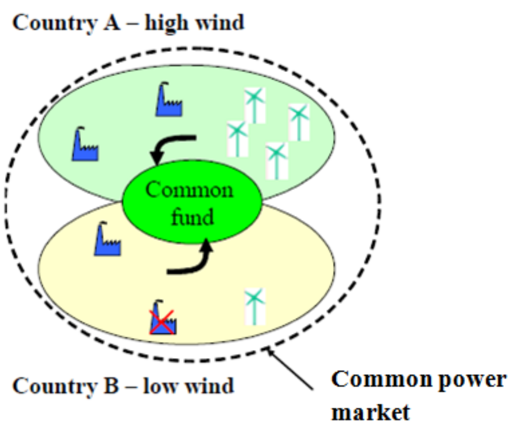

Figure 1. Schematic illustration of a regional joint feed-in tariff system, supposing joint power markets (Jensen–Morthorst 2006)

Jensen and Morthorst examined the possible effects of a joint support system compared to the original case where only a regional electricity market exists.

Regarding renewable electricity production, those RES technologies will deploy whose marginal cost of production is lower than the given feed-in tariff and the power produced by RES technologies will get priority on the electricity market. Renewable power production will thus realize in that country where the potential of RES (e.g. wind) is high, irrespective of the former agreement of the member countries. This way more wind power plants will be built in country A than in B.

As we assumed that renewable power has priority access and there is a common power market, renewable power plants will squeeze out inefficient fossil power plants in country B. Spot power market prices would decrease as cheaper renewable power production is replacing more expensive fossil based electricity production. With a common power market, spot price decrease would be felt in the whole region.

New RES power plants in country A have to be supported by all consumers in order to avoid a higher consumer burden in country A. This can be done by a joint fund, in our case with common burden sharing, but other options also exist (e.g. in proportion to RES target or power consumption).

Country A would export power to country B but with a higher share of intermittent electricity, it would face higher balancing costs, which should be also shared between countries.

In the second theoretical case, two countries with separate national power markets would combine their renewable support schemes (see Fig. 2.). For example, Austria and Greece keep their national power markets but introduce a common feed-in tariff system.

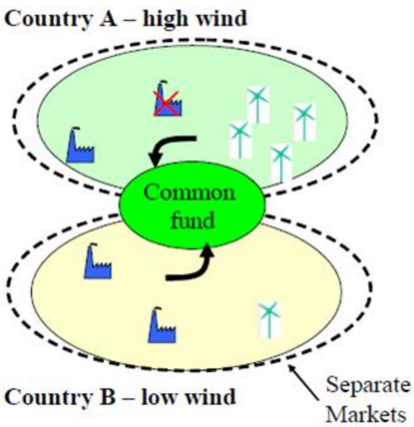

Figure 2. Schematic illustration of a regional joint feed-in tariff system, supposing separate power markets (Jensen–Morthorst 2006)

Regarding renewable power production, the consequences are the same as in the first case with a common power market: renewable electricity production would increase in country A and decrease in country B.

As there is no common power market, renewable power plants cannot squeeze out inefficient fossil power plants in country B, thus it can happen that they will push efficient fossil power plants in country A out of the market. This is a problem because the decreasing spot power price in country A caused by higher renewable electricity production doesn't induce investment into fossil power plants, though the country would need additional back-up capacity for the balancing of volatile renewable power production. So if there is no common market for electricity, the country with the highest RES potential will face problems in its power market. Jensen and Morthorst thus suggest to have a common power market in place before introducing a joint renewable support system.

4. Expected and past experiences of the Swedish-Norwegian joint green certificate market

In 2011, the Swedish and Norwegian government agreed to introduce a joint green certificate market, which started its operation from the 1st of January 2012. So far this is the only joint renewable support scheme in Europe.

According to the agreement, the joint green certificate scheme would operate until 2035 (when the last green certificate entitlement issued in 2020 will have expired). The main objective of the cooperation is to increase renewable power production in the region with 26.4 TWh. This quota target will be financed equally by the member countries (i.e. both Sweden and Norway have to support 13.2 TWh of renewable electricity production) but the market will decide where renewable power plants are actually built. RES power plants that were commissioned before 2012 are supported separately by member countries.

The joint green certificate scheme is based on the former Swedish model. It is expected that the number of market participants will increase, which induces market competition and enhances the liquidity of the market. At the same time, this helps to mitigate volatile green certificate prices. Renewable investments will flow to the country where conditions for given RES technology are the most favourable (e.g. Norway: better hydro power potentials), thus the cost of reaching quota targets will probably decrease at an aggregate level. The joint green certificate scheme is open to other countries but this requires a new agreement between the parties.

In 2012, 21.6 million green certificates have been issued on the joint market, thereof 21.4 million in Sweden and only 0.2 million (200 thousand) in Norway. This is because renewable quotas in Norway were introduced in 2012 and at a lower level. In Sweden, most of green certificates have been issued for biofuel (biomass and biogas) based power production but wind power received also a considerable part of green certificates. In Norway, however, almost exclusively hydro power plants received certificates, only an insignificant part has been issued for wind power plants (see Fig. 3.). This shows also the difference in RES potential between the two countries.

Figure 3. Green certificates issued in Sweden and Norway in 2012 by renewable energy sources (million; %) (Swedish Energy Agency)

Both Swedish and Norwegian green certificates can be traded on the joint green certificate market. This can happen with an agreement between renewable power producers and obligated market players (e.g. energy suppliers) or through brokerage firms.

According to data from the three biggest brokerage firms in the region (SKM, ICAP, CleanWorld), the average green certificate spot market prices declined by about 10% in early 2012, when the joint market was introduced. However, looking at the whole year, there was a 44% price increase in the second half of 2012 so that in the end of the year, the average green certificate price reached 210 SEK/MWh. (see Fig. 4.) However, this upward trend seems to have reversed in 2013 as prices fell under 200 SEK and since then, prices tend to fluctuate around this lower level.

Obliged energy suppliers can pass costs of green certificate acquisition on their customers so in the end, support in the form of green certificates is paid by electricity consumers. Even though Sweden and Norway finances RES targets equally, support costs per kWh of electricity consumed differ considerably in the two countries as they have different RES quota targets (i.e. equal price but different quantity leads to different support costs).

As in Sweden RES quota targets were higher in 2012 than in Norway, Swedish electricity consumers paid on average 3.6 SEK/kWh (~ 41 cent/kWh) for RES support, while consumers in Norway only 0.7 SEK/kWh (Swedish Energy Agency).

Figure 4. Average spot green certificate prices between 2003–2012 (SEK) (Swedish Energy Agency)

5. A possible joint feed-in premium system in Central-East Europe

On request of the European Commission, Ecofys (Busch et al. 2014) investigated the practical opportunities of joint renewable support schemes. In our region, a theoretical joint feed-in premium system between Austria, the Czech Republic, Hungary and Slovakia has been outlined. As all countries have a feed-in tariff system (combined with a green bonus in the Czech Republic), it would be easy to convert that into a joint feed-in premium one. On the other hand, the new Guidelines of the Commission on state aid for environmental protection and energy (EUR-Lex 2014) require Member States to integrate RES power production into the market from 2016, which can be done with the introduction of an appropriately designed feed-in premium scheme. Moreover, from 2012 there is a Czech–Hungarian–Slovak joint day-ahead power market in place which can assure that reference power prices (on top of which the premium is paid) are levelling off on long term. The joint renewable support system may improve investor confidence (see balanced country risks) and can decrease costs of RES target fulfilment. Participating countries should introduce a joint fund from which premium support is financed.

Ecofys used the so called Green-X model to make an impact assessment for each country. They examined two basic scenarios: according to the reference scenario, countries keep their national support schemes and do not cooperate with each other, while in the cooperation scenario countries integrate their support systems in order to reduce support costs. The joint support scheme would operate between 2015 and 2020. Authors tried to compare estimated RES support expenditures, avoided fossil import costs and avoided CO_2 emissions between the two scenarios. Detailed model parameters and calculation methodology can be found in the report.

One outcome of the investigation was that cooperation would bring about more than 400 million EUR savings (–25%) in RES support costs compared to the reference case (see Fig. 5. left axis). Moreover, cooperation could reduce total capital costs of RES investments by about 325 million euros, as a result of optimal use of RES resources.

Regarding indirect effects (change in avoided fossil import costs and CO_2 emission costs), Austria would be the winner of this kind of cooperation as most of RES projects would realize in this country (this could be explained by a better investment climate, easier licensing procedures, etc.) The right axis of Fig. 5. shows that the net indirect effect (corrected with the loss of other countries) would be about 600 million euros, which even exceeds savings in RES support expenditures. It should be, however, noted that costs and benefits arise differently in each country, so these have to be equally shared between participants.

Fig. 6. shows the indirect benefits (avoided fossil import and CO_2 emission costs) in the reference and cooperation scenario. Austria would be the only winner of the cooperation, other countries would have to face losses of indirect benefits. But losses can be compensated by the gains of Austria and there is a highly positive outcome of cooperation at cluster level.

6. Possibility of a joint premium system in the Visegrád countries

The Visegrád countries (the V4: Czech Republic, Hungary, Poland, Slovakia) have already a very strong cooperative relationship and Poland is expected to join the Czech-Slovak-Hungarian day-ahead electricity market, so this can be a strong basis for a regional power market. It should be also mentioned that Poland is planning to phase out its green certificate system and switch to a premium system. The other Visegrád countries will probably also opt for a premium system as new EU guidelines require market integration of RES from 2016 (in case of re-notified, modified or new support systems). This can give momentum for a joint premium system in the region.

But before introducing such a joint support system, many questions have to be answered which can basically influence the operation and even the effectiveness of the common support system.

First of all, participating countries have to decide on the joint RES-E target value for 2020.

Regarding the type of the premium, a floating premium would be the most suitable, where the premium value is aligned with reference market price fluctuation in such a way that the sum of the market price and the premium ("strike price") is constant. This way RES power producers face lower market risks as they have to bear only the gap risk between the reference market price and the power price they can actually achieve on the market.

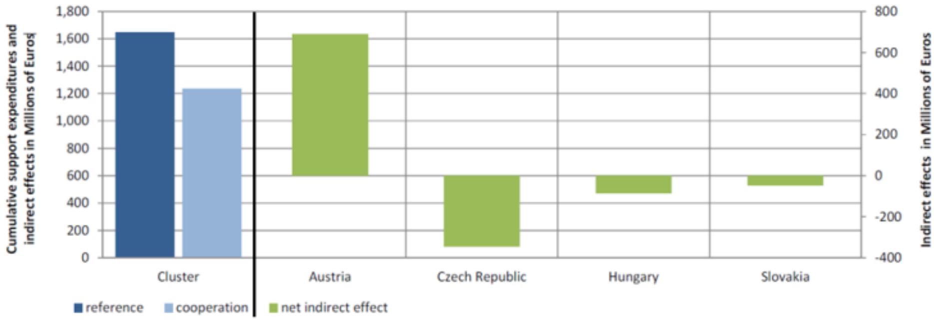

Figure 5. Cumulative RES support costs in the reference and cooperation scenario, indirect effects in member states (million euros) (Busch et al. 2014)

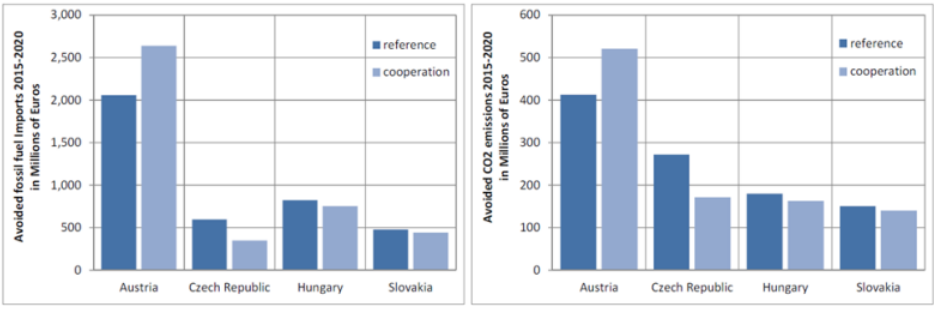

Figure 6. Cumulative avoided fossil import costs (left diagram) and avoided CO_2 emission costs (right diagram) in the reference and cooperation scenario, million euros (Busch et al. 2014)

The premium shall be allocated within a tender scheme where RES power producers can bid for the strike price and the lowest bids win the tender (up to the tendered capacity or support amount). Competition between RES producers can bring about reduction in support costs and this is also in line with EU requirements (EU guidelines request to introduce tender schemes from 2017 above a given capacity threshold).

In order to be able to equally share costs and benefits of cooperation, a preliminary cost-benefit analysis has to be carried out which would assess the possible outcome of a cooperation. When assessing support cost expenditures, costs of separate national support schemes and the aggregate cost level of a joint support scheme have to be compared. If cost savings can be identified, those have to be equally shared by participating countries. This requires the establishment of a common fund to which every member state has to contribute in proportion to its relative cost savings.

In the cost assessment model, additional balancing costs (e.g. in the case of intermittent RES power production) have to be also taken into account.

A more difficult question is the sharing of benefits as one part of them (e.g. spillover effects, local value added, etc.) can be hardly quantified and is a matter of political negotiation. The method of quantifiable benefit sharing (e.g. avoided fossil import costs and avoided CO_2 emission costs) can be, however, previously agreed between parties.

Another question to be explored is how parties would like to share RES power produced in their region (if this is required). This can be done easily by a statistical transfer but other options also exist like market swaps or physical power trade (which latter is, however, difficult to trace).

7. Conclusions

This report tried to outline renewable cooperation mechanisms in theory and practice and gave a deeper insight into joint renewable support schemes. Theoretical works underline the fact that the functioning of regional power markets can be a good basis for a joint renewable support scheme, which can bring about more effective and less costly RES target fulfilment.

However, up to now there is not much evidence of these positive effects in practice as Member States are not yet willing to enter into cooperation in this field. There is only one joint support scheme between Sweden and Norway but the evolution of green certificate prices hasn't yet really shown those support cost reductions which have been expected.

The biggest problem is the sharing of indirect benefits (local job creation, spillover effects, local value added, etc.) which makes cooperation difficult. For example in the case of a joint support system, those countries will reap most of the indirect benefits where RES potential is high and investment climate is favorable. As we could see from the practical analysis of Ecofys, Austria would be the winner of a cooperation in the CEE region. In this respect, a previous compromise in cost-benefit sharing can be crucial for effective cooperation.

A joint premium system has been identified as a possible form of cooperation between Visegrád countries. The Czech–Slovak–Hungarian (and perhaps Polish) market coupling and the new EU requirements can serve as a good starting point for cooperation. It is recommended to carry out a previous cost-benefit analysis in order to identify possible cost savings and benefits which have to be equally shared between countries. That way a win-win situation can be ensured and a political consensus can be reached. However, it should be noted that indirect benefits can be hard to share and therefore further examinations in this respective field are required.

Conflict of Interest

The authors declare no conflict of interest.

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HYDROPOWER POTENTIAL

Hydro Energy Potential in the Danube Region and in Hungary

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Abstract: Hydropower is Europe's major renewables source today. With its dispatch ability and flexibility but also its cost-efficiency, hydropower backs up variable generation and delivers important system services. It is a well-established, proven and flexible technology. The importance of a generation technology depends mainly on capability to stabilise fluctuations between demand and supply. This function that will be even more valuable in the future. Hydropower has been identified as highly valuable for climate change mitigation, due to its low carbon footprint and high generation efficiency. Without hydropower it would be impossible to meet the EU's ambitious RES targets. The hydropower is accounts 70% renewable electricity generation in Europe. Half of the technical hydropower potential in Europe has not yet been developed. Technical potential of Danube region is about 96 TWh/a and of Hungary is 4.59 TWh/a. The pumped storage development potential is independent from the natural hydro power potential. Most of Danube region's countries planning pumped storage development, mainly for integration of renewable energy. The total planned capacity of pumped storages in Europe over 30 GW. In Hungary 18 location are identified for large capacity pumped storage projects.

The rules for supporting renewable energies are under modernization to make support systems sustainable. Feed-in tariffs will be progressively replaced by competitive bidding. According to the plans of the EU the integration of electricity market continued. In the Hungarian power system the electric energy import in 2014 year reach 33% of total consumption. The growth of annual consumption about 0.6%. The import share in annual peak load in last year reaches about 50%.

In the last years the difference of peak and off-peak prices decline to 25–30% of 2008 value. This destroys the commercial basis of the conventional energy storage. For system services markets allowed the double fee system. The Hungarian electricity system is missing the modern regulation capacity with the required flexibility and load change manoeuvrability.

No reason to ignore hydro power from plans. Complex, scientific investigations are necessary.

Keywords: hydro power; renewable energy; pumped storage; generation; security of supply; integration of renewables; sustainable development; price stability; dispatch ability; flexibility; cost efficiency; climate friendly; market integration; system services; balancing and ancillary services; portfolio effects

1. Introduction

Hydropower is Europe's major renewables source today. With its dispatch ability and flexibility but also its cost-efficiency, hydropower backs up variable generation and delivers important system services. It plays a key role in today's electricity mix. As a multifunctional technology, it is indispensable to our electricity system, and will be even more important tomorrow.

The importance of a generation technology for the overall system depends mainly on its capability to stabilise fluctuations between demand and supply. Hydropower already contributes to balancing these differences – a function that will be even more valuable in the future. In particular, reservoir hydropower storage and pumped storage hydropower plants are enabling technologies for a well-functioning European electricity system.

Europe's electricity systems are undergoing significant changes, linked to the aim of a more renewable and low-carbon energy sector. The EU's integrated energy and climate change policy sets the ambitious target of producing energy from renewable sources by 2020. As a consequence, power systems will not only have to follow the varying electricity demand throughout the day, but also adjust to an increasingly variable power intake. Ensuring system stability and a continuous flow of electricity by balancing fluctuations in frequency and voltage will be the challenge of the future. By providing the necessary flexibility and storage capacity to ensure the stability of the electric grid, hydropower already supports the integration of increasing amounts of wind and solar.

Multipurpose hydropower projects also provide services beyond the electricity sector. They contribute to improved water management, such as flood control, which could valuable in context of climate change adaptation.

As for the decarbonisation agenda, hydropower has been identified as highly valuable for climate change mitigation, due to its low carbon footprint and high generation efficiency. This makes hydropower the most competitive and reliable renewable energy source. The estimated LCOE and average generation cost is very low, lowest of renewables and conventional generators.

Without hydropower it would be impossible to meet the EU's ambitious RES targets, which imply some 35% of RES-electricity by 2020. This role is set to increase further in the future.

Hydropower is situated at the crossroads of different policies, from water management to electricity generation or other environmental policies. Already today hydro power tries to balance these sometimes conflicting objectives.

2. Role of hydropower in the generation

Electricity generation from water exist more than one hundred years. The world's first hydro-electric project was used to power a single lamp in 1878. Within a decade, hundreds of hydropower plants were in operation. The first three-phase hydro electric system operates from1891.

In the first half of the 20th century, the USA and Canada led in hydro power engineering. From the 1960s through to the 1980s, large hydropower developments were carried out in Canada, USSR, and Latin America. Over the last few decades, Brazil and China have become world leaders.

The hydropower is the major renewable energy source. It is able to deliver manifold services to the electricity system, which is currently undergoing significant transition. The hydropower is widely used to produce electricity, among other useful purposes.

In the Danube region are in use three types of hydropower: the run-of-river projects, the storage hydropower and pumped storage projects. Hydro power is dispatch able, flexible and cost-efficient. In addition, hydro pumped storage backs up variable generation and delivers important system services and acts as an enabler of renewables.

In the global electricity generation the hydropower representing 20% and in the European electricity generation 17%. Hydropower largest renewable energy source in Europe and globally. Total installed hydropower capacity in the EU27 is 136 GW with 338 TWh/a electricity generation. EURELECTRIC's European members have 200 GW of installed hydro capacity with electricity generation 552 TWh/a.

The hydropower is accounts 70% renewable electricity generation in Europe. The ratio of renewable sources after 2008 significantly changed, mainly because of quick development in Germany.

The available primary hydro energy potential to be develop, in EU27 amounting to 276 TWh/a, and 336 TWh/a including Switzerland and Norway – without pumped storages. The EURELECTRIC has estimated that half of the technical hydropower potential in Europe has not yet been developed. The unused hydropower potential in EURELECTRIC member countries is over 650 TWh/year. Further development of the economically and environmentally acceptable part of this hydropower potential could contribute to meeting the EU energy and climate goals.

In the forecast of International Energy Agency expected that the hydropower will remain the major renewable energy source.

Today hydropower plays a prime role in securing stable electricity supply and in supporting the increased integration of variable renewable energy sources. Pumped storage power plants provide important balancing and ancillary services, facilitating the integration of renewable energy generation. Significant pumped storage capacity are under construction and preparation in Europe, USA and Asia. If all planned projects will realised, the total installed pumped storage capacity in Europe would rise to over 30 GW. Eighteen countries in Europe have new pumped storage facilities in planning stage. According EU statement the pumped storage development represents Community interest.

The sustainable hydropower has to play significant role in Europe's energy future because of the following main factors:

- Hydropower is a major renewable generation technology in Europe's electricity mix.
- It is competitive, efficient, climate-friendly, and contributes to system stability.
- Hydropower improves Europe's security of supply.
- Hydropower is extremely resource-effective. High payback ratio and high conversion efficiency.
- Hydropower helps to mitigate climate change. Hydropower is a renewable generating technology with a very low carbon footprint.
- Hydropower is the only renewable large-scale storage technology available today, and represents the most efficient and economical way to store electricity.
- Hydropower is a local source, contribute in reducing energy import dependency of Europe.
- Still available a significant hydro potential to be developed in Europe.
- Hydropower provides flexibility to stabilise the grid and support increased integration for variable renewables,
- Hydropower is the most affordable and cost-competitive renewable energy source.
- Hydropower needs to be seen as a balancing tool on a European, not only on a national or regional level. Building infrastructure is essential to bridge the gap between demand and supply. Without hydro power and pumped storage, it would be impossible to meet the EU's ambitious RES targets. This role is set to increase further in the future. Europe's hydropower potential can – and should – be further developed. Investments in hydro- and pumped storage are therefore of vital importance for Europe's energy transition.

3. Hydropower potential in Danube region and in Hungary

The gross hydropower potential of Hungary is 7,446 TWh/year, of which 4,590 TWh/year is estimated to be technically feasible. About 5% of technically feasible capacity developed.

The total installed capacity of hydro power plants is 48.2 MW. The annual generation of hydro power plants is about 0.20 TWh/year – only 0,5% of national electric energy consumption. There are only two hydro plants with individual capacities 10 MW or larger. The three main hydro plants in operation are: Kesznyéten – 4,4 MW – on Hernád River and Kisköre – 28 MW, Tiszalök 11,4 MW – on Tisza River.

The country has a small hydropower potential 28.2 GWh/year. There are 26 small, mini or micro hydro plants in operation. The total annual precipitation volume is 58 cubic km, of which 6 cubic km is run-off. There are no large dams. Total water storage volume of country is 0,065 cubic km.

Hydro energy potential of Hungary representing about 4.5% of Danube region's potential. The installed hydro power capacity only 0.15% of the region capacity.

The hydro energy potential of Hungary, including theoretical, technically feasible and economically feasible potential, last time updated in 1984. From the 1984 the technical basis and the economic environment significantly changed. The actualization of earlier resource evaluations needed.

In the Danube region's power generation the hydro power is the second largest primary energy source after coal. The estimated installed capacity of Danube region's hydro power plants is about 36000 MW and their annual generation 110 TWh/a. Majority of existing hydro power plants located in territory Austria, Germany, Romania, Slovakia, Serbia and Bulgaria.

The estimated gross theoretical potential of Danube region is 165 TWh/a, and from this technically feasible 96 TWh/a. In the Danube region the largest economically feasible hydro potential located in Austria 53,7 TWh/a, Romania 30,0 TWh/a, Germany 20,0 TWh/a, Bosnia and Herzegovina 19,0 TWh/a, Ukraine 16,5 TWh/a, Croatia 10,5 TWh/a.

In the Danube region the pumped storages have more than 100 year experience. Historically in Germany, Austria built the firs pumped storages, but during of the past hundred year significant pumped storage capacity are in operation in Germany, Austria Slovenia, Croatia, Slovakia, Czech Republic, Serbia, Bulgaria. Even Hungary builds in 1912 a pumped storage.

The pumped storage development potential is independent from the natural hydro power potential. Mainly depend on local conditions and power market demand. In case of closed cycle type the pumped storage development can be independent also from water flows, rivers or lakes. In case of closed cycle both of reservoirs is artificial with limited small influence on natural water bodies. Only the first filling up and compensation of water losses (evaporation and filtration) shall be from natural water resources. In case of open cycle one of reservoirs substituted by natural water body, mainly rivers and shall meet the nature protection requirements.

Most of Danube region's countries planning pumped storage development, mainly for integration of renewable energy into power system. In Hungary 18 location are identified for large capacity (above 600 MW) pumped storage projects. The pumped storage possibilities exist in the head range from 70 m to 530 m.

4. Power market for hydro power services

The major functions of hydro power show the transition trend from the local primary energy use to system support services. Today the services of hydro power show competiveness on the integrated power market of EU. The integration of liberalised competitive markets into EU’s single market is in progress.

Below certain capacity limits (in Hungary 5 MW) the hydro power operators sell renewable electric energy on the regulated renewable energy market. This is a supported market with feed-in tariffs or green certificates. Above certain capacity limits the energy the hydro power operators sell on wholesale electric energy market. This is a liberalised competitive market. The double market with supported and not supported activity results some torsion.

System operation support tools for support of safety and stability of power supply the hydro power operators sell on ancillary services market. This is a liberalised competitive market also.

5. The supported renewable energy market situation

The large volume renewable energy, the large amount of financial support arise questions in Europe concerning support of renewable energy. Beyond 2020 renewable energy designed be market-based.

The primary problem is the instability of the CO_2 market. The actions towards stabilizing the CO_2 market were not efficient. The low CO_2 price is not sufficient to transform the power generation structure. No mutual understanding between European Parliament and Commission. The future of the CO_2 market is unpredictable.

The cost of financial supports of renewable energy, results from side of EU member countries a claim to reduce support. The economic crisis reduce acceptance overload of supports. In addition to rising unemployment, the extra burden associated by increasing political risk. The rapid growth of greenhouse gas emissions outside of Europe, endanger targets.

The employment benefits will not here. The advantages of employment in manufacturing slip away from the EU disposition. China has become a dominant player. In spite of the efforts of the CO_2 emissions grow, the EU's competitiveness is weakening. Scientific debates on climate change context.

The rules for supporting renewable energies are under modernization to take account of their increasing share in the electricity market and the need to make support systems sustainable. Feed-in tariffs will be progressively replaced by competitive bidding processes that will increase cost effectiveness and limit distortions of competition.

From 2016, generators need to sell their electricity in the market and be subject to balancing responsibilities. Member States are also obliged to use as support instruments market premiums – a top-up on the market price – or certificates in order to promote the better integration of renewable energy into the market. In 2015–2016, Member States will start implementing competitive bidding procedures for a small share of their new capacity from renewables. From 2017 on, Member States shall set up tenders to grant support to all new installations. The future renewable tariffs for hydro power still unpredictable.

In many cases preferred the small hydro power plants, but they are less favourable from point of economic conditions. Their specific investment costs of achieving or excess unit costs of the new nuclear power plant construction, but their deployment is much lower. The small hydro can be feasible only in case of high economic support. The reducing of their investment cost would be crucial, but not yet economic breakthrough. Promising details, but missing the complex, low-cost solutions.

6. The energy wholesale market situation

Because of economic crisis, the trends of consumption interrupted, and the prices fall. Significant changes are in the economic environment and energy demand. The economic uncertainty results decreasing electric energy investment. Frozen the natural gas fired plants and the use of coal is the uncertain due to unpredictable CO_2 market evolution. Electricity consumption and peak demand is decreased after 2008. In the region the wholesale electricity prices fall.

The massive entry of the new solar power stations results transformation of the generation structure. The peak prices are decreased, in some cases the base load price higher than peak load price. Continuously is decreasing the difference between the peak and off-peak energy prices. Economy of the market based energy storage is weak, independently of its type of solution. The economic climate of the emission trading scheme is unstable (EU ETS). The interventions of EU to stabilise ETS market were unsuccessful.

The current electricity wholesale price is turned back to price level before the introduction of the EU ETS. The quarterly average EEX electricity prices in 2014 vary between 30 and 35 €/MWh. The EEX electricity prices from first half of 2011 the annually decreasing by 6.50 EUR/year. This is probably the result of over generation of energy transition of Germany. The current electricity price level is too low, the investment new generation capacities economically cannot be viable. But the state support of new capacities is restricted by EU competition law.

According to the plans of the EU the integration of the single electricity market continued and until end of 2016 shall be completed. The experience similar in European countries – because of high natural gas prices and low electricity wholesale prices – the natural gas fired power plants excluded from the market. Parallel with the progress of integration expected the increasing of import pressure. In Hungary the domestic electricity generation can participate in the base load supply, the load following power plants was not competitive with the imports.

The value in power system of the low cost and high price-stability hydropower is expected to be higher. The driving force of large hydro development is the long term benefits. The central task is to ensure consistency between use of long term benefits and environment protection.

In the Hungarian power system the energy import very high, in last year reach 33% of total consumption. The growth of annual consumption about 0.6%. In 2014 the difference of 2008 plan and fact consumption is about 5 TWh. The import share in annual peak load in last year reaches about 50%. In 2014 the difference of 2008 plan and fact peak load is about 1000 MW. Questionable what is the real need for new domestic capacity and domestic generation?

7. The power system services market situation

The market of system services including load-frequency control, voltage- reactive power regulation, black-starts and emergency reserves is a part single electricity market. According plans continued the integration process of system services markets. The integration results shows very high benefits because of radical decreasing prices.

In the last years the difference of peak and off-peak prices decline to 25–30% of 2008 value. This destroys the commercial basis of the conventional energy storage on the base of wholesale electricity prices. For system services markets allowed the double fee system. First is the capacity fee for available system tool capacity and the second the electricity wholesale market price. Because of double fees the energy storage operation based on sales of ancillary services can be economically viable.

In the large portfolio of generating plants the improvement of capacity use and efficiency – portfolio effects – could serve for basis of economic decision. In case of extension of Paks nuclear power plant with two new 1200 MW block, the difference of generation with without load balancing pumped storage is 5–7 TWh annually.

The pumped storage today is the quick response, manoeuvrable system tool. The regulating capability of pumped storage in +100% and –100% limits is continuous. Among the regulating capacity options the pumped storage offers the highest quality at lowest cost. The annual allowed number of starts 10 000–15 000 and the ramping rate 1800–3000 MW/min. Independent regulating pumped storage capacity can operate without operating constrains and without cross-subsidies.

In the Hungarian power system required a radical transformation. The Hungarian electricity system is missing the modern regulation capacity with the required flexibility and load change manoeuvrability. The night load minimums are out of hands. The currently available capacity is not sustainable in the longer term. The electric system needs can meet the pumped storage with the high efficiency and large complexity of services.

In the EU energy infrastructure development plans the border-crossing lines and energy storage units get priority and supported.

8. Conclusions

The hydropower is proven and significant power generation tool. Have lowest generation cost, increasing the price stability and support energy independence. The hydropower potential is available and predictable. Hydropower also provides ancillary services and electricity supply for balancing the grid. Mostly local working force required to construction. With its excellent flexibility hydropower is the quick response and manoeuvrable system tool. The possibility to meet climate protection targets without hydropower is not predictable.

The environment of Hungarian power generation and power market changed significantly. In accordance with the system security and sustainability needs clearly required a radical transformation. The hydropower may play significant role in the new structure.

The renewable energy potential, regulation options and system management capacities, offered by hydro power shall be taken into account in the system development plans. No reason to ignore from plans. The economic interest to the use domestic primary renewable energy source, equal – to 10 to 12% domestic electricity consumption, as well as to use of regulating and integration options is high.

Regarding use of hydropower complex, scientific investigations necessary!

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WIND RESOURCES

Perspectives of Wind Energy in the Danube Region

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Wind energy utilization in Europe began about twenty years ago. Based on EWEA statistics there is now 128.8 GW of total installed wind capacity in EU countries. Still the rate of wind power capacity installations with 43.7% is the highest among renewable energy resources (RES)[1]. Solar PV came to the second place. The future trends expected to increase further, although European Commission reduced its earlier plans by 11%.

Most of the central, eastern and south-eastern European countries are at the beginning of the wind energy application. In 2005 there was around 200 times less capacity in new EU member state countries compare to EU12. In 2014 the annual installation was 12.819,6 MW across Europe, of which only 6.7% was in Danube region[2].

Figure 1 illustrates increasing of wind energy sector in Danube countries during the past seven years and the plans until 2020. Since the last few years the largest investments occurred in Romania due to legislative changes[1]. Totally 2,59 MW wind power capacity was installed till 2013. This dynamical growth caused that in Romania exceeded it's EU target in respect total wind power capacity and it had to be increased.

A detailed study of EWEA[3] (2013) called the region as the "new wind energy frontier". Report gave an overview of the economical aspects of wind energy sector, the energy supply chain, the legal framework, support mechanism and financing situation for each country. It highlights some general obstacles and opportunities. One of the main barriers is the regulatory instability, which limits financing mechanisms. Supporting systems are diverse in designing and effectiveness. Unclear, unpredictable or frequently changing rules are also limiting factors. Study recommends

[1] Wind energy Scenarios for 2020 by EWEA2014.
[2] EWEA Annual Statistics 2014.
[3] Eastern wind Emerging wind energy market. Report by EWEA, 2013

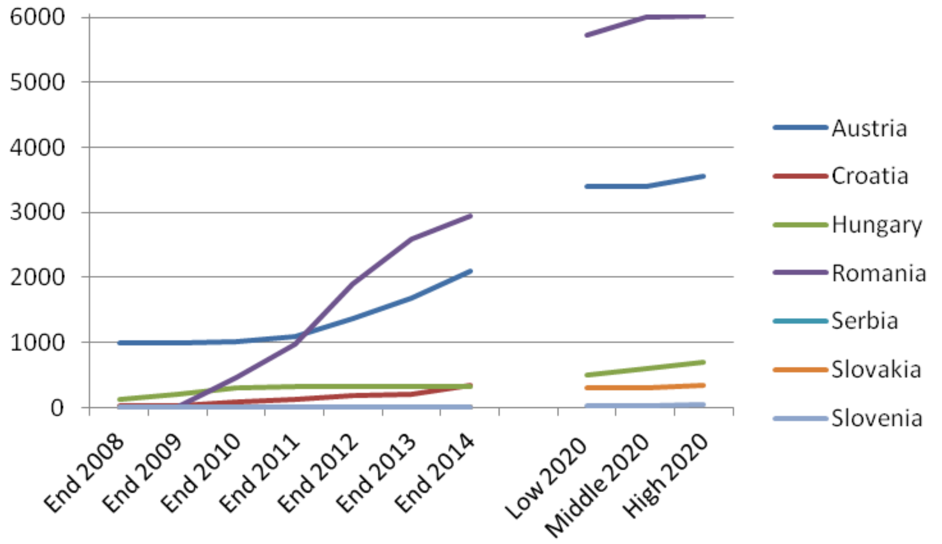

Figure 1. Status and scenarios for wind energy production on Danube Region Based on EWEA data

establishing long-term, stabile, predictable economic and legal framework environment. Clear definition of protected areas and transparency of grid connection cost. Among several technical barriers it has to emphasize the importance of power system stability issue. Wind prediction is a critical component of intelligence integration of wind power into the existing supply system. Short reviews of the main findings for countries of Danube region based on referred publication are below.

Romania has a large wind energy potential for on and offshore investments. Electricity generation from RES are driven by wind energy (about 70%). The current support shame is robust. Foreign utilities are prominent. It is estimated about 6000 direct job in the wind energy sector but still there is not enough skilled domestic labour. Grid capacity could be a strong limit in the near future.

Hungary has moderate wind energy potential. The total capacity had been fixed at 330 MW in 2011. Only small wind turbines (below 50 kW) are supported since then. The future of support mechanism is still uncertain.

In Ukraine the wind speed and local condition are ideal for wind energy application. Beyond unfavourable political environment, the unclear administrative procedures and inapplicable grid connections limits the wind utilization.

Serbia has good wind resources. The feed-in-tariff is limited to 450 MW of total wind energy capacity, although grid would hold up to 2000 MW. Permitting and land use legislation can block wind energy projects.

Slovakia is net importer of electricity. In spite of the quite good potential the wind energy deployments had been stopped.

Slovenia is a net energy exporter country. According to mid-term plans wind energy investment are limited to 600 MW, but currently there is no significant wind energy development. Administrative procedures are opaque. An attractive role that grid connection cost of wind farms would be covered by authorities up to 25 MW.

Researchers make many efforts to overcome these problems. Conferences on RES organized by RKK promote cooperation to exchange information and experiences. In wind energy session methods for estimation wind energy potential and a statistical tool for daily wind forecast are discussed.

Optimization of Wind Farm Location Planning with GIS Methods Based on a Hungarian Case Study Area (Csongrád County)

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Abstract: In Hungary the utilization of renewable energy sources lags behind the EU average. Only about 1% of the energy produced in the country comes from wind power. GIS can turn out to be an excellent toolkit for regional planning professionals when designing the optimal placement of wind farms based on digital map databases. The aim of our work is to present a methodology for locate those areas that are perfectly or moderately suitable for building wind. The presented methodology can be adapted to other areas by helping the placement of wind farms during the optimization of regional planning. On the basis of the Second Military Survey we created a map showing wind mill density, which in turn was used for describing the wind power potential of the area. Average annual wind speed was calculated from the collected meteorological wind speed time series and we calculated at the height of 100 meter wind speed data using the Hellman exponential function. Based on this map it can be stated that the average annual wind speed calculated at the height of 100 m is about 4.5–5.5 m/s, which means that wind turbines would probably operate profitably. Lastly, by overlaying the wind potential map and the thematic maps limiting the establishment of wind farms, we were able to locate those areas that are unfit, not entirely or highly suitable for the installation of wind turbines. Relying upon our maps we done detailed wind potential calculations were estimated annual amount of electricity can be produced in the study area. Calculated on the basis of 2 MW turbines, 25 % of actual performance and a space of 360x630 meters per turbine, 872 MW of energy could be generated annually if we placed wind turbines in every suitable or perfectly suitable area.

Keywords: wind power; wind energy; renewable energy source; wind turbine

1. Introduction

Nowadays the importance of the use of renewable energy sources is researched more and more from the spatial planning point of view. The growing use of hydro power, wind power, solar power, biomass electricity, biomass heating, photovoltaic and geothermal electricity, geothermal heating, biodiesel and bioethanol creates a new challenge and new tasks for regional planners. For the development of renewable energy sources there is a need for a very detailed, GIS-based spatial analysis of the energy potentials (such as wind energy potential) and the limiting factors (such as protected areas, built-up areas etc.). Out of renewable energy sources, wind energy has the second largest energy potential in Hungary (Imre 2006).

The aim of the study is to use GIS methods for the spatial optimisation of wind turbines. Our goal is to elaborate a methodology which can be used for the spatial planning of wind farms in other areas (regions, countries), and can be expanded by new databases (e.g. aesthetic evaluation). The administrative unit of the county was chosen as the study area, as although the suitable areas for wind farm installation are delineated in the regional plans of Hungarian counties as "areas that can be taken into consideration for wind turbine placement", we need a more detailed spatial delineation based on the geographical characteristics of the study area (Fig 1). The second reason why we have chosen the county level as the study area is that our digital database has a scale limitation.

2. Materials and Methods

2.1. The used databases

For our spatial analyses, we used the following 1:100,000 scale digital databases: the CORINE 2006 Land Cover Map and the digital road and electricity network map. Based on the Hungarian Digital Information System of Protected Areas, we used the 1:100,000 scale NATURA 2000 map of Csongrád county. The synoptic meteorological (especially wind speed) databases of the Hungarian Meteorological Service were also used for wind energy mapping.

2.2. GIS analysis of the limiting land use factors for wind turbine installation

Based on the international literature and the Hungarian legal restrictions, it is possible to identify the limiting factors which exclude the possibility of the use of lands for wind farms in the study area. By assigning the limiting factors to multiple buffer zones, we were able to develop land use scenarios to determine the suitability of each area for wind farm placement.

In our study the following limiting factors were spatially analysed with GIS methods: spatial pattern of protected areas (NATURA 2000 areas), forests, lakes, built-up areas, transport and energy networks. Hungarian and international laws prohibit new wind farm building within the NATURA 2000 protected areas, forests, lakes and built-up areas. Surrounding the built-up areas, the NATURA 2000 areas and the line infrastructures (road and energy networks), we created different buffer zones, within which we precluded the establishment of wind farms.

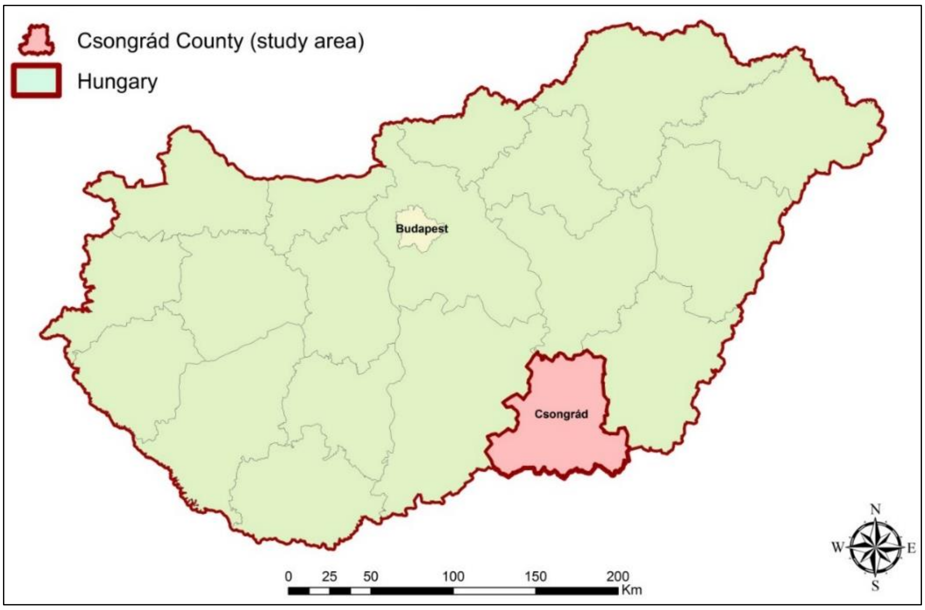

Figure 1. Geographical location of study area

2.2.1 Protected areas as limiting factors for wind power installation

Inside the protected areas, the following regulations have to be considered for the installation of wind turbines.

Natura 2000 sites include two kinds of protected areas: Special Protection Areas for birds and Special Areas of Conservation. The establishment of wind farms is prohibited under the relevant EU legislation in these areas. According to the recommendation of Hungarian Environmental Authorities, an 800–1000 meter buffer zone should be established around Natura 2000 sites and protected areas so that the animals inside these buffer zones would only be exposed to a minimal disturbance by the wind farms (KvVM, 2005). In our evaluation two kinds of scenarios were used and we delineated the 800 and the 1000 meter buffer zones where it is not allowed to build new wind farms.

Based on the Hungarian Digital Information System of Protected Areas, we selected the polygons of Natura 2000 sites and then we created an 800 and 1000 meter buffer zone around the polygons in the ArcGis 10 software. The created buffer zones were defined as unsuitable areas for wind farm installation.

2.2.2 Forests and water land use units as limiting factors for wind power installation

According to Munkácsy (2011), the creation of a 250 meter buffer zone is recommended around the forest areas where it is not allowed to build new wind power infrastructure due to animal protection reasons.

Inside and nearby permanent water bodies it is not possible to install any kind of wind power facilities due to conservation reasons and the fact that the soil structure is not stable enough for a wind turbine basement. We recommended 800 and 1000 meter buffer zones instead of 250 meter buffer zones surrounding the surface water bodies. In our opinion buffer zones need to be extended because the lakes and other water surfaces often have high ecological value and considerable significance for natural conservation purposes.

From the 1:100,000 scale CORINE 2006 Land Cover Map of Hungary the land cover polygons of “water bodies” and “forests and semi-natural areas” have been selected and then we created 250, 800 and 1000 meter buffer zones around the polygons. The created buffer zones were defined as unsuitable areas for wind farm installation.

2.2.3 Built-up areas as limiting factors for wind power installation

According to the Hungarian Environmental Authorities, the creation of a 500 meter buffer zone is recommended in the case of settlements because the wind turbines’ noise disturbs local inhabitants. For our analyses the recommended 500 m buffer zones were used around residential areas (Urban fabric CORINE land cover units).

Using the dromstorre.dk sound calculator software, we were able to verify the buffer zone parameters with our quantitative results. A 2 MW turbine’s sound level is 105 dB in its immediate vicinity, 40 dB 500 meters away while it decreases to 35.9 dB in an 800 meter distance. The results obtained correspond to the above mentioned limits. In such a distance, the resulting noise and vibration would not disturb the local inhabitants.

In our opinion the holiday resort areas must be distinguished from the residential areas because their noise sensitivity is higher. We used 800 meter buffer zones around these land cover polygons, which we selected from the “urban fabric” CORINE land cover units based on visual interpretation. Wind turbine installation also has a strong visual impact, so it would diminish the visual values of the landscapes surrounding the holiday resort areas. From the 1:100,000 scale CORINE 2006 Land Cover Map of Hungary we selected the polygons of urban-fabric areas and then we created 500 and 800 meter buffer zones around these polygons. The created buffer zones were defined as unsuitable areas for wind farm installation.

2.2.4 Road and energy networks as limiting factors for wind power installation

We have taken into consideration and digitized the 120 kV and 400 kV electrical networks and the main international and Hungarian hydrocarbon networks (Tóta 2009). The created 250 meter buffer zones were defined as unsuitable areas for wind farm installation because of the accident risk (Fig 2).

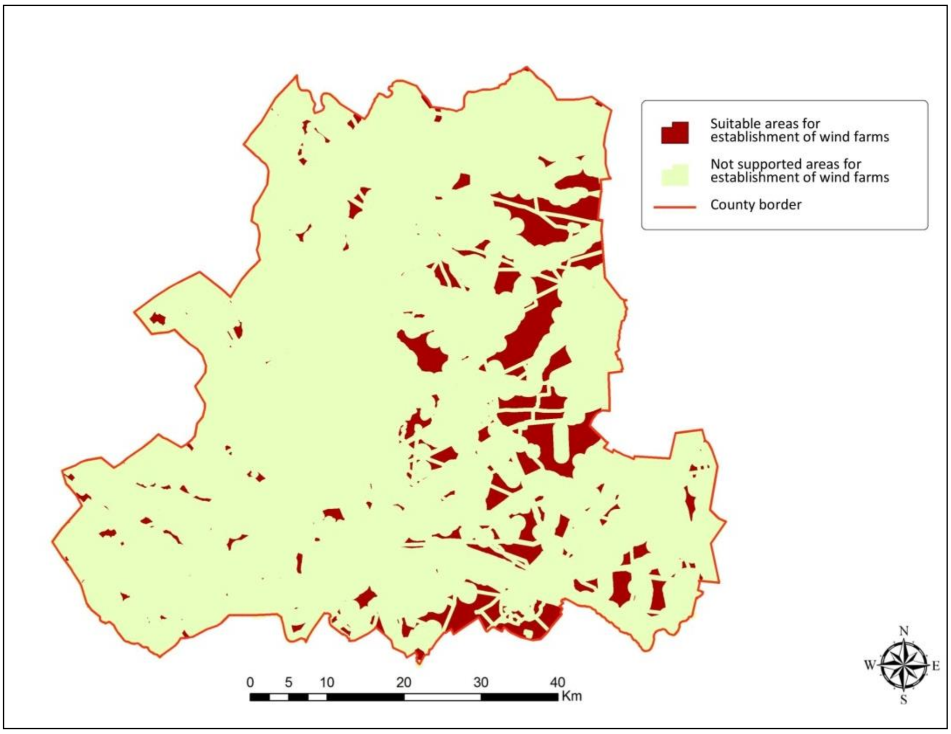

Figure 2. The limiting land use factors for wind turbine installation with buffer zones of the study area

2.3. GIS analysis of *supporting* aspects of wind power installation

The supporting aspects include the paved road network and the electrical networks in case of multiple turbines because both of them can reduce investment costs. In the case of the 120 and 400 kV high voltage networks, the produced energy is transported by electrical cables 1.5 meter deep in the ground. As environmental impact assessment is only required if the underground cable is longer than 15 km, it is practical to develop wind farms within this distance (buffer zones).

A paved road network is also very important for the installation and maintenance of wind turbines. It significantly reduces costs if there is no need for creating new paved ways for service cars. Therefore in our opinion the road network is a supporting factor for wind turbine installation. We digitized the 120 and 400 kV high voltage network in Csongrád County and then we created 250 meter buffer zones surrounding the road network, and 15 km buffer zones surrounding the electricity network. We merged these two buffer zones and used the resulting map to delineate those areas that are highly suitable for the installation of wind turbines (Horváth 2005).

After the road and electricity network analyses we used historical military maps and a wind energy potential map based on synoptic meteorological data to delineate the most suitable areas for wind farms in the study area (Fig 3).

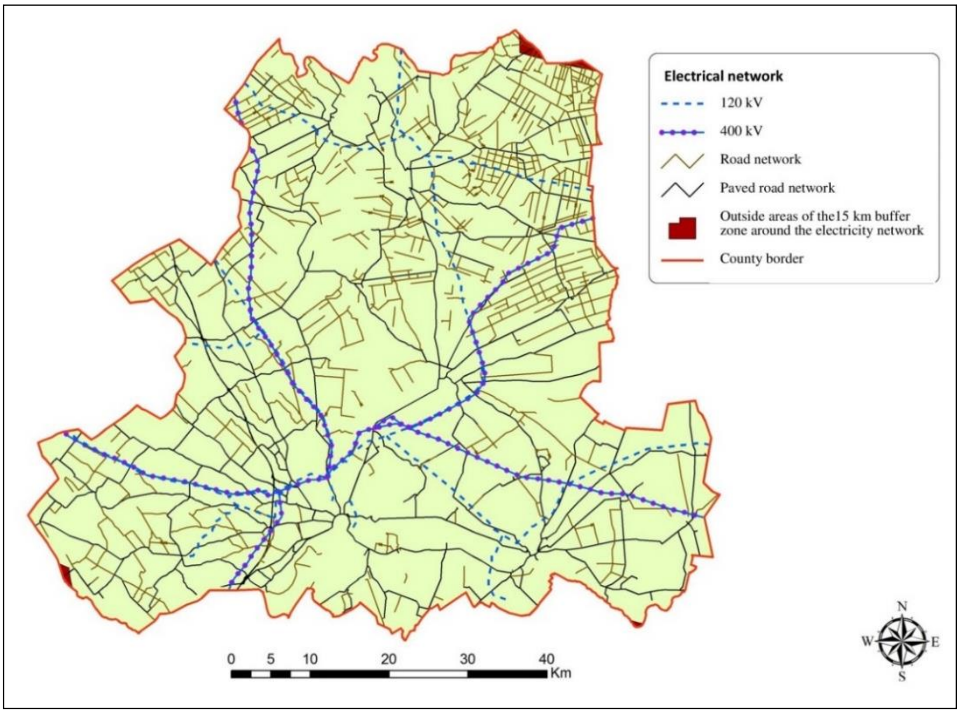

Figure 3. Supporting aspects of wind power installation of the study area

2.3.1 Historical windmills as indicators of the wind energy potential

In her publication, Keveiné Bárány I. (1991) underlined that wind energy potential was first utilized by windmills. She called attention to the fact that the spatial analysis of windmills would be a suitable tool for estimating wind energy potential. Keveiné also demonstrated the spatial distribution of the windmills of the great Hungarian

Plain with the help of a map. During our research, we created a windmill density map that could be an important historical dataset for the wind potential prediction of our study area (Csongrád County).

We used the DVD of the historical military maps of the II. Military Survey georeferenced by Arcanum Ltd. (Arcanum, 2006). The county was divided into equal areas during the digitization and we identified all the windmills by examining them one by one through visual interpretation. Based on the military map sheets created in the indicated period, 96 windmills were identified and digitalized in the study area.

We created a windmill density map from the digitized windmill points with the following method: for every digitalized windmill point data a 3 km buffer zone was drawn in ArcGis 10. By counting the points in the buffer zone and assigning this value to the points, we generated a density map (Fig 4).

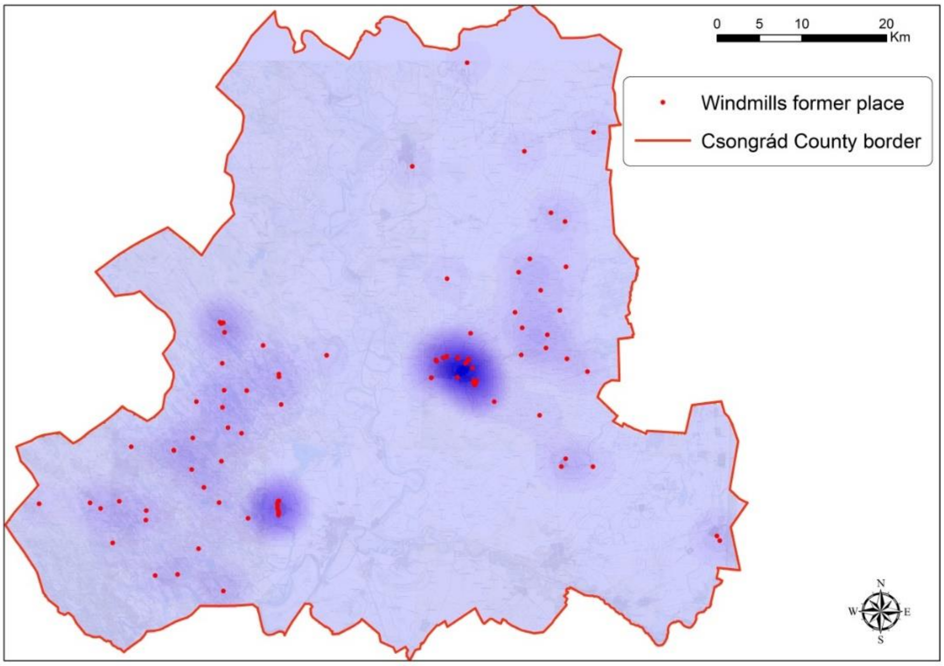

Figure 4. Windmill density map of the study area based on II. Military Survey (1870)

2.4. Creating a wind potential map of the study area using GIS methods

For the installation of wind turbines, it is essential to know the average wind speed data of the study area. In 2005, The Hungarian Meteorological Service produced a wind speed map for the whole country, which was made in a resolution of 2 x 2 km rasters. For our county level analysis, we needed more detailed, higher-resolution annual wind speed averages from a more dense station network. We received the long-time averages of 4 synoptic meteorological stations from the Hungarian Meteorological Service. We also got monthly average wind speed datasets from 3 stations found in the database of the Időkép.hu website. Regarding the M43 motorway and the Csongrád county section of the M5 motorway we also got wind speed datasets from the Motorway Service Companies (AKA Zrt.). Within the study area, 15 meteorological stations' monthly average wind speed data set was available. However, the used interpolation methods require wind speed data that comes from outside the study area. The wind speed datasets of Arad, Baja, Békéscsaba, Kecskemét, Kikinda, Újvidék (Novi Sad), Palics, Szolnok and Zombor were used for this purpose from the ogimet.com website.

For the interpolation of the wind speed data the ArcGis 10 software and the Inverse Distance Weighted (IDW) interpolation method were used. To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location. The measured values closest to the prediction location have more influence on the predicted value than those farther away. IDW assumes that each measured point has a local influence that diminishes with distance. It gives greater weights to points closest to the prediction location, and the weights diminish as a function of distance, hence the name inverse distance weighted. The points are not even located far away from each other, which could affect the accuracy of the interpolation.

The synoptic stations represented the station data which has been measured 2m above the surface, therefore we calculated the wind speed at 70 m, 100 m and 120 m using the following formula (Tóth et al. 2006).

Hellman exponential function:

$$v_W(h) = v_{10} * \left(\frac{h}{h_{10}}\right)^{\alpha}$$

Where: $v_w(h)$= velocity of the wind at height [m/s], h=turbine height [m/s]
v_{10}= velocity of the wind at height, h_{10} = 10 meters [m/s]
α= Hellmann exponent

We determined the Hellman exponent under Davenport's classification. We used the 0.25 “Rough” class for most calculations: cultivated or natural area with high crops or crops of varying height, and scattered obstacles at relative distances of 12 to 15 obstacle heights for porous objects (e.g. shelterbelts) or 8 to 12 obstacle heights for low solid objects (e.g. buildings). The 0.5 „Very rough” class was applied for intensively cultivated landscape with many rather large obstacle groups (large farms, clumps of forest) separated by open spaces of about 8 obstacle heights and for low densely-planted major vegetation like bush land, orchards, young forest. It was also used for areas moderately covered by low buildings with interspaces of 3 to 7 building heights and no high trees (Jon W. 1992). We calculated the data measured near the surface for 70 m, 100 m and 120 m heights using the Microsoft Excel software. Based on the studies made by Kircsi A. (2004), surface roughness does not cause significant interference in Hungary in regions higher than 60 m. We created the wind energy potential map with values calculated at 100 m using IDW interpolation, since according to Szalai et al. (2010) it is the recommended height for county level wind speed calculation in Hungary (Fig 5).

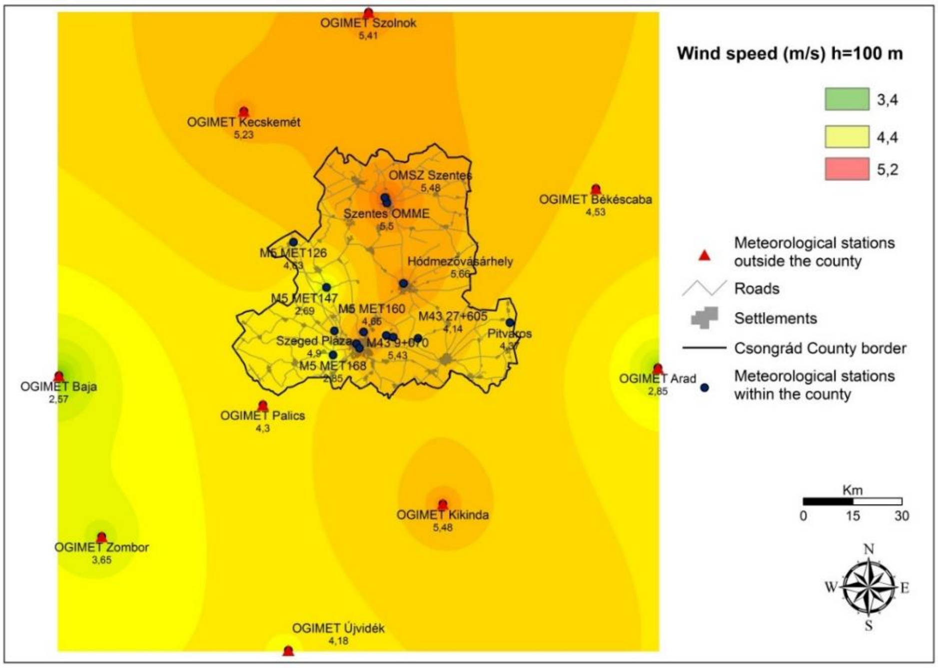

Figure 5. Wind potential map of the study area

3. Result and discussion

Delineation of the areas which are suitable for the installation of wind turbines within the study area (Csongrád County):

By merging the digital map databases of the supporting and limiting factors in the ArcGis 10 environment, the fairly and highly suitable areas for wind turbine installation have been delineated. Based on our results, we can conclude that Csongrád County is suitable for renewable energy development because it has good wind energy potential and many suitable areas for wind farms. The resulting wind potential map clearly shows that in the Northern parts of the county wind speed values are higher. Regarding the Eastern and South-Eastern parts of the county, higher values were obtained as well.

Henceforth, the maximum possible numbers of turbines were estimated inside the delineated suitable areas in Csongrád County. According to the suggestion of the dromstorre.dk website, turbines should be placed 7 diameters apart in the prevailing wind direction and 4 diameters apart in the direction perpendicular to the prevailing winds. A 2 MW turbine's rotor diameter is 90 m, which means that the turbines need to be placed 360 m and 630 m apart parallel and perpendicularly. 4.4 turbines fit in one square kilometre.

Based on our calculations, approximately 1744 wind turbines could be installed in the areas that are suitable or highly suitable for the establishment of wind farms. For the estimation of the total wind energy potential of the study area (Csongrád county), we calculated with 2 MW turbines, 25% of the actual performance and a space of 360 x 630 meters per turbine. Our results show that a total of 872 MW energy could be generated annually if we placed wind turbines in all suitable or highly suitable areas (Fig 6). Our results, regarding both the scale and the methdology, approximate the results of Munkácsy et al. (2015) research on Csongrád county and other counties of Hungary.

4. Conclusion

In the presented study we analysed the supporting and the limiting factors of wind farm establishment in digital thematic maps using different buffer zones.We created a windmill density map and a wind energy potential map with GIS methods based on historical maps and synoptic meteoroligical data. After we merged the supporting, limiting factors and the wind potential map, we could create two land use scenarios and were able to delineate the areas which are suitable or highly suitable for the establishment of wind farms. Lastly, we estimated the annual amount of electricity which can be produced in the areas that are perfectly suitable for the establishment of wind turbines inside the delineated suitable and highly suitable areas of the study area.

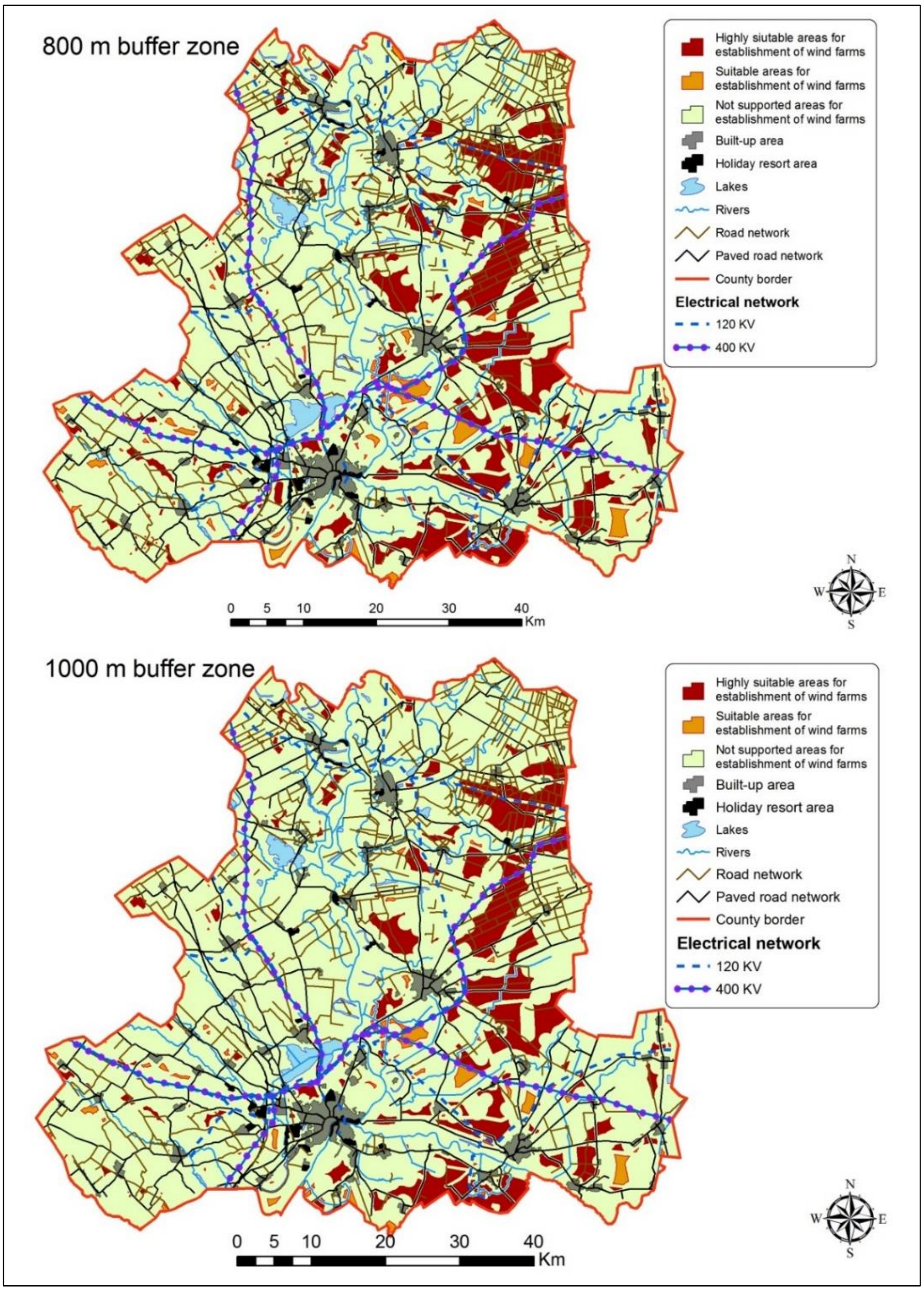

Figure 6. Suitable areas for establishment of wind farms of the study area (2 scenarios)

Summarizing our results, we concluded that indeed 91.02% of the study area is unsuitable for the installation of wind turbines due to some environmental restrictions and considerations. Based on the used GIS methods (overlaying different kinds of limiting and supporting factors, buffer zones and supporting factors maps), we created a county level wind potential map, and based on our calculations, we estimated the annual amount of electricity that could be produced by wind power in the study area. We found that approximately 1744 wind turbines could be installed in the areas which are suitable or highly suitable for the establishment of wind farms. According to our calculations, 872 MW of energy could be generated annually if we placed wind turbines in every suitable or perfectly suitable area.

The GIS and calculation methods we applied can also be used for analysing other areas with a similar purpose and for estimating their wind power potential.

From user aspect it is important to mention that this is a theoretical estimation and in practice, as a consequence of wind fluctuation there are several other limiting aspects which influence the final energy production.

Conflict of Interest

The authors declare no conflict of interest.

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The Limits to Wind Energy in Hungary – the Geographical Aspect

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Abstract: The main challenge for the mankind is to create a sustainable energy system within a very limited timescale. This transition is started also in Hungary, although the official documents provide just an unstable foundation for this procedure – therefore it is not really surprising that the Hungarian decision makers focus on other solutions. For example the values of renewable energy potentials are rapidly changing in national strategies and plans. The highest level of uncertainty can be found in the field of wind energy, as the official figures which describe the possibilities (and calculated by engineers), are varies between 34 MW and 920 MW. Therefore it seems that using only the technical approach it is not possible to work out a useful methodology in the field of calculation the wind energy potentials. To solve this problem, there is an urgent need to involve other branches of sciences, as the geography, in order to find the real limits of wind energy utilization in this continental part of Europe. Using GIS applications we can declare that the Hungarian wind energy potentials are much higher than the official values, as the technical potential is around 48000 MW, whilst the social-economical potential is approximately 10000 MW. Considering the capacity factor of the existing wind turbines the above mentioned 10 GW wind turbine capacity could make it possible to produce 21000 GWh/year (76 PJ/year) of electricity – compared to the recent national net electricity consumption that was 36000 GWh in 2012.

Keywords: Energy planning, Sustainable energy scenario, Wind energy potentials, Legal regulation

1. Introduction

The mankind's sleep-walking towards an ecological disaster is increasingly apparent. To reduce the negative impacts of the human activity, the issue of energy is in the first place amongst the crucial fields. There is an urgent need to break with the narrowly defined technological approach and involve other fields of knowledge, like geography, sociology, psychology – in order to find sustainable solutions. Therefore it is not surprising that modern geographers are seeking the possibilities to shape the energy future (Nadaï, Van der Horst 2010, Frantál, Kunc 2011, Calvert, Simandan 2010). Some outstanding results – with the help of the above mentione fields – have been achieved in several countries regarding not only new research documents (the Danish Society of Engineers' Energy Plan 2030 [IDA 2006]; Zero Carbon Britain [Kemp 2010]), but concerning the official energy plans (Danish Energy Strategy 2050 [The Danish Government 2011]; The UK Low Carbon Transition Plan [The UK Government 2009]), as well. According to all of these concepts, the wind energy will have a significant role in the future. The objective of this paper is to outline the wind energy possibilities in Hungary. It reveals the spatial aspects of the wind energy planning process and draws the attention to the importance of geography based regional planning.

2. Most important types of energy potential

In Hungary, earlier studies in the 1950–1960s which focused mainly on wind characteristics and calculated only theoretical wind energy potentials were made by meteorologists (Kakas, Mezősi 1956). Since 2000, research has accelerated and shifted into the technological fields, as mostly engineers conducted calculations without any GIS applications (Hunyár 2004; Hunyár et al. 2004; Hunyár, M. et al. 2006). Moreover, they calculated the wind energy potential just in general, without considering the several types of potential. This paper has an important goal to underline: in order to determine the real possibilities, it is important to use and assess the different types of wind energy potential. Although there are several other as well, the following types will be used in this paper.

The Technical Potential is the maximum achievable capacity by the use of all legally available territories, considering the present technological level.

Socio-Economic Potential addresses the technological and economical aspects moreover the social acceptance of wind energy systems. International comparisons were made between proper “per capita” and “per km^2” data of leading wind exploitation areas and the relevant data for Hungary. It is important that in this comparison the wind climate of the areas must be similar.

3. Technical potential

3.1. Methodology

During the last 10 years, 2/3rd of the Hungarian counties were analysed separately to determine the possibilities of wind energy applications by the Department of Environment and Landscape Geography of the ELTE University. Calculations were made by different authors in different time, however all of them were made according to the same Geographical Information System (GIS) based methodology.

In different stages of the research the following softwares were used: ArcView 3.2a; ArcGIS 9.2; ERDAS 9.1. Using these tools the potential area could be determined with square centimetre accuracy.

3.2. Results

Since there are strict limitations due to the protected natural areas or the regulations of public health (for instance the problem of noise pollution), this potential is influenced by legal regulations. Secondly, there are technical limitations, for example, the distance from the nearest suitable transmission line. This last aspect can likely be the starting-point of an expected wind energy project. Still, this is just a technical problem that can be solved with technological development and does not seem to be a strict limitation. Therefore such a wind energy development project's most important assumption is the meeting of the legal and infrastructural limitations connected to the below mentioned features (KvVM 2005, VÁTI 2007):

a) protected natural areas (national, local, and international level);
b) protected landscapes (national and county level);
c) Environmentally Sensitive Areas (ESA);
d) forest areas;
e) hydrographical elements;
f) roads, railways and airports;
g) transmission lines (generally it is a primary condition of these kind of projects but in this context it is a vulnerable element of the infrastructure).

Proper buffer zones were also used around these areas. The buffer distances varied between 0 m and 1000 m depending on the relevant legal regulation.

All these above mentioned limitations restrain the potential land areas to 5.13% of the whole territory, which is 4770 km^2 (Table 1). It is important to underline that these figures are estimations, calculated by the values of the following counties.

In order to obtain the technical potential, the next step is to quantify the power capacity/km^2. Using the instructions of the Danish Wind Industry Association (DWIA 2013) and taking into account the average 2 MW turbine's parameters had a result of around 10 MW/km^2. If we calculate with this value, the Hungarian technical wind energy potential is *47700 MW.*

Figure 1 shows an example of the result of the GIS analysis for Békés County. The suitable areas for wind energy are indicated with orange colour. The overall technical capacity is 6108 MW, however, there are significant spatial differences. Some subregions can host more than 1000 MW capacity, while 2 subregions in the northern and eastern part of the county are totally excluded from wind energy utilization. The most important limiting factor is the landscape protection.

Table 1. Potential areas for wind energy applications in Hungarian counties, calculated with GIS applications (Munkácsy et al. 2007, Munkácsy, Borzsák 2008, Kása 2009, Szabó 2010, Kovács 2009, Kneip 2012, Tóta 2009, Kerti 2013)

County	Potential areas in %
Bács-Kiskun	4.14
Baranya	3.85
Békés	8.62
Borsod-Abaúj-Zemplén	2.16
Csongrád	1.99
Győr-Moson-Sopron	8.37
Heves	8.31
Komárom-Esztergom	7.20
Nógrád	2.80
Pest	3.00
Szabolcs-Szatmár-Bereg	1.85
Tolna	5.20
Vas	9.16
Average	*5.13*

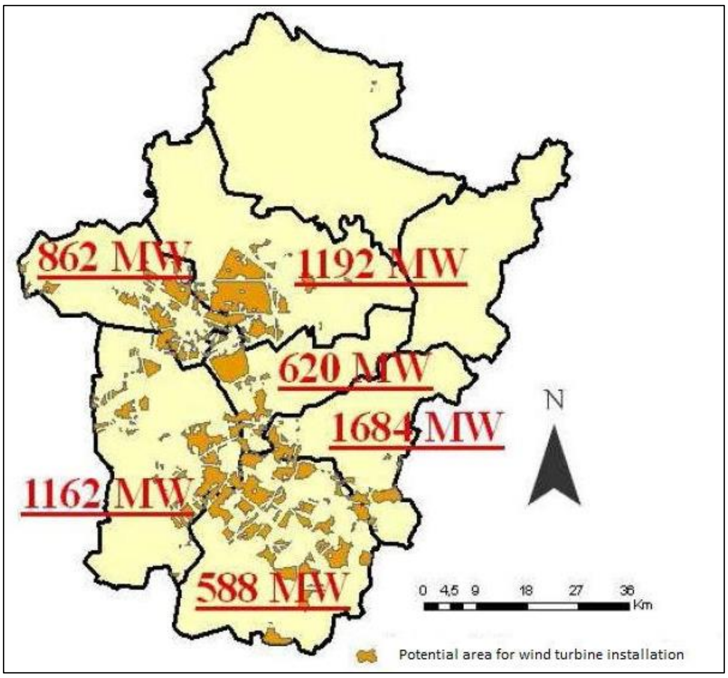

Figure 1. Technical wind energy potentials and area limitations for wind energy in districts of Békés County (Tóta 2009)

4. Socio-economic potential

4.1. Methodology

The calculation of the socio-economic wind energy potential is based on statistical comparisons. The first step is to find a proper territory that is leading in wind energy and is similar to Hungary in basic aspects such as territory, population density, power consumption and wind climate. This territory serves as an example that it is a real option to create such a big wind turbine capacity. In the second step correction can be made with territory, population and GDP (Munkácsy 2011).

4.2. Result

To make comparison with Hungary, the eastern part of Germany (the territory of the former German Democratic Republic) seems the best. Most importantly, their progress in the wind energy sector is exceptional, even looking on a global scale. Their territory is only slightly bigger than Hungary and their wind climate – with the exception of Mecklenburg-Vorpommern situated on the Baltic Sea – is also similar. This coastal location, however does not distort our results, as due to the special economic regulations, its turbine capacity is not higher than that of other, continental states. A key fact about this Eastern German area is that *14048 MW* wind turbine capacity was installed there between 1990 and 2014 (Ender 2014). To determine the Hungarian potential, our hypothetical scenario was that progress would resemble the above mentioned German example, and the starting date was the erection of the first Hungarian wind turbine (2000). The steps are:

1. calculation of the "per capita" indicator;
2. calculation of the "per km^2" indicator;
3. correction with GDP/capita.

1st step: In the Eastern part of Germany the wind turbine capacity is 0,861 kW/capita. Using this figure in a calculation with the population of Hungary (9 908 798 inhabitants), the result is around 8531 MW.

2nd step: In the Eastern part of Germany the wind turbine capacity is 0,129 MW/km^2 in 2012. Using this figure in a calculation with the territory of Hungary (93,030 km^2), the result is around 12,041 MW.

3rd step: It is possible to use a correction factor, as the economical performance of the two areas is different. The Eastern German area has a GDP of 24345 Euro/capita; as the same indicator is 12735 Euro/capita in Hungary.

One may suppose, that this half economical performance means a significant difference between the implementation times. As such a development in the case of East-Germany was 23 years, one can assume that in Hungary the potential can be reached in a longer period. It seems a realistic scenario that Hungary can reach the above mentioned potential by 2050.

Due to this calculation the Hungarian socio-economic wind energy potential is around *10286 MW ±15%* (the average of the 1st and 2nd step value) *by 2050.* This method is slightly distorted by the fact that the Hungarian scenario starts with a 10-year delay compared to the German example, resulting in different technological possibilities. However, this only means that our predictions are conservative and the actual potential could be even greater. Finally, we can state that wind farms and their service areas should only have to cover 1.1% of the total Hungarian territory in order to establish this vast wind turbine capacity. In the case of the legally available land areas, this ratio is 19.6%.

In the next phase the power production of the predicted wind turbine capacity needs to be calculated. In this evaluation the average capacity factor of the whole Hungarian wind turbine fleet was used. According to the Hungarian system operator, the latest capacity factors were 21,3% (2011), 26,0% (2012), and 24,1% (2013), respectively (MEKH 2014). It means that using these figures the power production of the predicted wind energy capacity would be 19–23.5 TWh by 2050.

5. Conclusions

Spatial limitation is one of the crucial aspects in wind energy development. As the most important conclusion we can underline that wind energy investors generally have a sufficiently big area, about 4770 km^2 to develop. Considering the most outstanding international developments in this field and assuming a similar growth, wind energy could reach 10286 MW ±15% and could cover around 40–50% of the power production by 2040–2050 in Hungary – if the wind climate and the level of the electricity production and consumption will not change significantly. In order to reach such a high level of wind energy, it would be important to create energy storage facilities, as pumped storage systems, power to gas applications or compressed air energy storage. As for the latest possibility, a new analysis shows that the geological conditions are favourable in Hungary to create 7*300 MW (altogether 31,5 GWh) storage capacity in the north-western part of the country, under the most advantageous wind climate (Havas and Hrenkó 2015). Nevertheless, we can use other methods also in wind energy integration, as intensifying the cross-border trade of electricity and using the tools of demand side management.

This result would be similar to the recent figures of the continental German states of Saxony-Anhalt or Brandenburg, where the ratio of the wind energy hit 53.3% in the field of power consumption (Ender, C. 2014). In this situation wind turbines may cover only 1.1% of the whole land area of Hungary. It is very important to underline that wind turbines are not excluding factors in the land use for all the other economical activities, compared with the recently used power production technologies. The wind energy also means a local energy source compared with other sources, as nuclear energy, which means a 100% dependency on foreign, basically Russian sources.

This research confirms that the focus change of the national energy policy would be admissible from the land use point of view. The encryption of almost every details of the planned nuclear investment can draw the attention to other important aspects of this problem: the shift to such sustainable energy solutions, as the wind energy, means a profound step ahead in the field of (energy) democracy, as well.

Acknowledgments

The authors would like to thank the students (namely Tóta, A., Tóth, T. P., Kneip, Zs. É., Kerti, B., Kovács, G., Kása, I., and Szabó, F.) of the energy courses of the Eötvös Loránd University, Department of Environmental and Landscape Geography for their contribution to this research.

Conflict of Interest

The authors declare no conflict of interest.

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Statistical Estimation of the Next Day's Average Wind Speed and Wind Power

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Abstract: One of the sticky problems of the wind turbine operators is to prepare the so-called timetable, namely the estimation of wind power quantity for short periods of the next day. With the presented statistical method, we would like to help in this process. Our model is suitable the determine the probability of increase or decrease of daily average wind speed and wind power to the next day in case of different periods and weather conditions. The application and results of our model is presented by using hourly wind speeds of five meteorological observatories in Hungary (Szombathely, Pécs, Budapest, Szeged and Debrecen) in the period of 1991–2000. The daily average wind potential and the electricity produced by wind turbines can be estimated from the daily average of cube of wind speed. If only the measured or estimated values of daily average wind speed are available, then the daily average of wind speed cubes can be determined from a regression equation. If we want to estimate the next day's wind potential than as a first step we have to model the next daily wind speed from the present daily wind speed. So the most important elements of our method are the comparison of average wind speeds of subalternating days and the statistical analysis of day-to-day absolute and relative changes. One of the most important results of this analysis is that the highest probability value of relative change (its mode) can be considered equal to good approximation at the five stations (by our other investigation in the whole country). The next day's average wind speed was estimated from this value of the model and the average of the relative change that alters from place to place in the country. From today's daily average of wind speed cubes – which is commensurate with the daily average wind power – the following day's average wind power can be estimated, with the regression equation. Therefore, it is possible to determine whether the wind power will increase or decrease the subsequent day. The precondition of the use of the model in practice is the continuous measurement of hourly wind speed. This can materialize in the case of operating wind turbines. The present daily average wind speed can only be calculated at the end of a day, and this calculation is then used as input data for the model. The size of the miscalculation was also examined, when the present daily average wind speed was determined from the so called term-times (7, 13 and 21 hours). The error of the estimation does not increase significantly, in the case when average term-times are used. The verification of the estimation of the next daily average wind speed has also been completed with other databases that did not take part in the modelling. No significant differences were found between the errors of estimations.

Keywords: daily average wind speed and wind power, day-to-day changes of average wind speed, statistical estimation, error of estimation

1. Introduction

Usually the estimation or forecast of the wind speed or wind power and verification of these is founded on the wind statistics of a shorter or longer former time period. Consequently the clear statistic models have relevant function beside the dynamic methods. We can read the review of statistic models in paper of *Aggarwal and Gupta* (2013).

The total capacity of established wind power plants in Hungary is 329.325 MW with 172 wind power plants operating at 39 sites (*www.mszet.hu*). One of the most complex problems of wind power plant operators is to compose a so called "schedule" that is based on estimating the amount of power produced on the next day divided into small time units. The complexity of the task is given by for example the difficulty of predicting wind speed for every hour over the next day.

Composition of this schedule could be improved using the statistical method presented in this paper. Basis for the model was established and published in previous works (e.g. Tar and Puskás 2010; Tar 2011, 2014a,b). The model presented here is suitable for predicting daily average wind speed for certain time periods (e.g. season, year) and in the cases of transition between various climatic conditions (macrosynoptic conditions, front types) and thus predicting the decrease or increase of average wind energy by the next day. Based on the above the average wind speed of the "next day" can be estimated on the basis of the average wind speed of the "present day" yielding a tool for wind power plant operators for composing the compulsory schedule.

Database of the study is composed of the hourly wind speed of five meteorological stations, namely Szombathely, Pécs, Budapest, Szeged and Debrecen for the time period between 1991 and 2000 supplied by the Hungarian Meteorological Service (Figure 1). Location of the stations is given in Figure 1. Anemometers at the selected meteorological stations operate at various heights. Furthermore, the devices were moved in the studied period at all stations except for Szombathely. The height of measurements was changed as a result of the moving of the device. In order to homogenise data and to make them comparable, wind speed values were transformed for 10 m at each station applying the widely used WMO formula:

$$v_h=v_{10}(0.233+0.656\lg(h+4.75)) \quad (1)$$

where h (≠10 m) stands for the height of the anemometer, v_h and V_{10} stand for the measured and the calculated (for 10 m) wind speeds.

Our statistical method includes the construction of a model based on the statistical structure of the change of measured daily average wind speed that enables the estimation of the average wind speed of the next day on the basis of the average wind speed of the present day using one of the base statistical values (e.g. mean or mode). For constructing the model the daily average wind speed has to be known for each subsequent day therefore one missing date for one day eliminates the data for both the previous and the next days. There were 3653 days in the studied period (1991–2000). Data are available for all days at Szeged therefore only the very last day has to be excluded. Number of missing data and therefore that of eliminated days are highest at Pécs with 166, and the further order is the following: Szombathely 80, Budapest 12, Debrecen 6.

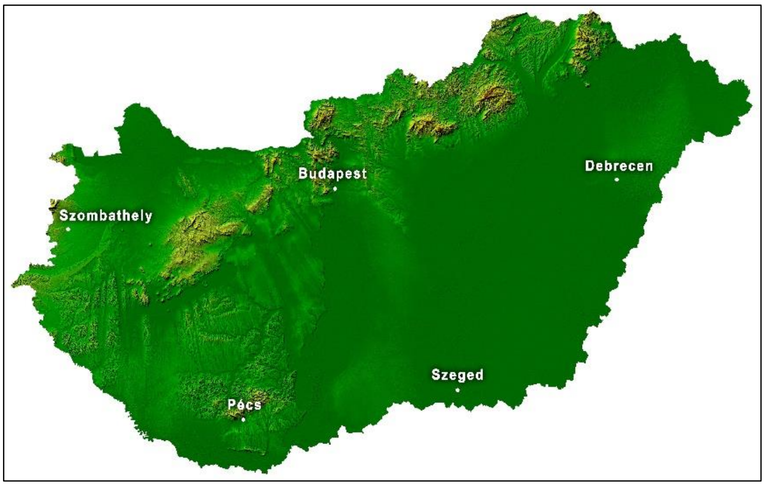

Figure 1. Geographical location of the observatories comprising the analyzed database

2. Statistical structure of the daily average wind speed

The model to be presented is based on the accurate and detailed knowledge of the most important statistical properties of daily average wind speed. On these grounds a good estimate can be given on the average wind speed of the next day from the average wind speed of the present day and thus changes in wind energy day by day can be estimated as well. This is only possible if the daily average wind speed of the present day is known. Accurate value of daily average wind speed can be obtained by averaging the hourly wind speeds of the day. This value is called *actual daily average wind speed*. This value, however, is only available at the end of the day. In order to estimate the average wind speed of the next day at a more optimal time *three-hour daily average wind speeds* were also determined based on 7, 13 and 21 hours wind speeds, i.e. not from Hungarian terminus time. It is presumed that values closer to the real daily average have been obtained in this way. In case the three-hour daily average values are applied the estimated values become available three hours before the end of the day.

Most important statistical characteristics of actual and three-hour daily wind speeds for the entire studied period are presented in *Table 1*. Since element numbers are not the equal the value of variation coefficient (relative standard deviation) was also determined in order to measure variability around the mean. Value of mode was estimated on the basis of frequency distributions to be discussed in the followings.

As can be seen there is no significant difference between the statistics of the two types of daily average relevant for the entire studied period except for the mode values at Szombathely. Values of variability, standard deviation and the variation coefficient are higher in the case of the three-hour values at every station. Skewness and kurtosis coefficients are used only for describing the difference between the distribution of the averages and normal distribution. Both parameters are 0 in the case of normal distribution. Based on the values in Table 1, the distribution of the three-hour averages is closer to normal distribution except for Budapest.

Decreasing order of averages (and standard deviations) relevant for the entire period is the following: Szombathely, Szeged, Pécs, Debrecen, Budapest. Decreasing order of the grade of variability, the variation coefficient is different: Szombathely, Debrecen, Szeged, Pécs, Budapest. No orographic distribution could be experienced. Both parameters are important considering the utilization of wind power.

Table 1. Basic statistics of daily mean wind speeds at 10 meters

		Mean M/s	Standard Dev. M/s	Varia-tioncoeff.	Median M/s	Skew-ness	Kurtosis	Mode M/s
Szombathely	24 hours	3.4	2.05	0.61	2.7	2.00	5.32	2.5
	3 hours	3.4	2.20	0.65	2.7	1.91	4.78	1.5
Pécs	24 hours	2.9	1.30	0.45	2.6	1.03	1.37	2.5
	3 hours	2.9	1.42	0.49	2.6	0.99	1.17	2.5
Budapest	24 hours	2.4	1.06	0.44	2.2	1.32	2.29	1.5
	3 hours	2.4	1.14	0.47	2.2	1.33	2.82	1.5
Szeged	24 hours	3.1	1.45	0.46	2.9	1.10	1.89	2.5
	3 hours	3.2	1.55	0.49	2.9	1.02	1.55	2.5
Debrecen	24 hours	2.7	1.29	0.47	2.5	1.01	1.25	2.5
	3 hours	2.8	1.38	0.49	2.6	0.87	0.67	2.5

The question, however, whether the two random variables from which our samples were taken have similar distribution or not. The question can be decided using the χ^2 test in relation to the homogeneity of empirical distributions (Dévényi and Gulyás 1988).

Frequency distribution of the two types of daily average is given in Figure 2. The Figure shows the answer for the above question: neither of the 24-hour and three-hour daily average wind speed distribution can be regarded as homogeneous at either station. I. e. the distribution of the two probability variants is not the same.

Homogeneity measurement was carried out for comparing the distribution of the two types of average at every station as well. Distribution of the 24-hour average differs significantly from the rest. Distribution of the three-hour average is the same in Pécs and Debrecen with 0.05 significance level according to the test (Figure 2).

The next issue is the description of the statistical characteristics of the difference between the two types of average. The most important ones are given in Table 2 and their distribution is presented in Table 3. 24-hour average wind speed of the present day will be marked by v_{p24} while the three-hour average wind speed will be marked by v_{p3} henceforward.

According to the table the average of the differences at Szombathely, Pécs and Budapest is not significant, however, in Szeged and Debrecen one is three times that of the other. Variation, however, is significantly lower at these two stations than that at the rest. According to Figure 3 the majority of the differences belong to the (-1)-1 m/s interval. This means that if the three-hour averages are regarded to be the daily average wind speeds then in 91–98 % of the cases the absolute value of differences will be less than 1 m/s.

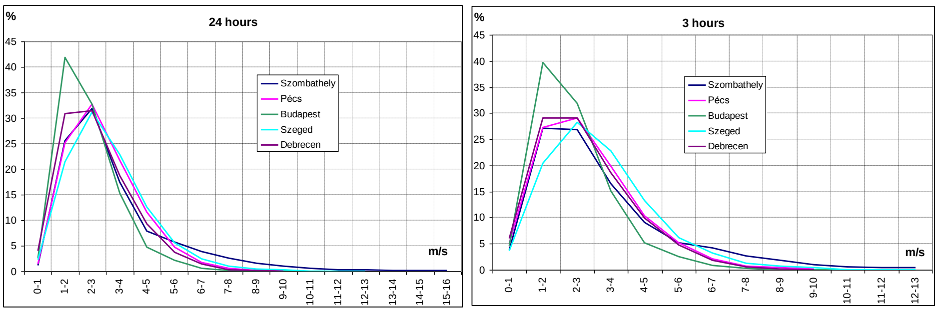

Figure 2. Frequency distribution of 24 and 3 hours daily mean wind speed.

Table 2. Statistics of differences between the 24 and 3 hours daily mean wind speed

v_{p24}-v_{p3}		Szombathely	Pécs	Budapest	Szeged	Debrecen
mean	m/s	−0.01	−0.01	−0.01	−0.07	−0.06
standard dev.	m/s	0.57	0.47	0.35	0.46	0.45
minimum	m/s	−2.8	−2.3	−3.8	−3.5	−1.9
maximum	m/s	3.0	2.2	2.0	3.8	6.1
variation coeff.	–	−60.63	−46.61	−33.83	−6.86	−7.75

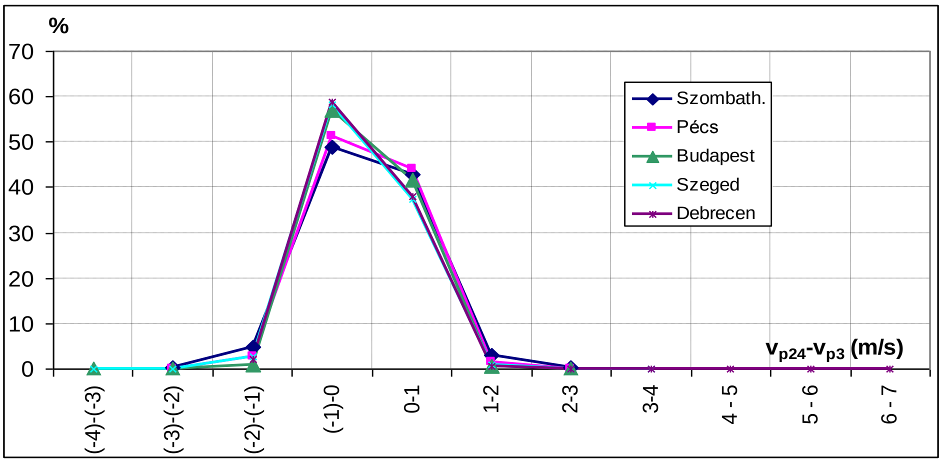

Figure 3. Frequency distribution of differences between the 24 and 3 hours daily mean wind speed

3. Relation of the average wind speed of present and next day

Stochastic relationship between the average wind speeds of days following each other are sought in linear form. Strength of their relation is described by the simple linear correlation coefficient r(x,y), its shape is given by the regression equation y=a+bx.

In the case of the 24-hour averages the two time series differ from each other only in their first and last elements. The average wind speed of the present day is v_{p24} and that of the next day is v_{n24}. Values of the correlation coefficient, $r(v_{p24},v_{n24})$ and that of the regression coefficient, $b(v_{p24},v_{n24})$ can be regarded as equal. When the relationship of the 24-hour average of the next day and the three-hour average (v_{p3}) of the present day is studied the above statement will not be true. Results of correlation regression analyses are presented in Table 3.

Table 3. Linear correlation (r) and regression (b) coefficients between the daily mean wind speeds of the present and the next day

	$r(v_{p24},v_{n24})=b(v_{p24},v_{n24})$	$r(v_{p3},v_{n24})$	$b(v_{p3},v_{n24})$
Szombathely	0.473	0.464	0.432
Pécs	0.471	0.452	0.415
Budapest	0.460	0.448	0.417
Szeged	0.474	0.458	0.428
Debrecen	0.479	0.472	0.442

These parameters are determined by the structure of the time series therefore no significant orographic difference can be observed among their values. According to the table, the linear correlation is closest at Debrecen and weakest at Budapest in both cases. All correlation coefficients differ from 0 significantly due to the high number of elements (3652–3487). Regression coefficients show that if the 24-hour or the three-hour average wind speeds of the present day change by 1 m/s that of the next day will change by values between 0.4–0.5 m/s at every station. Figure 4 presents the closest (v_{p3},v_{n24}) relationship.

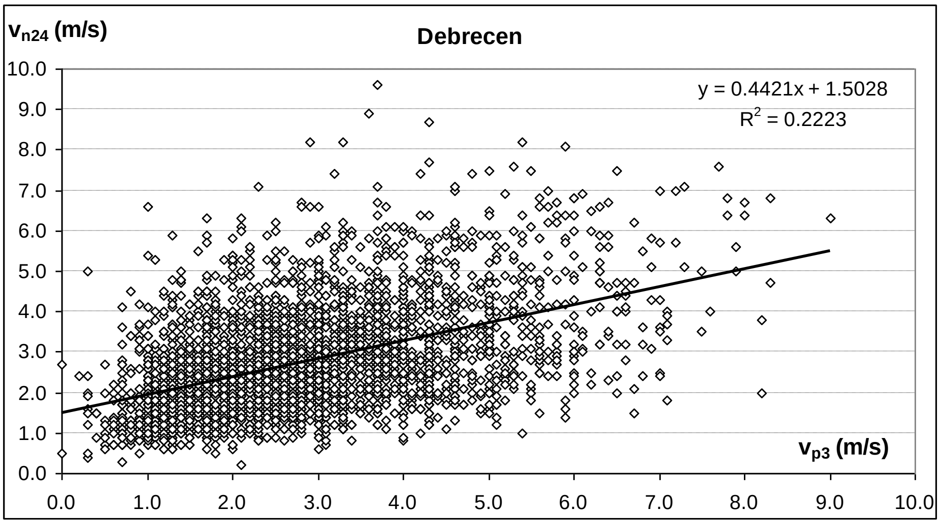

Figure 4. The closest connection between present day's 3 hours and the next day's 24 hours daily mean wind speeds

4. Statistics of the daily relative change of the daily average wind speed

Changing of daily average wind speed from day to day is characterised by

$$\Delta v_r = \frac{v_{n24} - v_{p24}}{v_{p24}} \tag{2}$$

relative quantity. This quantity is more-or-less independent from the height of the anemometer. Its determination is erroneous only on the day before changing the height of the measurement.

Basic statistics of Δv_r are shown in *Table 4*.

Table 4. Basic statistics of relative quantity (Δv_r) describing the day-to-day change of daily average wind

	Szombathely	Pécs	Budapest	Szeged	Debrecen
mean	0.17	0.11	0.09	0.13	0.13
standard dev.	0.72	0.55	0.50	0.65	0.62
variation coeff.	4.29	4.83	5.29	5.07	4.92
minimum	−0.88	−0.84	−0.79	−0.94	−0.89
maximum	10.13	4.80	4.71	15.00	11.00
median	0.00	0.00	0.00	0.00	0.00
mode	−0.10	−0.10	−0.10	−0.10	−0.10
skewness	2.46	1.75	1.90	5.67	3.67
kurtosis	14.64	6.38	7.51	96.00	40.80

Average of relative changes is greater than 0.1 (10%) everywhere except Budapest, its maximum is detected at Szombathely (0.17). Variation coefficient characterising its variability is 9–10 times higher than the similar parameter of the daily average wind speed, e.g. this characteristic is very instable especially at Budapest.

"Spatial average" of Δv_r is 0.13 that is roughly the same as the average (0.12) calculated for 6 stations in the Great Hungarian Plain (Tar 2014a), however, it is significantly lower than the average (0.18) of 11 NW Transdanubian stations (Puskás et al. 2014). The study for the former stations was prepared between 2000 and 2009.

Mean, median, mode together with skewness and kurtosis values indicate that the frequency distributions of Δv_r – presented in Figure 5 – cannot be normal. No difference can be found among the stations regarding the place of the mode. According to the frequency of elements in the interval containing the mode, Budapest and Szombathely differ from the other stations. Therefore it can be presumed that the distribution of the relative change of daily average wind speed from day to day at the other three stations can be regarded as homogeneous at a certain significance level.

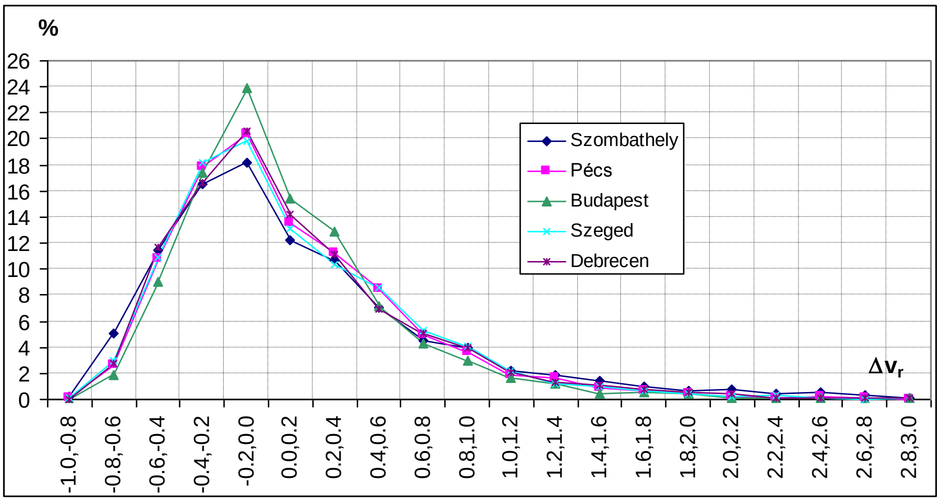

Figure 5. Frequency distribution of the day-to-day relative change of daily average wind (Δv_r)

It is clear that Δv_r values occur in the (-0.2-0.0) interval with greatest frequency at every station, i.e. the empirical counterpart of the mode is -0.1 at every station. The same has been observed at the stations in the Great Hungarian Plain and in Transdanubia mentioned before. Orographic difference does not occur and this can be explained by the special structure and inner framework of the time series.

Distribution of Δv_r according to its sign was determined. Positive ($\Delta v_r \geq 0$) and negative ($\Delta v_r < 0$) changes given in percent and the difference between the two are given in Table 5. Frequency of positive changes when the average wind speed of the next day will be higher than that of the present day exceeds the frequency of negative changes by 2.5–5.0%. Greater chance for positive changes can be observed at Debrecen, Pécs and Budapest.

Studying the connection of relative change and the average wind speed of the present day closest relationship was found with logarithmic regression. Parameters of the correlation index i(x,y) and the regression equation y=bln(x)+a are given in Table 6. Correlation between the present day's 3 hours daily average wind speed and the relative change was closest at Szeged and this is presented in Figure 6.

Table 5. Distribution by sign of the day-to-day relative change of daily average wind

	Szombathely	Pécs	Budapest	Szeged	Debrecen
pos.%	51.2	52.3	52.2	51.7	52.5
neg. %	48.8	47.7	47.8	48.3	47.5
pos.%-neg.%	2.4	4.5	4.4	3.4	5.0

Table 6. Parameters of logarithmic correlation and regression between the present day's 24 or 3 hours daily average wind speed (v_{p24} and v_{p3}) and the relative change (Δv_r), and the zero points of the regression curves (v_{p024}, v_{p03})

	Szombathely	Pécs	Budapest	Szeged	Debrecen
$i(v_{p24}, \Delta v_r)$	0.458	0.505	0.473	0.513	0.494
$i(v_{p3}, \Delta v_r)$	0.437	0.466	0.436	0.481	0.450
$b(v_{p24}, \Delta v_r)$	−0.63	−0.61	−0.57	−0.69	−0.64
$b(v_{p3}, \Delta v_r)$	−0.54	−0.50	−0.48	−0.60	−0.53
$a(v_{p24}, \Delta v_r)$	0.84	0.69	0.55	0.84	0.70
$a(v_{p3}, \Delta v_r)$	0.73	0.58	0.48	0.75	0.61
v_{p024} (m/s)	3.8	3.1	2.6	3.4	3.0
v_{p03} (m/s)	3.9	3.2	2.7	3.5	3.1

Figure 6. The closest logarithmic relationship between the present day's 3 hours daily average wind speed (v_{p3}) and the relative change (Δv_r)

The regression curve crosses the horizontal, i.e. the v_{p24} or the v_{p3} axis. Let's take these crossing points as zero points v_{r024} and v_{r03}. Considering the points of the curve with co-ordinates (x,y), y>0 before the zero points and y<0 after the zero points. This is why it is presumed that the sign of the Δv_r values approached by regression can be associated with the zero points. Values of v_{p024} and v_{p03} are also given in Table 6. According to the table, $v_{p024} \approx v_{p03}$, let's mark their joint value by v_0. In this way, it makes no different that which average speed of the present day is used for further analyses. Let's select v_p for this average.

Detailed results are presented in Tables 7 and 8. Considering the number of positive changes ($\Delta v_r > 0$) being 100 % Table 7 shows that around ¾ of them take place if any average wind speed of the present day is smaller than v_0. Regarding the total number of negative changes ($\Delta v_r < 0$) as 100%, around 60% of them can be detected when any wind speed of the present day is greater than v_0. Szombathely is an exception in both cases, ratios are different here. In the case of negative changes for example there are hardly any differences between the two cases. Values of v_0 are higher than the average wind speed of the whole period only by 0.2–0.5 m/s. Therefore these can be more or less substituted by the values of Table 1.

In Table 8 the conditional frequencies (%) determined based on all cases are given. For example $\Delta v > 0/v_p < v_0$ means that the change is positive given that the daily average wind speed of the present day is smaller than the zero point. It can be observed that the frequency associated to the above condition is the highest at every station. In other words, at every station the probability of that the daily average wind speed of the next day is higher than that of the present day is around 0.4 given that the latter is smaller than the zero point which represents the average wind speed of the whole period. Let's mark this probability by P(1) for simplicity, in this case P(1) ≈0.4. According to the columns of Table 8 the order continues as: P(4)≈0,3, P(3)≈0,2 és P(2)≈0,1. Significant differences can be observed only at Szombathely in the two latter cases.

Table 7. Distribution by sign of the day-to-day relative change of daily average wind speed (Δv_r) before and after the zero point of regression curve (v_0)

	$\Delta v_r \geq 0$ (100 %)		$\Delta v_r < 0$ (100 %)	
	$v_p \leq v_0$ %	$v_p > v_0$ %	$v_p \leq v_0$ %	$v_p > v_0$ %
Szombathely	83.3	16.7	50.1	49.9
Pécs	75.7	24.3	41.3	58.7
Budapest	76.7	23.3	40.9	59.1
Szeged	74.2	25.8	38.8	61.2
Debrecen	72.9	27.1	39.8	60.2

Table 8. Conditional frequencies of relative change's sign

	$\Delta v_r > 0/v_p < v_0$ (1) %	$\Delta v_r > 0/v_p > v_0$ (2) %	$\Delta v_r < 0/v_p < v_0$ (3) %	$\Delta v_r < 0/v_p > v_0$ (4) %
Szombathely	42.6	8.6	24.4	24.4
Pécs	39.6	12.7	19.7	28.0
Budapest	40.1	12.1	19.5	28.3
Szeged	38.4	13.3	18.7	29.6
Debrecen	38.3	14.2	18.9	28.6

5. Estimation of average wind speed of the next day

One important structural element of wind fields is energy content and what most of us would like to know is its amount. There are several methods to estimate the energy content of wind fields. Two statistical models created by us were already published earlier. These models can be used for determining the average wind energy potential of a time period composed of days and the total wind energy potential of one day (Tar et al. 2001a,b,c, Tar and Kircsi 2001a,b, Tar 2004, 2006, 2008, 2010, Tar et al. 2007, Tar and Szegedi 2009, 2011). Both methods can be applied only if hourly wind speeds are known. This condition is eliminated in the estimation procedure presented in the followings.

Potential wind energy is generally characterised by specific wind power which is the energy of movement of a body of air moving through one unit of vertical surface over one unit of time. Its calculation at a given time is based on the equation below:

$$P_f = \frac{\rho}{2} v^3 \tag{3}$$

where 'v' stands for wind speed, 'ρ' stands for air density and its dimension is Wm^{-2}. There are two ways to determine the specific wind power of a longer period of time: the average wind speed of the given period can be used for 'v' in the above equation or the values determined at each time (discrete) of the period are summed.

Logically the second method reflects reality better; however, problems are set by the dependence of the summed value on the number of measurement times in the time period. This dependence can be reduced by averaging. In this way the daily average specific wind power, i.e. the average wind power for *one measurement time* is obtained.

Daily average of wind speed cubes is proportional to the daily average specific wind power. Very strong linear correlation between electric energy produced in an operating wind power plant and the daily average of wind speed cubes has been detected (Tar and Szegedi 2011). Unfortunately the exact daily average of wind speed cubes ($[v^3]$) can be determined at the end of the day. That of the next day can be estimated based on any characteristic of the wind speed of the present day.

Select the 24-hour daily average wind speed of the present day, v_{p24} for this characteristic. First the stochastic relationship of $[v^3]$ and v_{p24} has to be determined. Closest correlation in this case is shown by the power function: $[v^3]=a(v_{p24})^b$ since the correlation index varies between 0.975 and 0.982 at the five stations. Following the determination of constants 'a' and 'b' the estimated value of the daily average wind speed cubes of the next day are obtained if the estimated value of the 24-hour average speed of the next day is written in the regression equation above.

Estimation of the 24-hour average speed of the next day is performed using the three-hour average wind speed values of the present day applying also the average value ($[\Delta v_r]$) and mode ($\langle \Delta v_r \rangle$) of the Δv_r relative change. Equations used in the process of estimation are the following:

$$v'_{n24} = v_{p3}(1 + [\Delta v_r]) \tag{4}$$

and

$$v'_{n24} = v_{p3}(1 + \langle \Delta v_r \rangle) \tag{5}$$

Since $[\Delta v_r]>0$ at every station estimation (4) yields values that are always higher than v_{p3}. As mentioned above $\langle \Delta v_r \rangle$ can be regarded as -0.1 at every station thus estimation (5) yields always 0.9 times v_{p3}. Simple errors of the estimations are (m/s):

$$E_s = v'_{n24} - v_{n24} \tag{6}$$

Some statistical characteristics of the estimations are given in *Table 9*.

First two rows in the table contain the distribution of the sign of the simple error. Values of estimation based on the average of Δv_r are higher by around 60% than the original value (the error is positive overestimation). In the case of estimation based on the mode of Δv_r the negative error, the ratio of underestimation will be around 60 %. These determine the positive or negative sign of the average values as well. Studying the absolute values the error of the estimations on average is greatest at Szombathely and smallest at Budapest and Debrecen. Average error of estimation based on the mode is smaller except for Budapest. Variation coefficient showing the grade of variability has its maximum at Budapest and minimum at Szombathely when the estimation is based on the average. These limit values replace each other when the estimation is based on the mode.

The interval containing the errors of estimations, however, has its maximum at Szombathely and minimum at Budapest in both cases. Mode values were determined from the distribution of the simple errors. Distribution similar to that depicted *in Figur*e 7 was found at every station: errors of estimations based on the average fall into the (0.2) m/s interval while those of estimations based on the mode fall into the interval (–2.0) m/s with greatest frequency. Thus the values of mode can be regarded as 1 and –1 m/s. As shown in Figure 7 errors fall into the interval (–2.2) m/s fairly frequently. According to *Table 9* this frequency is between around 90 and 70 % and it is always greater in the case of estimation based on the mode.

Accordingly to the statistical characteristics of simple error analysed above the 24-hour average wind speed of the next day can be estimated if the three-hour daily average wind speed is known. The next step will be the estimation of the daily

Table 9. A couple of statistical characteristics of simple errors of next day's mean wind speed estimations

	from the mean/mode of Δv_r	Szombathely	Pécs	Budapest	Szeged	Debrecen
pos. %	mean	60.1	57.3	58.1	61.1	61.8
	mode	41.6	41.2	40.1	43.2	42.7
neg. %	mean	39.9	42.7	41.9	38.9	38.2
	mode	58.4	58.8	59.9	56.8	57.3
mean (m/s)	mean	0.58	0.33	0.23	0.48	0.42
	mode	−0.33	−0.28	−0.23	−0.25	−0.22
Standard dev. (m/s)	mean	2.44	1.53	1.22	1.69	1.48
	mode	2.09	1.35	1.10	1.49	1.30
var. coeff.	mean	4.18	4.66	5.29	3.52	3.51
	mode	−6.40	−4.85	−4.72	−5.91	−5.87
Minimum (m/s)	mean	−9.38	−5.71	−4.40	−5.15	−5.47
	mode	−10.20	−6.26	−4.96	−5.74	−6.27
Maximum (m/s)	mean	15.49	6.50	6.69	10.97	7.27
	mode	10.90	4.97	5.23	8.19	5.38
max.-min. (m/s)	mean	24.87	12.22	11.09	16.13	12.74
	mode	21.10	11.23	10.19	13.93	11.65
mode (m/s)	mean	1.0	1.0	1.0	1.0	1.0
	mode	−1.0	−1.0	−1.0	−1.0	−1.0
(-2)-2 %	mean	68.6	82.0	89.6	78.2	82.0
	mode	73.7	85.6	91.6	83.5	87.1

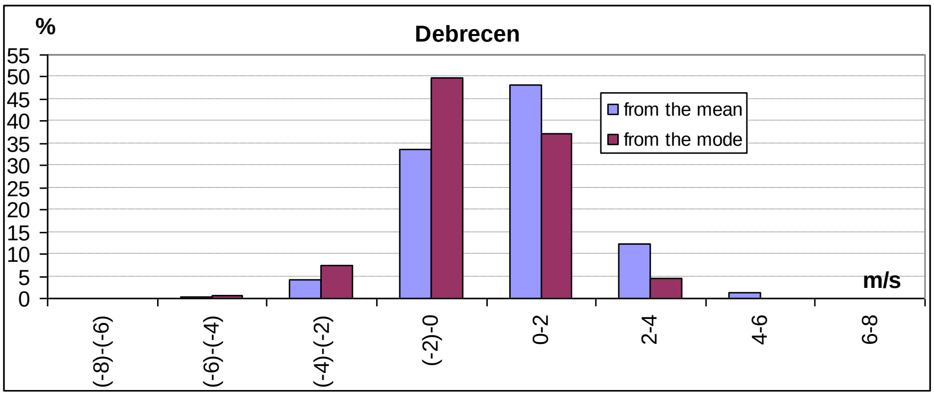

Figure 7. Frequency distribution of estimations' simple errors

average of wind speed cubes that is proportional to the daily average specific wind power which is proportional to the amount of produced electric energy. For testing the entire estimation process and its applicability further production data are required.

6. Conclusion

One difficulty of wind power plant operators is the preparation of a so called "schedule" that means the estimation of the amount of produced electric energy on the next day by short periods of time. Hopefully the presented statistical method gives help for the solution of this difficulty. The method basically involves the establishment of a model from the statistical structure of the change of average wind speed detected from day to day that enables the estimation of the average wind speed of the next day from the average wind speed of the present day based on one of the basic statistics (e.g. average or mode).

The study was performed using 34-hour real and three-hour (7, 13 and 21 o'clock) daily average wind speeds. It is likely that no significant difference exists between the statistics of the two types of daily average relevant for the entire period. The distribution of the 24-hour and three-hour daily average wind speeds, however, cannot be regarded as homogeneous at either station, i.e. the two probability variables have different distributions. Most of the differences of the two types of average fall into the interval (-1)-1 m/s. This means that if the three-hour averages are regarded to be the daily average wind speeds the absolute value of differences will be smaller than 1 m/s in 91–98 % of the cases.

Stochastic relationship between the 24-hour and the three-hour average wind speeds of days following each other is looked for in linear form. Correlation and regression parameters are determined by the interior structure of the time series therefore no significant orographic difference can be detected among their values. Linear connection is closest at Debrecen and weakest at Budapest in both cases. Regression coefficients show that if the 24-hour or the three-hour average wind speed of the present day changes by 1 m/s that of the next day will change by a value between 0.4-0.5 m/s.

Changing of daily average wind speed from day to day was characterised by a relative quantity produced from the average wind speed of the present day and the next day. The average of the relative changes is greater than 0.1 everywhere except Budapest and its maximum (0.17) occurred at Szombathely. The variation coefficient showing its variability is 9–10 times higher than that of the same parameter of daily average wind speed, i.e. it is a very stable characteristic. Regarding the values of mode no differences were observed at the stations since the values of relative change were in the interval (-0.2-0.0) with greatest frequency at every station, i.e. the empirical form of mode can be taken as -0.1 everywhere.

Distribution of relative change by its sign was also determined. Frequency of positive changes when the average wind speed of the next day will be higher than that of the present day exceeds that of the negative changes by 2.4–5.0 %. Greater chance for positive changes was detected at Debrecen, Pécs and Budapest.

Studying the connection of relative change and the average wind speed of the present day closest relationship was found with logarithmic regression. It can be presumed that the sign of the values approached by regression can be associated with the zero points. These zero points can be regarded as the average wind speeds of the whole period. Results of the detailed analyses show that around ¾ of positive changes take place if any average wind speed of the present day is smaller than the average wind speed of the whole period. Around 60% of negative changes can be detected when any wind speed of the present day is greater than the average wind speed of the whole period.

Estimation of the 24-hour average wind speed of the next day was performed based on the three-hour average wind speed values of the present day using the average value and the mode of the relative change. Because these daily average wind speed values become available three hours before the end of the given day.

Based on the simple errors of the estimations (estimated – real values), around 60 % of the errors are positive, overestimation in the case of estimation from the average of the relative change. When the estimation is based on the mode the ratio of negative errors, underestimation will be around 60 %. On average the error of estimation is greatest at Szombathely and smallest at Budapest and Debrecen. Average error of estimation from the mode is generally smaller except at Budapest. The interval containing the errors of estimations, the range (max-min.), however, has its maximum at Szombathely and minimum at Budapest in both cases. Mode values were determined from the distribution of the simple errors. At every station the followings were found: errors of estimations based on the average fall into the (0.2) m/s interval while those of estimations based on the mode fall into the interval (-2.0) m/s with greatest frequency. Thus the values of mode can be regarded as 1 and -1 m/s. Errors in all cases fall into the interval (-2.2) with a frequency between 90 % and 70 %, i.e. their absolute value is less than 2 m/s.

Accordingly to the statistical characteristics of simple error analysed above the 24-hour average wind speed of the next day can be estimated if the three-hour daily average wind speed is known. Wind speed measurement is continuous in the vicinity of wind power plants therefore the three-hour daily average wind speed can be calculated easily. The next step will be the estimation of the daily average of wind speed cubes that is proportional to the daily average specific wind power which is proportional to the amount of produced electric energy. For testing the entire estimation process and its applicability further production data are required.

Acknowledgements

The authors would like to express their thanks to the Hungarian Meteorological Service (OMSZ) for providing data for the analysis.

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GEOTHERMAL RESOURCES

Untapped Potentials and Enhanced Use of Deep Geothermal Energy in the Danube Region

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Abstract: Based on a thorough analysis of the DRS countries' deep geothermal resources and markets complemented by detailed data collection and consultations with experts from their respective governmental organizations (mainly national geological surveys, universities, scientific associations responsible for geothermal at a national level) Nádor (2014) provided the first macro-regional overview about the potentials and possible utilizations of deep geothermal energy in the Danube Region, also tackling some of the technical and non-technical barriers. This state-of-the art summary intends to raise the awareness on the sustainable use of the untapped geothermal resources and will provide useful information for decision makers, for investors interested in geothermal development in the region, as well as to the concerned public.

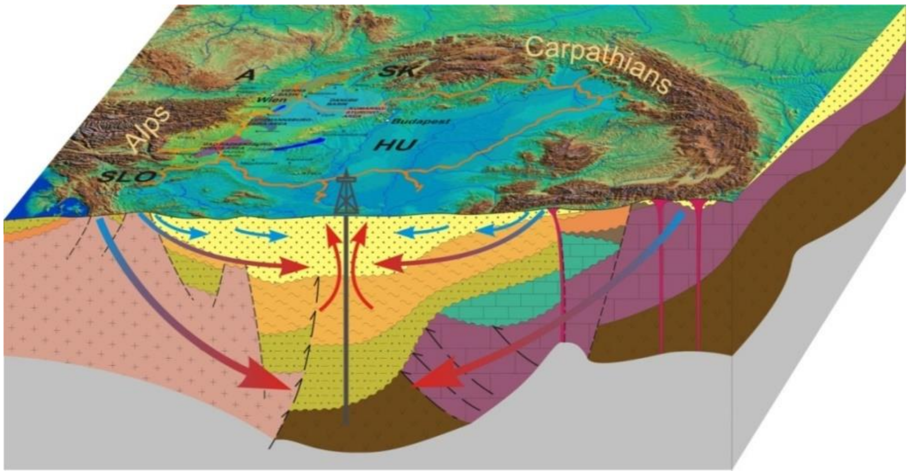
Key words: deep geothremal energy, enhanced use, regional analysis

1. Introduction

The macro-regional approach of the EU has created a new planning level between the Union and the Member States. After more than two and a half years of implementation, the Energy Priority Area (PA2) of the Danube Region Strategy has proved to be a successful platform for forming the common position of the Danube countries in several fields of energy. The macro-regional thinking cannot replace the work of the Member States but it can provide a comprehensive framework for the harmonized planning of national energy strategies.

The Strategy tackles various topics relevant for the region in a structured way through 4 pillars and 11 priority areas, one of which is the "Sustainable Energy Priority Area" (PA2), jointly coordinated by Hungary and the Czech Republic. The Energy Priority Area is engaged in gradually mapping out the current energy landscape of the Danube macro-region. Taking into account the limited resources available, the Energy Priority Area decided to prioritize and focus on those renewable sources of energy, which still offer significant untapped potential for the Region, i.e. biomass and geothermal energy.

Due to the favorable geological conditions, the deep geothermal potential is high in many areas of the Danube Region, especially in Baden-Württemberg, Bavaria, the eastern parts of Austria, Slovakia, Hungary, NE-Slovenia, Croatia, Serbia, Bosnia and Herzegovina, the western parts of Romania, parts of Bulgaria, etc. (Figure.1). Nevertheless, in the majority of the countries the most common way of thermal groundwater utilization is balneology, with direct-heat applications being subordinate (dis trict-heating in Hungary, Romania, Serbia, to less extent in Austria, Croatia and Slovakia; in agriculture in Hungary, Serbia, Slovakia, Slovenia and Croatia), whereas power production hardly exists (Austria, Germany, Romania) (Table 1), although reservoir conditions would be suitable in many places.



Main geothermal reservoirs	Paleo-Mesozoic fractured, karstified basement rocks	Miocene porous and carbonate reservoirs	Mio-Pliocene porous basin fill: multi-layered sandstones, shales
depth (top)	>2-3000 m	Basement highs	600-1500 m
temperature	>100-150 °C	50-150 °C	50-100 °C
prospect	power, CHP	CHP, direct heat	direct heat, balneology

Figure 1. Schematic geological model of the Pannonian basin and adjacent neighboring areas showing the most important potential geothermal reservoirs and their utilization potentials (Nádor 2014)

Table 1. Current utilization of geothermal energy in the Danube Strategy Region

	Geothermal power plants		Geothermal district heating plants		Geothermal heat in agriculture and industry		Geothermal heat in balneology and other	
	Installed capacity (MW_e)	Production (GWh_e/y)	Installed capacity (MW_t)	Production (GWh_t/y)	Installed capacity (MW_t)	Production (GWh_t/y)	Installed capacity (MW_t)	Production (GWh_t/y)
Austria	1,85	2,2	117,6	158,9	2	4,6	2,4	20,6
Bosnia and Herzegovina	0	0	0	0	1,6	11,25	19,94	59,36
Bulgaria	0	0	1,83	8,03	1,65	7,67	82,3	586,08
Croatia	0	0	36,66	NA	NA	NA	77,24	NA
Czech Republic	0	0	6,56	25	0	0	2,12	NA
Germany	4,11	18,83	157,25	331,17	0	0	48	380
Hungary	0	0	132,97	339,65	250,14	825,066	312,37	1648,743
Romania	0,05	0,4	106,63	148,34	8	50	10	12
Serbia	0	0	53,646	231,254	16,955	82,881	55,595	258,41
Slovakia	0	0	27,5	NA	29,5	NA	73,6	NA
Slovenia	0	0	3,72	6,27	13,96	31,61	45,48	126,42

Source: Nádor 2014.

2. Methods

As a first step countries/regions with prosperous deep geothermal conditions in the Danube Region have been identified using publicly available information (publications, online search, etc.). These are: Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Romania, Serbia, Slovakia and Slovenia. As the deep geothermal potentials of Montenegro, Moldova and the regions of Ukraine being part of the DRS are not prominent compared to the above listed countries, country review is not provided for them.

After the selection of countries with promising deep geothermal potential, governmental institutions (national geological surveys, ministries, agencies) and research organizations (e.g. universities, geothermal associations) dealing with the exploration of geothermal energy and being authorized to handle national geoscientific datasets were contacted with the assistance of the EUSDR PA2 Steering Committee. A detailed questionnaire requesting information on the resources, utilization and most important technical and non-technical barriers in geothermal development in each country was sent to these institutions.

Parallel to this, a preliminary summary was made for all selected countries based on the country update reports (CUR), compiled by the local geothermal experts of each country for the International Geothermal Congress, organized by the International Geothermal Association (IGA) every 5 years (Bojadgieva et al. 2013, Fendek and Fendekova 2010, Ganz et al. 2013, Goldbrunner and Goetzl 2013, Jelić et al. 2010, Jirakova et al. 2013, Miosic et al. 2013, Nádor et al. 2013, Nuhovic and Djokic 2013, Rajver et al. 2013, Rosca et al. 21013).

In 2013 a one-day workshop was organized in Budapest, at the Geological and Geophysical Institute of Hungary to overview the current situation on the utilization of deep geothermal energy in the Danube Region, where altogether 38 participants attended from 10 EUSDR countries. Based on the preliminary literature survey, the outcomes of the workshop and the infilled questionnaires, the following chapter provides a concise summary on the state-of-the art of the geothermal energy resources and utilization in the DRS countries. Furthermore a short information is introduced on the renewable energy policy targets, as well as the regulatory framework, available financial incentives and data policies.

Although countries are introduced in a uniform structure, some disparities may arise from the uneven data availability and sporadic information.

3. Results and discussion

The country overviews prove that the deep geothermal potential is significant in almost all DRS countries and many of the resources are still untapped. There is a great diversity of use in the different countries from combined heat and power production (even though only at small pilot scales at the moment), to a large variety of direct heat applications including innovative solutions utilizing low temperature resources by the help of heat pumps. However in the majority of the countries the most common way of use of thermal groundwaters is balneology, direct-heat applications are subordinate, although reservoir conditions would be suitable at many places.

All DRS countries foresee an increase in the share of geothermal energy by 2020 and beyond (Table 2). However to reach these goals it is obvious that favourable geological conditions are not enough, a wide range of technical and non-technical issues should be addressed in order to speed up the expansion of the geothermal sector, which are briefly discussed below.

Table 2. NREAP target numbers of the EU countries of EUSDR. Most of the countries aim a 2-3 X increase by 2020

Country	Geothermal energy in NREAP (PJ)	
	2010	2020
Austria	0,803	1,682
Bulgaria	0,042	0,377
Czech Republic	0,000	0,694
Germany	1,521	34,676
Hungary	4,229	16,423
Romania	1,047	3,349
Slovenia	0,754	0,837
Slovakia	0,126	3,876

Although all countries have profound knowledge on their geothermal resources, the available information is still not sufficient enough. Both geothermal developers and policy / decision makers require *detailed and up-to-date, scientifically based information on the available geothermal resources*. However the type and details of information are quite different. While a project developer needs site-specific, mostly technical information at a local (reservoir) scale (special surveys, e.g. 3D seismic, specific well-tests, etc. are usually done by the project company); policy makers, licensing authorities require a more general and regional overview on the geothermal resources, limits on their sustainable use (e.g where and how much thermal water abstraction can be licensed without threatening the depletion of the reservoirs, expected environmental impacts, etc.).

In the EU (and also in the DRS countries), geothermal data and information are currently organized by national geothermal information systems tailored to the specific needs of the individual countries, and their content and formats are depending on the expertise and objectives of those organizing the data. Even though relevant data are very similar in each country (e.g. subsurface temperature maps), it is difficult for a potential operator, local/regional government, or citizen to get a comprehensive overview at a regional/macro-regional scale. Moreover, information is fragmented, often available in the local language only and has to be retrieved from a multitude of websites and documents.

Another import issue, especially in the Pannonian Basin and its adjacent areas, is that the large-scale geothermal reservoirs are strongly linked to geological-hydrogeological settings irrespective of state-borders and are often shared by neighboring countries (Figure 1). Thermal water abstraction from the same *transboundary* hot water aquifer without harmonized cross-border management may have negative impacts (depletion or overexploitation, even environmental issues) in a neighboring country leading to economic and political tensions. In order to align national strategies and establish a multi-national management system, a joint assessment of geothermal potential on regional level done by the neighboring countries is essential.

In addition to the above outlined large-scale actions (joint data sources and common evaluations) that are necessary for the sustainable management of the geothermal resources of the Danube Region, there are many tasks that address directly the current utilization.

Overexploitation of the geothermal aquifers in areas with intensive thermal water abstraction is a potential problem in several DRS countries. The increasing demand for thermal water from the same aquifers (especially coupled with insufficient reinjection – see below) causes negative quantitative trends in the reservoirs (e.g. drops in yield). Furthermore, as the number of users is increasing, potential *interference* among the different sites and disputes between nearby users may also arise, as already noticed at several locations. Therefore, users and national authorities should as soon as possible establish unified and objective *monitoring systems* of geothermal resources, by controlling groundwater level, temperature, yield, and chemical composition of thermal water. Such combined interpretation of the active (carried out by water users) and passive (carried out by governmental organizations in non-exploited observation wells) monitoring data would allow to follow systematically the changes in aquifers, and make regional evaluations of the available thermal water resources possible that is necessary for leasing new water permits.

In most of the countries the lack of / *low share of reinjection* is a straightforward consequence of the *low share of energetic use* (thermal water used of baleneological purposes cannot be reinjected due to human induced pollution). In addition to maintaining proper reservoir conditions (pressure, yield), reinjection also helps to mitigate the thermal / chemical pollution of surface waters which might result from the emitted and untreated thermal water. As already mentioned in chapter 2, re-injection, especially into porous reservoirs has its technical challenges (plugging of perforation in the well and pore throats of the reservoir formation leading to a decreased permeability). Reinjection wells represent a large investment cost, which – without suitable financial support – are not feasible for most of the users. However, due to the positive effects on aquifer hydraulic conditions and mitigation of environmental pollution, reinjection into the same aquifer should be required for all users utilising non-treated thermal water for the purpose of use of geothermal energy. Limited time of derogation and appropriate financial support should be given to current users for the implementation of (new) reinjection wells, while new users should establish the necessary doublet system before starting production. Location and design of reinjection wells should be based on numerical simulation of aquifer capacities, appropriate technical design of reinjection wells and cost-benefit analyses, which require significant R&D support.

Several countries reported a set of technical problems, which are associated with the *low thermal and utilization efficiency* of the existing wells. Only a few users cool thermal water near to the mean annual air temperature (12 °C). Higher thermal efficiency (i.e. using a higher temperature difference between the inlet and outlet water) would lead to a reduction in the total amount of abstracted thermal water, as well as lower thermal pollution of surface streams into which waste water is emitted. With the more widespread use of heat-pumps, a great proportion of the heat content could be still utilized, which is otherwise wasted. It was also reported that in many cases geothermal resources are not exploited at the full capacity of the reservoirs and wells. A major cause is often the lack of adequate production facilities (e.g. geothermal waters often corrode the transport pipes due to the H_2S and CO_2, plugging of pipes due to scaling, etc.). Application of *cascade systems* (utilization in series, where each sequential utilization type uses the heat or the waste thermal water from the preceding utilization type) is not widespread either, although it would have a direct impact on decreasing the need for additional thermal water, thus increasing utilization efficiency.

Overviewing the (renewable) energy policies, it can be concluded that although all DRS countries acknowledge the importance of renewables, national characteristics (e.g. being rich in fossil fuels, such as coal, having significant capacities in other type of renewables, such as hydropower, nuclear power as a major contributor to power generation) often does not make geothermal energy an attractive alternative.

As the lifetime of a geothermal project is long (15–30 years), stable and reliable political and economical conditions are essential to ensure the safety and profitability of investments. Analysing the most important *non-technical barriers* practically almost all DRS countries reported a *fragmented regulatory system*, where the management of geothermal resources and licensing of geothermal projects are shared among different ministries and authorities, most common between the "environment/rural development" sector dealing with abstraction of thermal groundwater, and the "energy /industry /economics" sector looking at geothermal energy utilization without water production. This makes licensing procedures complicated and time-consuming.

Another major obstacle is the *lack of sufficient financial incentives* (direct subsidies, funds, low interest loans, tax incentives, feed-in-tariff, off-take and support schemes for green-heat). A major missing instrument is the risk insurance systems that would help to mitigate the high up-front costs of a geothermal project, where the risks are the highest at the stage of drilling the first wells.

The lack of qualified personnel in policy making, research, sustainable management of the resources, as well as the protection of the environment also holds back geothermal development.

At last, but not least we have to mention the low rate of *public awareness*. Although geothermal energy has the major advantage of offering a wide range of possible applications in the field of both electricity and heating and cooling, and is an ecologically and economically worthwhile local energy solution for a very wide public (local communities, citizens and consumers, and industry), its advantages are little known. Media reports often focus more on its disadvantages (e.g. induced seismic risk of EGS projects, negative impacts of fracking/stimulation on groundwaters, contamination of surface waters, swelling ground, etc.). As a result, political decision makers and potential investors have concerns about possible risks involved in implementing geothermal projects, and social resistance often results in practical obstacles, such as significant slowdowns of the projects.

This document intended to raise the awareness on the untapped deep geothermal energy potential of the Danube Region and by that, attract investors to the region. As Europe (and the whole world) looks for alternatives to fossil fuels – which are growing ever scarcer, with issues of security of supply and carbon emissions that can cause climate change – geothermal energy promises a clean, renewable alternative source of energy. This is underlined by numerous international and EU policies and strategies including roadmaps with concrete actions how to achieve the targets (see list of relevant documents separately). Based on the detailed analysis of these documents, as well as the in-depth enquiry of the national (renewable) energy strategies, it is clear that the increase of renewable/geothermal energy in the DSR countries is one of the biggest challenges in their energy policies during the coming years. The enhanced use of geothermal energy does not only support the fulfilment of EU obligations (achievement of NREAP target numbers), but the expected growth contributes to the security of energy supply, the decentralized rural development, creation of new working places and a safer and cleaner environment.

4. Conclusions

Almost all DRS countries have significant deep geothermal energy resources, however most of them are still untapped. There is a great diversity of use in the different countries from, the most common types comprise direct heat applications. However in the majority of the countries the overwhelming use of thermal groundwaters is balneology. Many countries face similar problems, such as overexploitation of the aquifers, which is strongly linked to the low share of reinjection and high proportion of baleneological use, low thermal and utilization efficiency coupled with non-technical barriers including a fragmented regulatory system and lack of financial incentives. Nevertheless, the increase of renewable/geothermal energy in the DSR countries is one of the biggest challenges in their energy policies during the coming years for which the natural resources are available.

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General overview of RES, focusing on the geothermal energy

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Abstract: In our article first of all we describe briefly the renewable energy sources in Hungary and in the world, their distribution and their changes. In the second half of our article we focus on the geothermal energy. The significant share of the Hungarian geothermal reserves can be exploited directly for heat supply with great efficiency and in large quantity (residential heating, hot water, greenhouse heating, crop drying) as the temperature of the exploited water is below 100°C. For geothermal based electricity production – with current technologies – at least 120°C temperature should have been available. According to recent estimations 10–100 MW is the theoretical geothermal based electricity capacity of Hungary which might be exploited. Recently the geothermal energy is used mainly for heating (district heating and heat pumps) but the electricity generation is planned also. The first Enhanced Geothermal System (EGS) is now being built in Hungary.

Finally we summarize the estimated environmental impacts of the renewable energy utilization on based of Life Cycle Assessment.

Key words: renewable resources, biomass, geothermal energy

1. Introduction

The utilization of renewable energy sources has a bigger and bigger role in the field of energy supply. The green-energy could help to increase the security of supply, reduce the environmental impacts and also boost the economy. "The renewable energy source is currently the one type of available energy, which corresponds to the urgent needs of sustainable development." (Dinica 2006)

The energy savings, the energy efficiency, the increasing use of renewable resource, the prioritizing of own resources are the key factors in the economic model, when we would establish the sustainable future.

In this regard, the use of renewable energy sources is both a necessity and an opportunity for Hungary. The main research question is how could we find the maximum benefit in the social, economic and environmental aspects of utilisation of the RES? It is also important how it can create new workplace and an opportunity for restructuring our national economy.

2. Methods

We applied literature review both of Renewable Energy and life cycle assessment and used statistical data (Eurostat, Worldbank and EurObserv'ER) to present the current Hungarian condition about the utilization of the renewable energy sources, and their impact, especially of the geothermal. We draw conclusions and synthesis mainly in using geothermal energy and biomass.

3. The state of the energy supply

The simplified energy system and renewable energy resources have been shown in Figure 1 below. It shows the most important elements of the utilization on renewable energy sources: biomass, geothermal energy, solar energy, hydropower and wind energy, these are essential for the optimal energy structure.

When we examine the total energy supply between 1990 and 2013, we could set out that the total supply is increasing in the world (Figure 2).

The sharing of the RES utilisation in energy consumption is strongly fluctuating, but it increasing in the recent years (Figure 3).

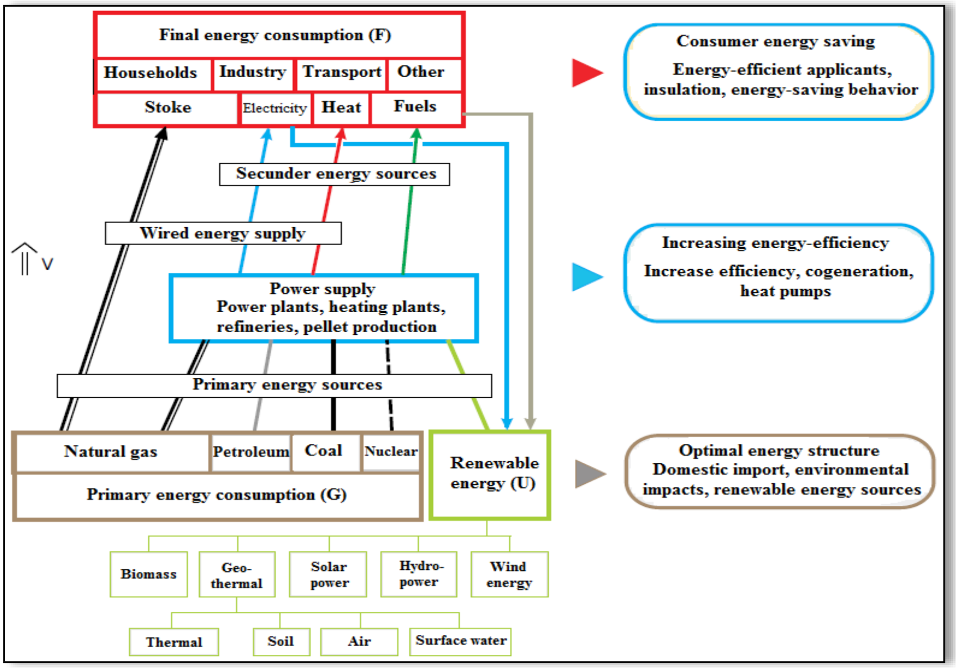

Figure 1. The simplified energy structure
Source: Own compilation based on MTA 2010.

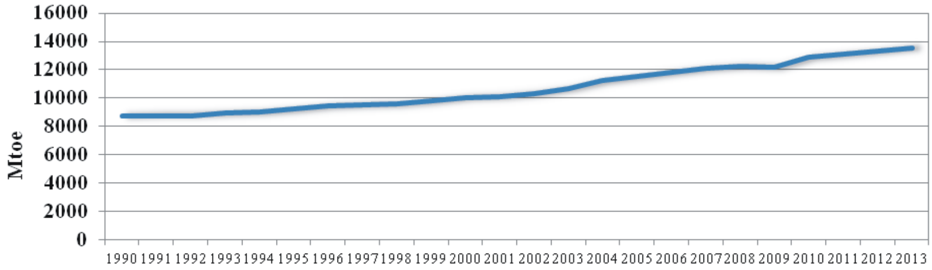

Figure 2. Total energy supply (Mtoe) between 1990 and 2013
Source: own compilation based on EurObserv'ER.

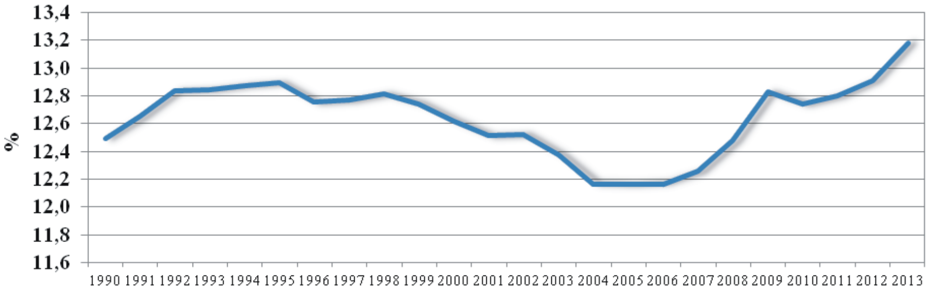

Figure 3. The rate of the RES % in the world
Source: own compilation based on EurObserv'ER.

When we examine the CO_2 emissions in the world it seems their trends are almost the same than energy supply (Figure 4).

The share of renewables in total power generation rises from 21% in 2012 to 33% in 2040, as they supply nearly half of the growth in global electricity generation. The global subsidies to renewables reached $121 billion in 2013, up 15% on 2012, and expand to nearly $230 billion in 2030 in the New Policies Scenario (IEA), before falling to $205 billion in 2040 due to the end of support commitments for recently deployed capacity. The EU remains the largest financial supporter of renewables in 2040.

For the analysis of the Hungarian energy system, in comparing with the European Union we can see the improvement of the efficiency, and decreasing of primary energy consuming about 30% over the last 12 years. But despite of this significant reduction, the primary energy-intensity in 2008 was more than 2.4 times higher than the EU27 average. The national energy efficiency is also improved, but it is about 4% lower than the EU27 average.

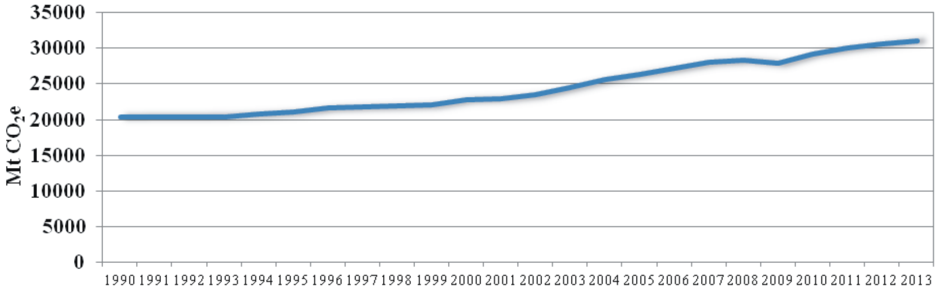

Figure 4. The CO_2 emissions in the world (in Mt CO_2e)
Source: Own compilation based on EurObserv'ER.

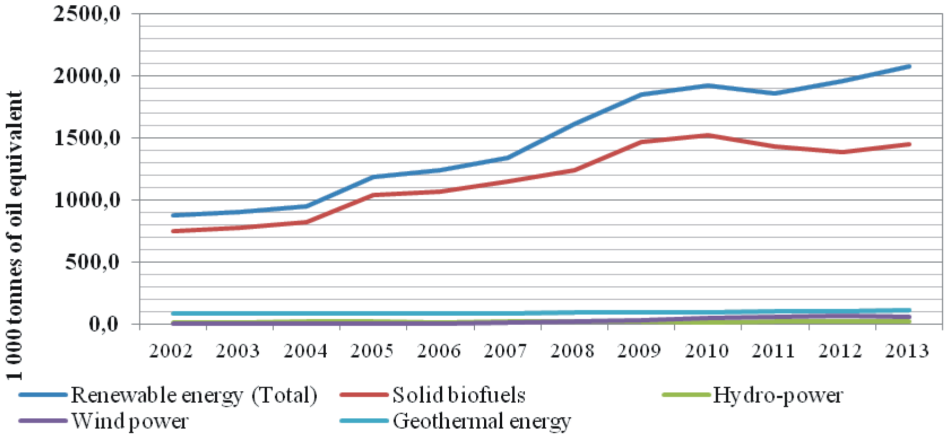

Figure 5. Primary production of renewable energy by type in Hungary between 2002 and 2013
Source: Own compilation based on Eurostat database.

We are at 13% of RES recently, what is the strategically goal of 2020. The biomass has the leading role across in the EU27 (69%) and also in Hungary (92%). The wind power has a fastest increase between 1997 and 2008. The level of the geothermal energy and it's increase is temperate.

Towards we compare the current RES utilization and the objectives for 2020. Definitely the 2 renewables which have the highest percents are the biomass and the geothermal energy (Figure 6).

Recently the geothermal energy, biomass and water energy utilisation are the nearest to the objectives for 2020 in Hungary.

As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of bio fuel.

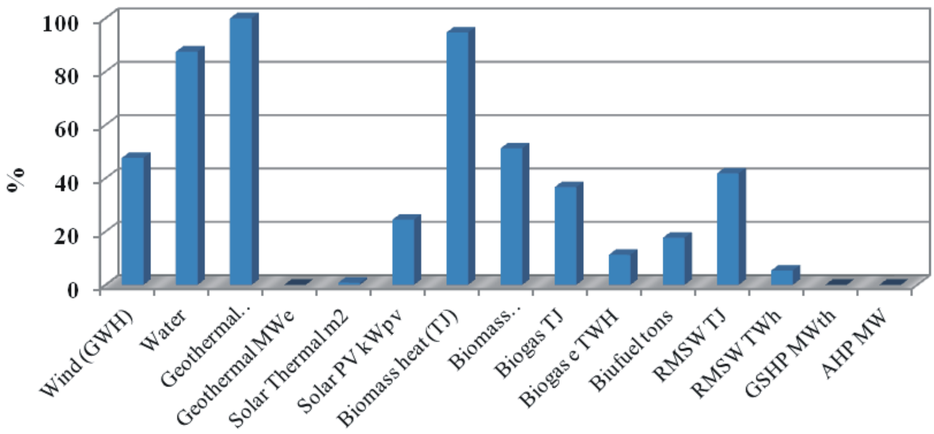

Figure 6. Comparison between the current utilization of the RES and the objectives for 2020 in Hungary
Source: Own compilation based on EurObserv'ER.

The biomass is the largest Hungarian renewable energy sector in terms of both installed and added capacity in 2013. It gives more than 70 per cent of total renewable energy sources and 28% of generated green electricity (in 2013 6.68% of gross inland electricity consumption was covered by RES in general). By 2020 the Hungarian Renewable Energy Utilisation Action Plan expects the biomass utilisation to reach the 60 PJ, but only with 50 % of total RES consumption ratio (Energiaoldal).

4. Geothermal energy

4.1. Geothermal energy in international overview

The examination of the phenomenon of geothermal electricity production, we examine the power generation. There are 24 countries globally who produce electricity from geothermal power sources. Some of them are significant rate (15–22%), they are Costa Rica, El Salvador, Iceland, Kenya and the Philippines (Figure 7).

The geothermal potential is especially good in Hungary. The heat flux and geothermal gradient are high in the Pannonian Basin. In mid of the last century more hundreds of geothermal wells were drilled, mainly for agricultural utilisation. At the 70's 525 geothermal wells were registered, with 1540 MW power capacity. So we could rich often 90 °C temperature. The depth of the typical geothermal well might be a 1000 and 2100 meter in Hungary. Recently 858 wells produce thermal water warmer than 30 °C. From these wells 55 were used in balneology. The balneology utilisation is well known Budapest, Hajdúszoboszló, Gyula, Bük, Hévíz, Zalakaros, Sárvár and other places. 176 wells used in agriculture what is very important for

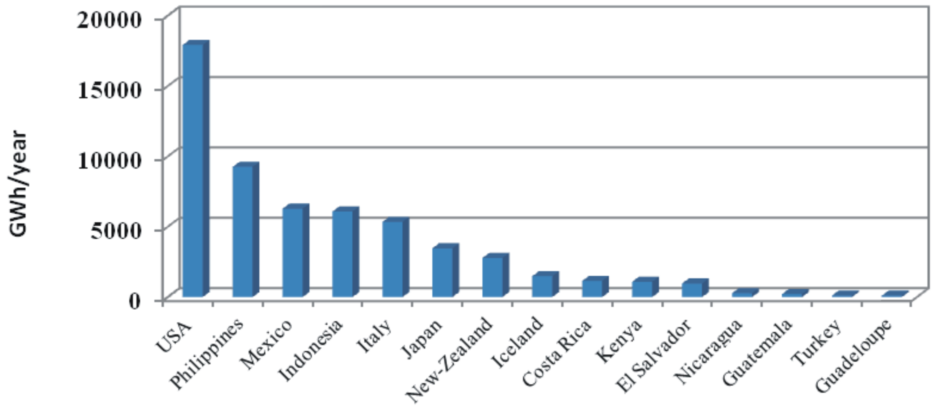

Figure 7. Geothermal electricity production
Source: own compilation based on Eurostat database.

1. Table. Geothermal heat utilization in Hungary (2014)

Geothermal heat utilization	Electricity production GWh/year	Direct heat utilization GWh/year	%
World	67,246	121,696	100
Hungary	–	3,750	3

$1GWh=3{,}6*10^{12}J$
Source: Own compilation based on Livo 2014.

heating of greenhouses, which take 500,000 m^2. The technical level of this heating system is changeable. It also used at the animal breading at least 50 cases (chicken and turkey, calf and pig farm, and fish).

In the direct utilization of geothermal energy is currently the 7th is Hungary, but in 2000 our country was the 3rd in the world rankings. The district heating started near to the balneology centres. In 2012 year 16 district heating systems were operating with thermal water in 9 towns. 71 wells were applied for industrial goal and 81 were used for multifunctional goal (Árpási 2013).We can conclude that the geothermal power plants have less greenhouse gas emissions. The low power hydrocarbon-based power plants can compared to other power plants. When the geothermal compared to other renewables, we can be said (Büki 2010):

- permanently available,
- independent from the weather conditions,
- using flexibility,
- reduce the dependence from import,

- geothermal energy is available in the extraction site, so it can be used in a decentralized way
- the research, deployment and the maintenance create jobs and retain them.

4.2. EGS (Enhanced Geothermal System) in Hungary

Geothermal utilisation has increased in the district heating system in 2013 after two big projects had been finished in this year in Hungary. One of them was (Miskolc Geothermal Ltd: PannErgy and Miskolc District Heat Supply Company) the geothermal based heating system for Miskolc (implementation started in 2009). The company supplies at least 91,366 GJ/year for the district. According to plans, another settlement, Kistokaj will join to the heating system. Here 65,000 GJ will be delivered per annum (approximately 11 MW capacity) (Győrki 2014; Portfolio.hu).

The other large project was finished in Szeged, the city that is considered one of the biggest geothermal water potential in Hungary. Project contained 2 wells (2,000 m each) along with 2 re-injection wells (1700 m and 1250 m) deep into the geothermal reservoirs along with the pipeline network to provide steady stream of hot water. Phase 1 of the district heating system is in operation since November 2013, providing heat for 25 large municipal customers during the wintertime (Kiss 2014).

Regarding to the geothermal energy can think to Hungary as a "highpower" because the geothermal gradient (°C/km) and the terrestrial heat flow density (kW/km^2) are much higher than the average. The current utilization of the geothermal energy is very low (it is 3.6 PJ and it is only 0.3% of the total energy consumption) (Dickson et al. 2003).

The occurrence of geothermal energy potential can characterize with the temperature (Büki 2010). We have to distinguish 4 categories, which are:

- High-temperature (>120 °C) thermal or steam.
- The high temperature (80–120 °C) – allows direct thermal heating supply.
- Lower temperature (40–80 °C) – the thermal water can partly used for directly.
- Above 0 °C and ambient heat (air, soil, surface water) – they are also mean a source of renewables.

The foundations of the geothermal fluid-based systems are the heat flow (convection). Convection formed by the continuous thermal expansion and the continuous heating; the heat is the base of the round system; it is the driving force of the flow system (Figure 9).

The conceptual schema of the EGS heat extraction can be shown in the Figure 9. The cold water in the discharge tube is introduced into the high temperature rock in the great depths. The water will be burst the rock, and it heated. The heated water (or steam) can we outlet into the surface.

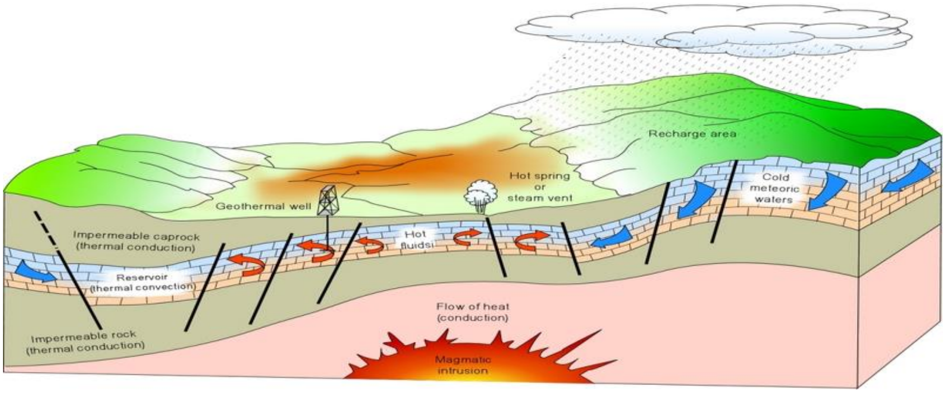

Figure 8. A schematic diagram of an ideal geothermal system
Source: http://www.geothermal-energy.org/

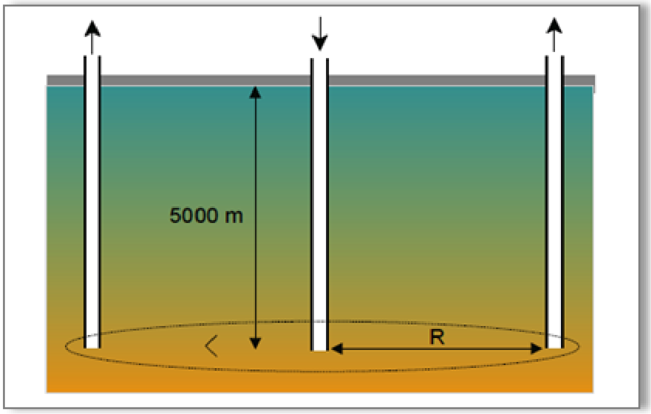

Figure 9. Large depth EGS geothermal heat- utilization system
Source: MTA 2010.

EGS means Enhanced Geothermal system – it is an electric power plant installed on an increased efficiency geothermal system. It uses of the utilization of the geothermal energy and it can be an alternative energy source which can replace fossil systems. It based on the HDR (Hot Dry Rock) technology. The main goal is to find high-temperature homogeneous rock systems in the charted depth. The EGS can support our commitments what have to undertaken in 2020.

The objectives of the project are to ensure minimum 5 MWe in nominal capacity, replace the import energy and could help to develop a regional electricity network.

The project has several parts: drilling, create an EGS reservoir, establish a binary cycle power plant and find opportunities to utilize the residual heat.

The main data of the planned "Dél-Alföldi EGS erőmű" (Kovács 2014):

- Deadline: 2016. December 31.
- Total project cost: 31.4 billion Ft
- EU subsidy: 11.8 billion Ft
- Reservoir: artificial fissure with 2,5 km^2 heat transfer surface
- 2 reinjection and 4 producer wells
- Gross production: 11,8 MWe (net 8.9 MWe)
- Potential place of the power plant: Kecskemét, Ferencszállás, Battonya

The Table 2 shows the parameters of the EGS heat exchange system. The data are featured to 5MWe. These factors are accepted internationally. The most crucial question is how to realize them in the location. The main tasks is develop a technology, which can be used any type of sub soils (Kovács 2013).

Table 2. Main elements of the reservoir

Fluid production rate	75 kg/s
Fluid temperature at wellhead	200 °C
Total effective heat exchange surface	10×106 m^2
Rock volume	3×108 m^3
Flow impedance	<0,1 MPa (kg/s)
Thermal drawdown	10%
Water loss	<10%
Capital interest rate	5%

Source: Own compilation based on EGEC 2012.

4.3. Heat pumps

By adding a small amount of drive energy, a heat pump can move heat from a low temperature to a high temperature. This means that the same piece of equipment can be used to remove heat from a space (cooling) at one end while at the same time adding heat to another space (heating). Table 3 shows the number of units is operating in Hungary.

According to the International Energy Agency, IEA, the buildings sector needs to reduce its CO_2 emissions by over 70% in comparison with 2010 levels in order to limit the increase in global temperature (IEA, 2014).

Table 3. The total geothermal heat pump capacity in Hungary

Geothermal heat pump (include Hydrothermal heat pump)	Total units in operation 2012	Total units in operation 2013	Cumulated in 2012 (kW)	Cumulated in 2013 (kW)
Brine/water	312	375	5 742	6 876
Direct expansion/Water and Direct expansion/air			3 800	3 800
Water/Water and Water/air	13	18	4 200	6 700
Total	325	393	13 742	17 376

Source: Own compilation based on collected and data of EurObserv'ER.

4.4. Environmental impacts

The environmental impact of the geothermal energy is connected mainly to depletion of resources and polluting waterways and air and risk of earthquake.

Depletion of resources – The process of extracting geothermal fluids (which include gases, steam and water) for power generation typically removes heat from natural reservoirs at over 10 times their rate of replenishment. This imbalance may be partially improved by injecting waste fluids back into the geothermal system. Extracting geothermal fluids can reduce the pressure in underground reservoirs and cause the land to sink (Bayer et al. 2013).

Polluting waterways and air – Geothermal fluids contain elevated levels of arsenic, mercury, lithium and boron because of the underground contact between hot fluids and rocks. A serious environmental effect of the geothermal industry is arsenic pollution. Geothermal fluids contain dissolved gases which are released into the atmosphere. The main toxic gases are carbon dioxide (CO_2) and hydrogen sulphide (H_2S). These gases are a recognised hazard for people working at geothermal stations or bore fields, and can also be a problem in urban areas. It can have impacts on both water quality and consumption. Most geothermal facilities have closed-loop water systems, in which extracted water is pumped directly, back into the geothermal reservoir after it has been used for heat or electricity production. The water is contained within steel well casings cemented to the surrounding rock. The gases removed from the well are not exposed to the atmosphere and are injected back into the ground after giving up their heat, so air emissions are minimal.

In contrast, open-loop systems emit hydrogen sulphide, carbon dioxide, ammonia, methane, and boron. Here approximately 10 percent of the air emissions are carbon dioxide and a smaller amount of emissions are methane, a more potent global warming gas. Estimates of global warming emissions are approximately 0.1–0.2 pounds of carbon dioxide equivalent per kilowatt-hour. While the GWG emissions of natural gas generated electricity are between 0.6 and 2 pounds of CO_2 eq per kilowatt-hour, and CO_2 eq emission of coal-generated electricity are 1.4 and 3.6 pounds per kilowatt-hour (Bayer et al. 2013).

Hydrothermal plants are sited on geological "hot spots," which tend to have higher levels of *earthquake risk*. There is evidence that hydrothermal plants can lead to an even greater earthquake frequency. Enhanced geothermal systems (hot dry rock) can also increase the risk of small earthquakes.

In the last several years were born a lot of LCA study for electricity generated from RES, but LCA studies on geothermal power production are rare. The primary reason is that environmental impacts from certain plants are often very local and case specific, and thus generally valid conclusions from single studies can hardly be drawn (Bayer et al. 2013).

5. Conclusions

The utilisation of renewable resources could help the implementation a green economy model. In which the new energy industries get central role. The main task is today, to use the knowledge and information and the renewable energy sources became available to everyone. It is clearly, that the utilization of the renewable energy sources has social, economic benefit but has risks and negative environmental impacts but in the long term it is the best solution.

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Geothermal energy applications developed in Bihor County and at University of Oradea

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Abstract: Geothermal energy is an important green, accessible and clean energy source, used all over the world for different industrial, social and domestic applications. First part of this paper presents the distribution of geothermal fields in the Western Plain of Romania and their use. In this part of Romania the geothermal water is used for heating localities, for the treatment of rheumatic diseases, for obtaining electricity, for entertainment, pools open all year and so on. Also, we will present a unique complex in Europe due to geothermal water, the thermal Natural Reservation from 1 Mai Spa (near Oradea). Researchers from University of Oradea have developed a successful work in the geothermal water use area and have obtained outstanding results, in converting geothermal energy into electricity and concerning the improvement of heat pump technologies. Based on these results the heating geothermal system for a big part of the university buildings and campus and a teaching laboratory was designed and developed. This system is presented in the second part of the paper.

Keywords: geothermal, energy, applications

1. Location of geothermal fields in Romania

1.1. Generalities on geothermal field's location in Romania

The geothermal reservoirs research started in Romania between 1962–1965 by digging the first drillings in West Plain, at Oradea, Felix, Călacea and Timişoara. Until now were digged and gave important geothermal data about 200 drillings; almost all of them were financial supported by the government, by a geological research program. These drillings were realized by Transgex S.A. (from Cluj-Napoca) and Foradex S.A. (from Bucharest) companies. The functioning and experimental exploitation of more than 100 geothermal drillings during the last 25 years, allowed the evaluation of resources and exploitable heat reserves of the hydro-geothermal systems from Romania.

The present total installed capacity, only for energy uses and considering a 25 °C reference temperature, is bigger than 350 MW_t (MW_t = megawatt thermal). Today only 130 MW_t are used by exploiting about 65 drillings. These drillings give geothermal water having temperatures between 55 and 115 °C (www.hurotherm.eu).

Main uses of the geothermal energy are: space heating, hot water, heating greenhouses, wood drying, pasteurization of milk, melting flax and hemp, intensive fish growth, etc. (Figure 1). Overall energy savings obtained per year is over 35,000 t.e.p.: space heating 36%, heating greenhouses 23%, industrial activities 7%, fish growth 2%, balneology 32%. For balneology therapeutic about 30 drillings are used (having a total flow greater than 360 l/s, the water having temperatures between 38–65°C). They ensure the functioning of 16 thermal resorts, where over 500,000 patients are treated per year and 31 swimming pools.

The location of geothermal reservoirs in Romania is presented in figure 2.

As shown in figure 2, most geothermal reservoirs are placed in western part of Romania, respectively in the east of Pannonia Basin. This area was formed by stretching and thinning of the lithosphere, together with the sinking started in Badenian and continued with high speed in Pannonian. In this period of time big amounts of sediments have been accumulated, having a thickness of up to 4 km in Romanian West Plain. The result of the lithosphere thinning was the appearance of an important thermal anomaly: the natural geothermic flow had values between 85–100 mW/m^2. Because of this reason the Pannonia Basin is considered to be the "warmest" region from central and east Europe (www.hurotherm.eu).

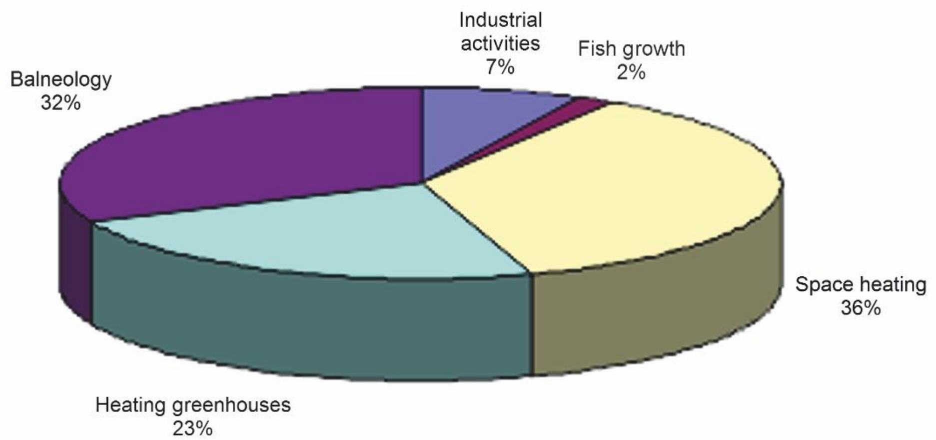

Figure 1. Geothermal energy use in Romania (www.hurotherm.eu)

Figure 2. Geothermal reservoirs in Romania (www.hurotherm.eu).

1.2. Geothermal field's location in western part of Romania

The geothermal reservoirs from the Romanian West are the result of the above mentioned natural geothermic flow. They are composed of:

- multi-layered closed aquifer, localized in some regions of the upper Pannonia,
- aquifer of small dimensions, localised in lower Pannonia rocks or in the sedimentary cracked rocks from the sunken foundation (for example Mesozoic limestone and dolomite, as is the case of the reservoirs from Borş – Oradea – Felix Spa – 1 Mai Spa).

The *Pannonia aquifer* is multi-layered and closed and is placed in the sandy rocks from the upper Pannonia, at a depth between 800 and 1200 m. This aquifer is spread on a surface of 2500 km^2 along the west Romanian border, from Satu-Mare in north and Timisoara-Jimbolia in south. This area was investigated with 80 geothermal drillings, all being used for production. Today, only 37 drillings are functioning, because these drillings are property of the Romanian state. If somebody uses them, that person is obliged to pay the used geothermal water. Because of this reason, some drillings are not used.

In this case the natural geothermal gradient is about 45–55 °C/km. The fluid temperature at the surface is between 50 and 85 °C (www.hurotherm.eu).

Most wells produce artesian. The annual energy provided by these geothermal wells is about 19.000 t.e.p. (t.e.p. = tonne of oil equivalent), for an installed power of

55 MW_t. The heat exploitable reserves for the next 10 years, using the existing wells, are estimated to be about $1,2\times10^{18}$ J. If new wells will be drilled and if will be generalized the production by pumping, heat resources will be about 9×10^{18} J in 20 years (www.hurotherm.eu).

The main geothermal exploitations in this region are, from north to south: Satu Mare, Tăşnad, Acâş, Marghita, Săcuieni, Salonta, Curtici, Lovrin, Tomnatic, Sânnicolau Mare, Jimbolia şi Timişoara. Here, the geothermal energy is used for heating greenhouses (34 ha), space heating (2.460 apartments), hot water (2.200 apartments) and 7 technological processes (the drying of cereals, melting flax and hemp, drying of ceramics, wood drying).

The Oradea – Felix Spa – 1 Mai Spa geothermal aquifer is composed of two distinct fields (Oradea and Felix Spa – 1 Mai Spa). They located at different depths, contain rocks of different ages and are hydrodynamic interconnected. This thermal aquifer is part of an extensive hydro-geothermal system, has a natural supply in Aleşd-Borod Basin and the water discharge in the 1 Mai Spa thermal sources area. The water from this aquifer is part of the active hydrologic circuit, 18–20,000 years old. During the last 30 years were extracted about 49 million m^3 of water, but this situation did not affected the pressure in the reservoir (www.hurotherm.eu).

Oradea geothermal reservoir contains cracked Triassic limestone and dolomites, placed at depths between 2200 and 3200 m. This reservoir has a surface of about 110 km^2, displayed almost entirely in the basement of Oradea. The geothermal water temperature at the reservoir surface decreases from 105°C, in the west, to 70°C, in east. This geothermal water do not corrode, contains only traces of dissolved gases and the mineralization is relatively small (0.9–1.2 g/l, depending on the well). So, they are not dangerous from chemical pollution point of view.

The 12 wells from Oradea city have an artesian potential flow of 180 l/s. This flow is limited by the Romanian National Agency for Mineral Resources at a level equal to 90 l/s, in order to extract the required flow for Felix Spa and 1 Mai Spa, without causing a severe decrease of the reservoir pressure. The artesian flow of the wells varies between 5 and 30 l/s, depending on the geological local conditions. Maximum possible flow, in the case of a submersible pumping, is about 20–50 l/s (www.hurotherm.eu).

This aquifer behaviour was analysed and PC simulated, for the case of re-injection production and considering the real geothermal energy possible uses, at the beginning of 2000 for the next 20 years. Also, was considered an annual rate of 240 l/s, for re-injection exploitation. Today, the installed power is about 30MW_t, for 11 wells with artesian production and one injection hole. But this level can be almost tripled by using pumping production followed by re-injection, in doublet type systems (production well – heat exchange – injection well) (www.hurotherm.eu).

By extending the geothermal energy use for hot water (for population use), considering a constant use during the whole year, can be extended even the use coefficient. In this case the annual energy saving, depending on fossil fuels, can be increased from a today level equal to 7.400 t.e.p, to about 37.000 t.e.p in near future.

Today, in Oradea the geothermal energy is used for university campus heating an also for the house heating of about 2000 apartments, for hot water for about 4000 apartments, for milk pasteurization (80000l/day), wood drying (5000 m^3/year), greenhouses heating (1.8 ha).

The basic schema of the cascade working system from University of Oradea it is presented in Figure 3 (Maghiar et al. 2003a, b).

The Felix Spa – 1 Mai Spa geothermal reservoir is composed of strong cracked cretaceous limestone. They are located depths between 45 m and 175 m (for I complex) and between 200 m and 500 m (complex II). It has to be mentioned the fact that "complex I" ensure 90% of extracted volume and "complex II" has a finer configuration, being placed in an area characterized by specific geo-structure conditions.

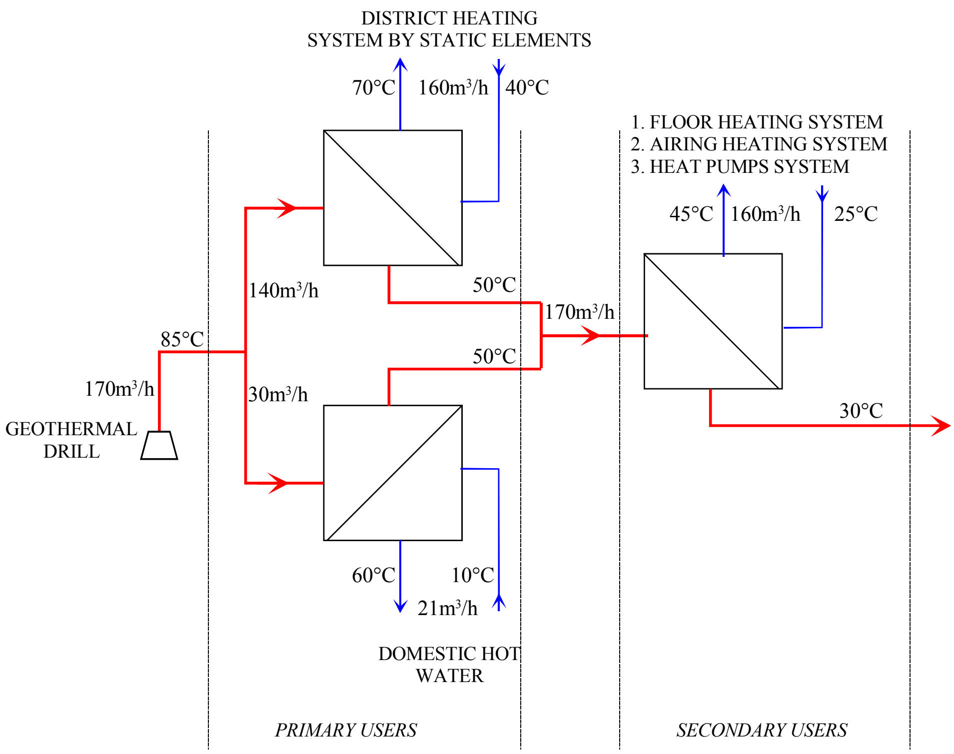

Figure 3. The basic schema of the cascade working system from the University of Oradea

In this special case, on an area smaller than 20 km^2 exists a big number of fissures, caused by the interconnection of multiple tectonic elements from the contact between Apuseni Mountains and Pannonia Depression (Figure 4) (www.hurotherm.eu).

„Complex I" can be considered as being the most important hydro-geothermal area from west Romania, because contains strong natural springs, which occurred along major fissures, in places were erosion removed quaternary sedimentary layer. The aquifer springs and wells have a uniform behaviour from hydro-dynamic point of view, with rapid effects of interference. The supply rate is about 300 l/s.

Due to the increasing flow statement, both in Felix Spa and Oradea, higher than refuelling capability, was necessary to reduce the artesian debits of the main wells and to stop the operation of two wells. Also, was strong reduced the flow of the spring from Ochiul-Mare. All these operations have disastrous effects on the *Nymphaea Lotus* tertiary relic, *Thermalis* type, which is currently endangered.

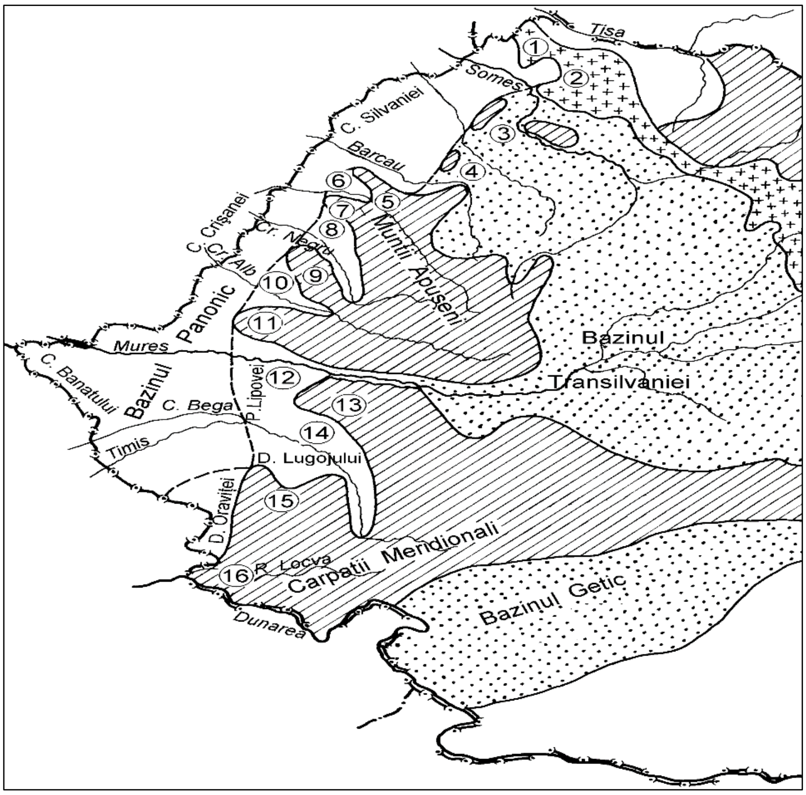

Figure 4. Pannonia Basin component parts and physical-geographical units (www.hurotherm.eu)

The chemical composition of the geothermal water from Felix Spa – 1 Mai Spa reservoir is similar to the one of the Oradea reservoir. Both of them are part of the same water natural circuit. The geothermal water temperature at the surface decreases slightly from west to east, having values between 35–45°C in complex I and between 40–50°C in complex II. The 6 existing wells can have a debit of about 210 l/s.

The geothermal water is used especially for balneal-therapy, in a rehabilitation hospital and in hotels treatment bases, and for all the outside or indoor swimming pools from Felix Spa and 1 Mai Spa (more than 7000 accommodation or treatment places, 5000 tourists daily/year and about 25,000 tourists daily/summer time).

The maximum requirements are about 180 l/s – annual average, with a peak of consumption of about 209 l/s during summer. This peak value contains 100 l/s for therapeutically purposes, the rest of the water being used for the swimming pools and for apartments hot water needs (www.hurotherm.eu).

The Mesozoic deposits from Bihor county form the foundation of Oradea area (Figure 5.) and of the Vad-Borod and Beiuş Neocene basins and also of the Pădurea Craiului Mountains.

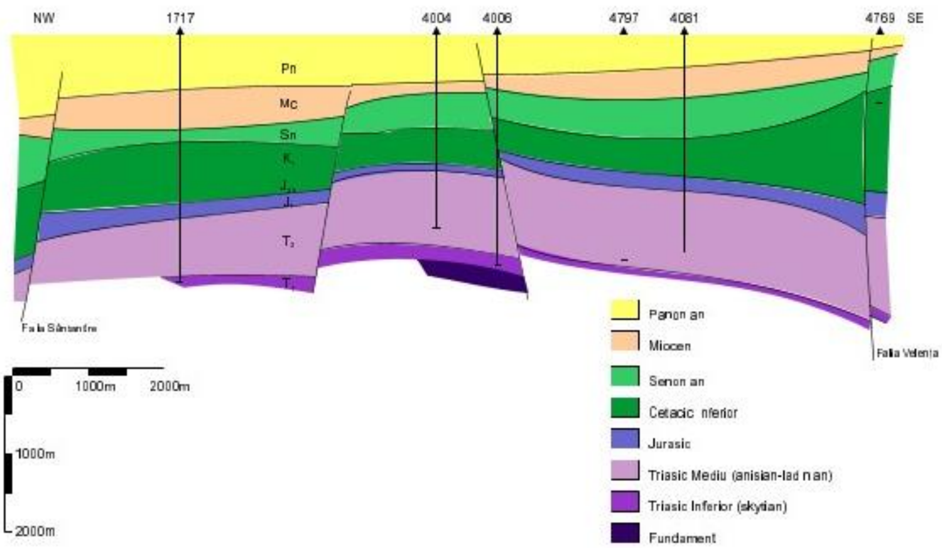

Figure 5. Geological profile of Oradea reservoir (www.hurotherm.eu)

1.3. Felix Spa – Natural Reserve

In Felix Spa is found the *„Lacul cu Nuferi – Pârâul Peţea"* Natural Reserve, which is the only place in Europe where grows tropical water lily (nimphaea lotus var. thermals – glacier relict), since tertiary.

The unique characteristic of this tropical water lily, together with the Racoviţă endemis (endemis – Scardinius erythrophatanuls racovitzai) and „Melanopsia parreysii" snail define the major scientific importance of this area.

Egypt is the second place in the entire world where tropical water lily has naturally survived, in spite of the global cooling of the clime from quaternary.

The unique Romanian national natural reserve "Lacul cu nuferi termali" – Nymphaea Lotus Thermalis (tertiary relict) has the tropical water lily with round floating leaves, geared and rolled up. From the middle of these leaves are growing the gentle white-blue flowers, with pleasant perfumed smell. This plant is native to the Nile and is supposed that its seeds were brought here either by the Turkish, or by the migrating birds. The plant has survived in this area because of the geothermal water (www.hurotherm.eu).

The lake, where these lilies grow, is formed by the stream Peta, which springs from 1Mai Spa and whose water temperature is about 30°C. This locality is place at an altitude of about 140 m and has a plain moderate continental climate. The annual medium temperature is around 10.5°C, but the medium summer temperature is 21.3°C.

Concerning this type of tropical water lily found on Peta Lake there has been much discussion. This lily flower was accompanied a long time by a special snail, which is today declared as a nature monument and is protected by law. In the same lake, among the lilies, grow the Racoviţă endemis, which is also protected by law (www.hurotherm.eu).

2. Thermoelectric conversion plant from University of Oradea laboratory

Second part of this paper presents the above mentioned laboratory, focused on the development of an original equipment for the static conversion of the geothermal energy in electricity (Wilt–Chubb 1997). This small original plant was designed based on the following principle, which enables thermal energy conversion of geothermal water into electricity: a surface of the thermoelectric generator is brought into contact with a high temperature source and the other surface is in contact with a cold source (Gordan et al. 2002, Gordan et al. 2014, Maghiar et al. 2002). The high temperature is coming from the geothermal water and the low temperature is given by a cold water circuit, a constant temperature difference being maintained during the system function (Figure 6).

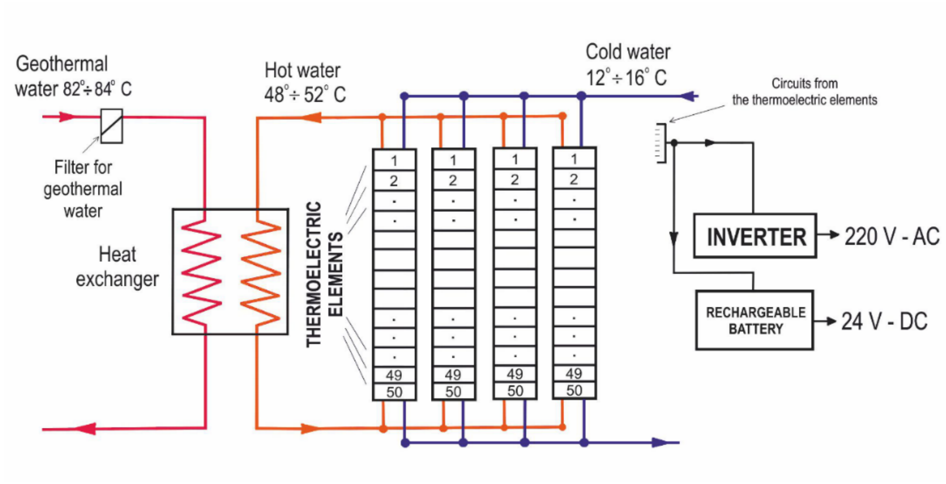

Figure 6. Conversion diagram developed at the University of Oradea.

Figure 7. Thermoelectric generators placed in 7 columns

This conversion installation contains three fluid circuits.

One of them is the geothermal water circuit. To protect the plant, it is not used direct geothermal water; this water cannot be neutralized and demineralised completely and for this reason, in order to avoid deposition and possible corrosion of the installation, it is used a heat exchanger. With this device, the thermal energy of geothermal water is transferred to a mixture of purified and neutral water, which will flow into the equipment.

As in Figure 7, the thermoelectric generators are placed in 7 columns and inside them are arranged the pipes, containing water heated by geothermal water. Hot water temperature is about 48–52°C. On the opposite side of each column are mounted pipes where cold water (12–16°C) is circulating, provided from a drilling.

This system contains 200 thermoelectric generators, placed first in parallel and then in series (Gordan et al. 2014, Vancea et al. 2014). This arrangement was designed in order to obtain the voltage needed to charge storage batteries (Vining 1994.). The obtained voltage can be converted to sinusoidal AC by an inverter. The installed power is about 30–50 W, for the case of optimum functioning situations (Gordan et al. 2002, Vining 1994).

3. Results (www.regenerg.ro)

During the installation functioning were registered the following results:

- For a 82°C geothermal water temperature, the heat exchanger brought the hot water at a temperature of about 51–52°C. This result was obtained after 35 to 40 minutes;
- In the battery charging circuit (6 batteries of 24 V) was placed an automatic control device for the generators voltage. Charging batteries started at a difference of about 23°C, between the temperature of hot and cold water temperatures (Kasap 2006).
- Only at this level the voltage given by the thermoelectric generators exceeded 24V.
- The cold water temperature increased from 12°C to 16°C during the measurements.

4. Conclusions

After analysing the functioning of this conversion equipment, during an interval of 783 hours, the specialists obtained the following conclusions:

- This plant efficiency is quite low (Gordan et al. 2002), but it was improved during the experiments by modification of the water supply circuit, by increasing the power of the heat exchanger, etc.

- Because deposits were found in the primary circuit of the heat exchanger, will be mounted a treatment system on the circuit a geothermal water.
- The automation and control system will be improved by implementing a control and data acquisition facility, based on LabVIEW software, and a data acquisition compatible board (Gordan et al. 2002, Maghiar et al. 2002, Maghiar et al. 2003a).
- Since this plant is experimental and laboratory work used, the results obtained so far are quite promising.

Conflict of Interest

The authors declare no conflict of interest.

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www.hurotherm.eu

www.regenerg.ro

Thermal Water Utilization and its Possible Development in the Early 21st Century in Hajdúság, East Hungary

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Abstract: Many thermal spas are located in the central and northern part of Hajdú-Bihar County such as the internationally renowned Hajdúszoboszló and Debrecen with great national importance. Increasing thermal water exploitation and the resulted significantly decreasing water level around the wells reveal the fact that utilization of thermal water and the adjacent heat requires more consideration. Despite increasing energy needs (possibly cheap, reliable, renewable) and favorable properties thermal water utilization in this part of the Danube Region still dominantly means balneological utilization. Potential, however, even in such low enthalpy systems is considerable energetically, as well. Being aware of the properties of thermal water reservoirs may help utilization, in general and in this case especially in the Danube Region, to be more reasonable. Our geological model is based on interpreting 2D migrated seismic sections integrated by well log correlations. The modelled aquifer and aquitard layers are the main input data of further (e.g. hydraulic, geothermal potential) modellings. The applied methods are seismic and sequence stratigraphic interpretations and well log facies analysis. Due to these approaches interpolation may be more sophisticated resulting in more reliable flow units in order to describe the hydraulic connections more accurately. Furthermore, studying many production wells and spas, properties (utilized and waste heat per year, etc.) are considered in order to develop the technical potentials resided especially in cascade utilization of thermal water. This paper aims to point out such details of the studied reservoirs presenting the used applications, data and methods. Our results and their consequences are to serve the development of the region in the field of geothermal energy utilization.

Keywords: Upper Pannonian, hydraulic connection modelling, energetic planning, geothermal cascade systems.

1. Introduction

Since geothermal investments hold many uncertainties the time of the great bloom of geothermal utilization has not come yet. The key to the development of geothermal utilization is to reduce the risk of investments which may be achieved by accurate knowledge of the targeted geothermal resources, the reservoir (Moeck 2014). Geology related uncertainty is a significant part of the total uncertainty, thus reducing it may encourage investors consequently it may result in developments.

In the case of porous thermal water reservoirs, meaning a certain available geothermal potential in almost all the lowlands of the Danube Region, the uncertainties can be reduced fairly significantly by applying an accurate method to describe the connectivity of sand bodies. In this paper the authors attempt to present the geological factors considered to be decisive and to describe the reservoir briefly, to study thermal water extractions in general in the Hajdúság located in the NE Great Hungarian Plain based on production data of some major thermal spa wells and to draw conclusions in order to help the harmonization and sustainability of thermal water utilization.

Though many thermal spas can be found across the Carpathian Basin, especially in the Great Hungarian Plain, so far greater geothermal investments, which would develop local and national economy, have to be waited for. Furthermore, meeting required energy (heating or electricity) by local renewables subserves import energy dependence reduction in an environmental friendly way.

Managing the amount of extracted water and the geothermal energy contained in it is also a key factor. Decrease of reservoir pressure due to exploitation results in decrease of the total pore volume, consequently hydraulic conductivity. Overproduction could also cause long-term depression of the dynamic water level with a certain yield. These facts mean that further investments are necessary to maintain the existing system since operating costs become higher by time. Signs of overproduction have been detected already not only in the focus area but in many other cases around the Danube Region (Buday et al. 2015, Szanyi – Kovács 2010, Tóth et al. 2010). The results of this study could be generalized and the role of geothermal energy utilization could be expanded for the whole Danube Region.

However, the harmonization of each locality should be managed and for that reason a proper initial regional model will found to be useful. To avoid loss, accurate modeling processes are strongly recommended. This study aims to focus on the 3D model of the Pannonian s.l. units at the location of Hajdúság which was used for further modelling and estimations, as well.

2. Methods

2.1. Geological frame

Study of Miocene-Pliocene sets in the Danube Region, was primarily founded by hydrocarbon exploration in the last century, however, at present it has a great importance in the field of renewables. Palaeogeographically the accommodation space of Pannonian s.l. successions was the former Lake Pannon forming an isolated part of Paratethys surrounded by the Alps, Carpathians and Dinarides, showing a wide range of diversification in geomorphology, palaeogeography and palaeontology, especially in time (Juhász 1991; Juhász 1994; Juhász et al. 2007; Magyar 2009). Parts of Lake Pannon can be characterized differently relative to each other. These relative differences should be studied and highlighted depending on which part is focused on since profitable and conscious geothermal investments are inconceivable without accurate knowledge of targeted resources that is the porous thermal water reservoir. In this case generalization may lead to incorrect conclusions resulting in ill-established, or even worse, over/under dimensioned investments.

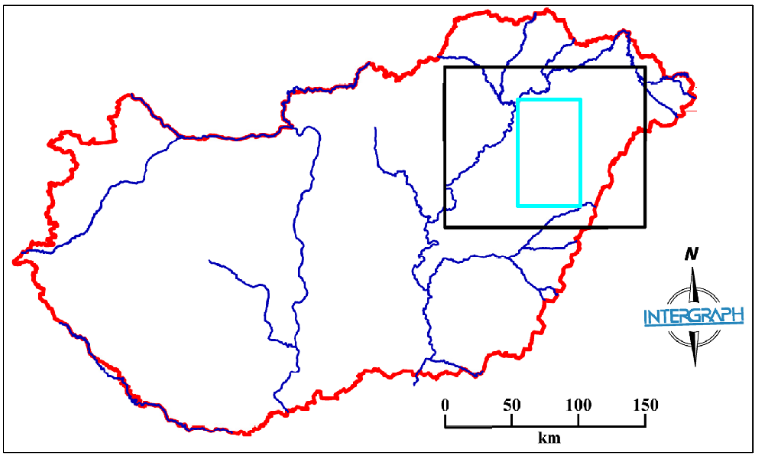


Figure 1. Location of the North Trans Tisza Region (black rectangle) and the focus area (cyan rectangle), including the so-called Hajdúság.

The study area is located in the northern part of the former Lake Pannon the infilling siliciclastic sediments of which are Upper Pannonian with shallower occurrence than in the southern part of the Great Hungarian Plain (Buday et al. 2015). The alternations of sandstone aquifers and interbedded clay aquitards are disturbed by e.g. volcaniclastics, tectonic faults and folds, clay, sand and gravel lenses; moreover, its basement shows variable geomorphology (Bódi et al. 2014).

Since in such relatively shallow layers, hydrocarbons can be seldom developed and trapped few research projects focused on the area (Hajdúszoboszló is an exception). Consequently, unlike other parts of the plains of the region, Upper Pannonian layers here are considered to be less studied, however, they also have great geothermal perspectives (Bódi et al. 2015).

2.2. Modelling

For clarifying the geological properties of the reservoirs migrated 2D seismic sections were interpreted and with the integration of well data a 3D model was interpolated (Fig. 2). In order to describe reservoir connectivity sequence stratigraphic units were identified. It is a new approach in the practice of thermal water management in this area. Since sequence stratigraphy emphasizes much more the factors affecting accommodation focusing on the genesis itself in addition considering cyclicity and by this, the whole story of sedimentation, sedimentary rocks, can be analysed better (Vail et al. 1977, Haq et al. 1987, Miall 1997, Cateneanu et al. 2011).

Accordingly, the sand bodies, that are the actual reservoirs, should be identified as units within a certain sequence. It is worth noting, that these units can be disturbed by fractures, which may affect flow pattern. Thus these were also integrated into our model.

The identified units were marked by border curves on 2D sections and point marks according to well data, based on these data surface were interpolated. By these surfaces a 3D model and a grid model were created. Each 3D grid unit can be parameterized; consequently calculations with a proper geometry could be operated (e.g. depth, temperature, energy density distributions, etc.).

2.3. Energy studies

Since the main purpose of geothermal energy extraction in the region is balneological use, but the heat content and temperature of the water is higher than that required for the pools, the heat content of the water is divided to three parts. Pre-pool usage of the water means energy extraction while the temperature of the water cools down to 40 °C. Post-pool usage means energy extraction of the water with temperature below 30 °C. Between 30 °C and 40 °C the water cools down in the pools (no other energy utilization is possible).

Heat content of the three parts is calculated by the monthly amount of extracted water on the spas' own admission in 2008. Although different years could mean usage of different thermal wells and producing different amount of water, the chosen datasets are appropriate for stating general considerations about more effective energy usage. The monthly values were summarized for yearly values, nevertheless in the small spas thermal water extraction occurs only in summer.

$$E = c_w \cdot \rho_w \cdot Q \cdot (T_{wellhead} - T_0) \quad (1)$$

$$E_1 = c_w \cdot \rho_w \cdot Q \cdot (T_{wellhead} - 40\,°\mathrm{C}) \quad (1.1)$$

$$E_2 = c_w \cdot \rho_w \cdot Q \cdot (40\,°\mathrm{C} - 30\,°\mathrm{C}) \quad (1.2)$$

$$E_3 = c_w \cdot \rho_w \cdot Q \cdot (30\,°\mathrm{C} - T_0) \quad (1.3)$$

where: E – whole extracted energy in 2008 (J); E_1, E_2, E_3: extracted energy in 2008 of the 1st, 2nd, 3rd part (J); c_w – specific heat capacity of water (4180 J/(kgK)); ρ_w – density of water (990 kg/m^3); Q – amount of extracted water in 2008 (m^3); $T_{wellhead}$ – wellhead temperature (°C); T_0 – ambient temperature (15 °C).

The methane content of the wells and the depth of screening were taken from the Thermal Well Registry of Hungary. Methane combustion means additive thermal energy or thermal energy and electricity. In this paper only thermal energy is presented based on Eq. 2.

$$E_m = \chi \cdot Q \cdot \rho_m \cdot H_m \quad (2)$$

where: E_m – whole energy by combustion of methane content of thermal water extracted in 2008 (MJ); χ – methane content of the water (m^3/m^3); Q – amount of extracted water in 2008 (m^3); ρ_m – density of methane (0.656 kg/m^3); H_m – higher heating value of methane (55.5 MJ/kg).

3. Results and discussion

3.1. Modelling

Based on the approach presented briefly above many problems can be solved. For example the reason for very different production values – unlike what is expected – of wells relatively near each other (10–20 km) like those around Hajdúszoboszló and Nádudvar could be revealed. Four theoretical wells were drawn along the section presenting that in fact to drill and screen wells in the same depth do not guarantee similar yield values (Fig. 2). However, to expect that wells screened in the same unit but in different depths would be equally productive, is also risky.

Other differences can be described in this area and justify the need for planning in smaller cases studiously taking into account the local occurrence of reservoirs and their hydraulic, thermal and chemical properties and possibilities.

Thermal water extracted for balneological purposes can be optimized in many ways. The easiest way to reach it is to extract less thermal water considering e.g. the seasonal change in the number of visitors.

If for energy purposes the need for thermal water increases in the future, since there is a variable but notable potential worth utilization (Fig. 4), in order to spatially harmonize the exploitation, other wells could be integrated in the energy system. By this the increased rate of exploitation will not stricken the reservoir around one or two wells significantly, but around more wells, showing favorable distribution, in a more moderately way.

3.2. Energy studies

In the studied region 24 thermal wells were used for balneological or geothermal energy extraction purposes. Most wells are located near Hajdúszoboszló and Debrecen, while around the other towns one or two wells were used in 2008. In the 10 settlements the total amount of extracted water was about 3.4 million m^3, 55.9 % and 19.4 % of which was realized in Hajdúszoboszló, and in Debrecen respectively (Fig. 5). These towns have regionally famous spas and medical centres based on these thermal water reserves. In most of the settlements thermal wells were constructed as a "secondary product" of CH exploration and their depth and temperature are higher than required for balneological purposes (Fig. 6). Consequently many of them possess significant useable heat content in the pre-pool temperature range, which was usually not used in the studied year. At most settlements ratio of E_2 is lower than 20 %, while ratio of the higher temperature range is more than 40 %. These mean that more than 80 % of the heat content could be used energetical purposes, which is about 280 TJ/y in the case of Hajdúszoboszló. The methane content of the wells is variable, in the case of 5 towns energy from the methane could be in the range of GJ/y (Fig. 5).

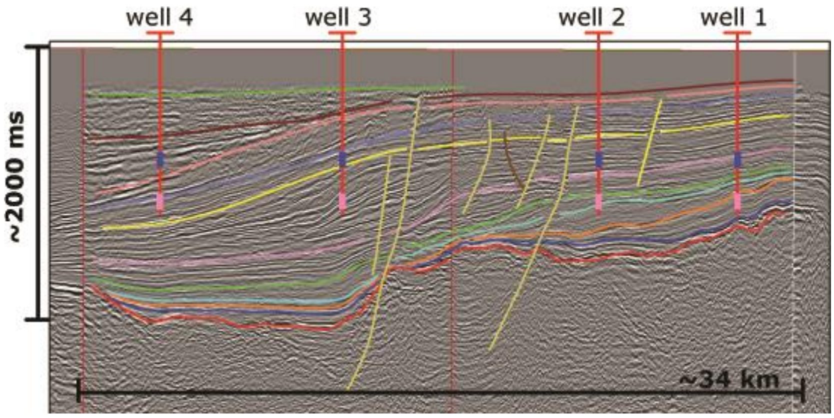


Figure 2. Interpreted 2D seismic section with theoretical wells with screening in two depths (pink and blue marks) presenting the suddenly changing geometry of thermal water reservoirs (Bódi et al. 2015).

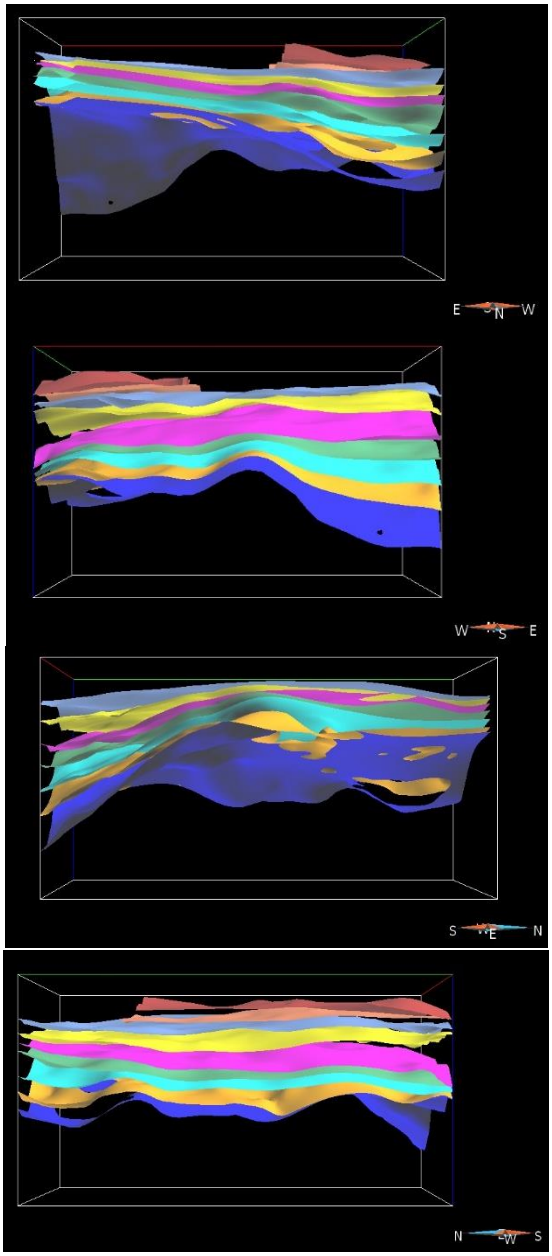


Figure 3. 3D model of Pannonian s.l. successions whereas surfaces present the sequence stratigraphic units identified by interpretation of seismic sections and well logs

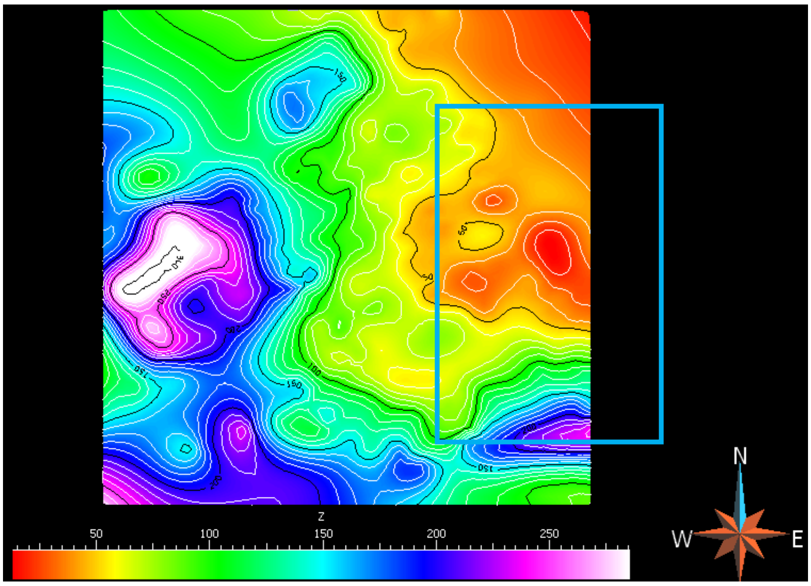
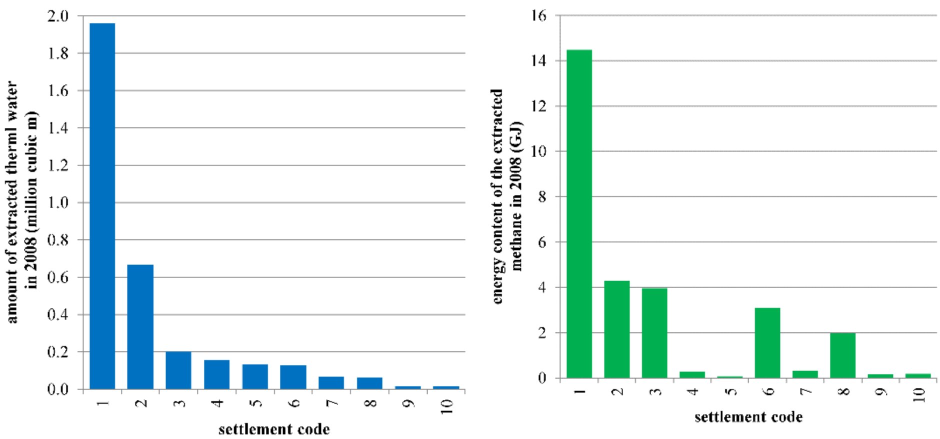


Figure 4. Energy density (GJ/m²) cyan rectangle presents the borders of the focus area (Bódi et al. 2015)



Settlement code: 1. Hajdúszoboszló, 2. Debrecen, 3. Hajdúböszörmény, 4. Tiszacsege, 5. Hajdúnánás, 6. Kaba, 7. Polgár, 8. Nádudvar, 9. Hajdúdorog, 10. Püspökladány

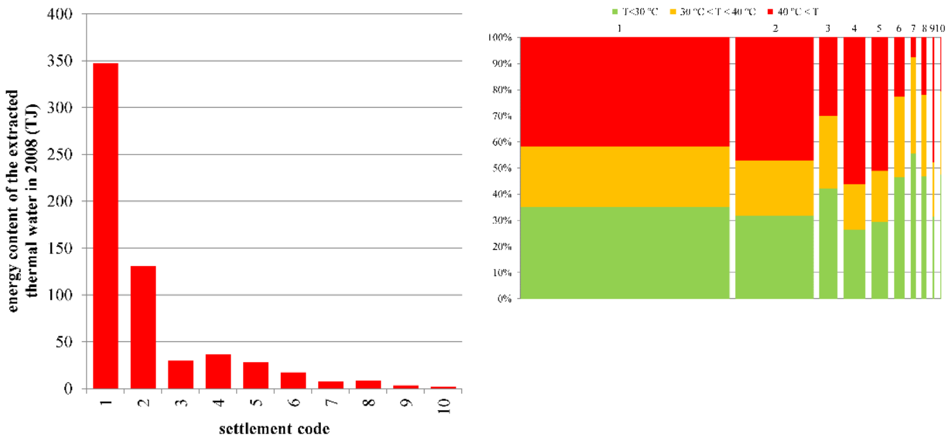


Figure 5. Amount of extracted water (above left), potential heat from methane combustion (above right) and amount and distribution of geothermal energy (below) in the studied towns in 2008.

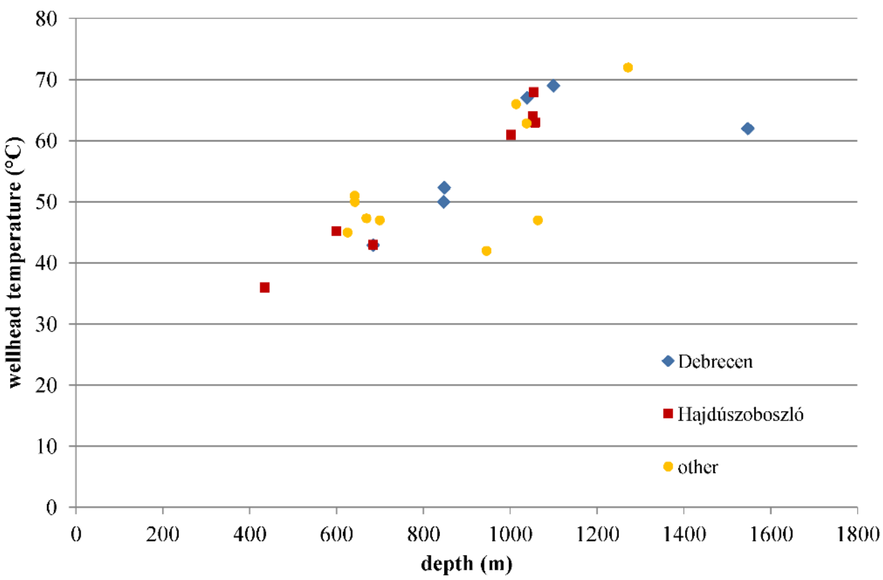


Figure 6. Wellhead temperature by the depth of the screening's bottom in the studied wells

The most important potential pre-pool utilizations in the spas are space heating (in winter) and sanitary hot water production. These systems require more than 50 °C, while the lower range of the pre-pool utilization could be used in pre-heaters, HVAC systems, or in some cases heating the pools. Since the temperature of post-pool utilization is usually lower than 30 °C, the heat content could be used in pre-heaters, warming the swimming pools (25–28 °C), or with the assist of heat pumps it could be used for heating and sanitary hot water production. The latter requires new solutions for the heat pump producers because of the relative high temperature (25–30 °C instead of 0–15 °C), high dissolved solids and possible presence of causative agents.

Comfortably there are some shallow thermal waters in the systems which produce water of appropriate temperature for being used in the pools. In this case the deep reservoirs dispose the loads. These reservoirs are usually not containing thermal water with curative power, in addition the deeper reservoirs could be used for medical purposes and shallower reservoirs could be used for recreation (Buday 2012). It is especially important in the largest spas, for avoiding overproduction (Buday et al. 2015).

In the last years spa managements of Debrecen and Hajdúszoboszló decided to carry out renewal of building engineering systems. It means practically, that plate heat exchangers were installed for cooling thermal water and produce heat and sanitary hot water. In addition in Hajdúszoboszló the separated methane is combusted in a gas engine producing electricity and additional heat. These developments should be pursued in the other spas.

4. Conclusions

Even in a relatively small area the possibly sudden changes in the distribution of the reservoirs (e.g. tectonic deformations, development, geometry, heterogeneity, connectivity, etc.) can cause significant differences in production. Thus without studying the reservoirs, or having an accurate model describing the system, sustainable and responsible utilization cannot be imagined. Potential energy of a certain area itself does not guarantee success, but the conscious utilization of it probably does.

Spa management should take notice of that increasing thermal water extraction for profit with short return may result damage in the reservoir and the expected production value will not meet. From a certain reservoir only as much water should be extracted as is needed for the utilization processes since overproduction can decrease the potential of the reservoir. Production should target less encumbered reservoirs even in the cases of already existing production wells, but in the cases of new wells necessarily. The heat and methane content of the thermal water produced for spas should be utilized more consciously.

These conclusions could be generalized and may be valid in other parts of the Danube Region in order to help to develop sustainable geothermal utilization systems.

Conflict of Interest

The authors declare no conflict of interest.

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Effect of the Solar Radiation on Underground Temperature Values and Heat Supply Around a Ground Coupled Heat Pump Based on Meteorological Data, Debrecen

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Abstract: The recovery of the underground energy around a ground coupled loop of heat pump system basically depends on the type and size of the loop, the targeted depth, the extracted and injected energy, the horizontal and vertical underground heat transport and especially in shallow systems the solar irradiance. The amount of summarized heat supply is the key to the sustainable and economic utilization of heat pump systems. Since solar radiation controls the temperature of the ground surface, in addition the yearly temperature changes of the air and in the shallow underground, thus it could determine the fundamentals of designing the systems (heat and cooling demand, recovery, etc.). In this paper one year data of a meteorological station is analyzed using diagrams and analytically for determining the relationship between the measured parameters. This could ascertain the role of solar irradiation in the energy flow around a heat pump system.

Keywords: solar radiation; underground heat recovery; heat pump system.

1. Introduction

The sector of ground coupled heat pumps is the most dynamic and largest sector in direct geothermal energy utilization (Lund et al. 2010, Rybach 2010). Heat pumps deliver energy from ambient underground substrate (soil, sediments, rocks, groundwater) to a heated building, which has higher temperatures than the underground (Ochsner 2007). The process requires auxiliary energy which is usually electricity. The systems' performance could be given as the quotient of the delivered energy and the auxiliary energy called as COP (coefficient of performance), and this parameter is important in the economic running and environmental impacts of the system.

Ambient temperature has fundamental effects on COP value due to themoanalytical reasons. Studies showed (e.g. Eugster – Rybach, 2000, Buday 2010) that if heat extraction is high (around or over the planning values) and only generated heat transport processes help the recovery, the underground temperature decreases year after year, resulting in increasing operation costs. The assumption of the economic operation of these systems is extra heat recovery during the summer period, when no or low heat extraction occurs. Most saving recovery modes are ground coupled cooling, unused solar heat storage in the underground medium, however, in shallow depth solar irradiation depending primarily on solar radiation, sun angle and the physical properties of the soil has a significant role in the heat recovery as well.

The types of ground coupled systems (Fig. 1) vary regarding the heat carrier fluid, the targeted depth, the space demand and expedience (Ochsner 2007). Groundwater based systems could be installed to locations with shallow (<15 m) aquifers, since water production and re-injection requires extra energy, in addition the amount of yieldable water determine the maximum heat power. In well-designed cases the cooling of the reservoir is not significant, therefore these systems are not discussed here. The so-called borehole heat exchanger means one or more borehole with

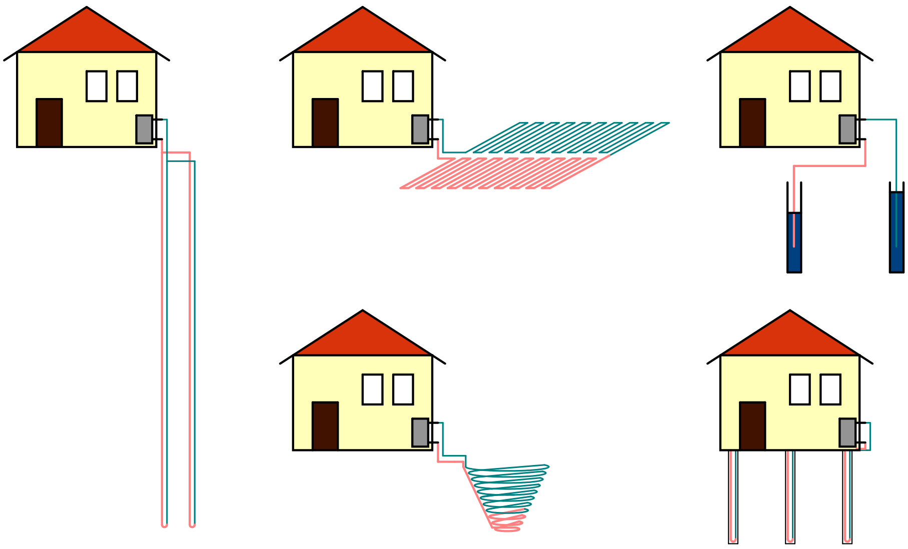


Figure 1. Typical installations for ground coupled loops: borehole heat exchangers (left), horizontal collectors (middle above), geothermal heat baskets (middle below), well doublets (right above), energy piles (right below).

vertical closed loops with length from 50 m to 150 m. The distance between the boreholes is usually more than 5 m, or more than 7 m if no summer heat injection is planned. Since solar irradiation takes effect only for shallow depth (roughly from 5 m to 10 m), in this mode the rate of irradiation in the total recovery is rather low.

Some ground coupled loop installation types target the shallow zones. So called horizontal collectors consist of horizontal pipes installed more than 50 cm away from each other. The pipes cover a larger area the extent of which is based on the required heat and cooling demands. The typical installation depth of these systems is in the range of 1.5 m and 2.5 m. Some technologies allow the use of smaller areas, since pipes form worm shape such as trenches or geothermal heat basket. This subserves heat extraction from different depths, thus energy extraction is more effective.

Larger buildings need pile foundations for static purposes (large design load, loose materials in shallow depth) length of which enables to use them as heat exchangers. Comparing with the borehole heat exchanger pile heat exchangers are shorter, have greater diameter and concrete grouting, however, their position is determined by architectural design instead of building engineering.

2. Methods

2.1. Data collection

The Renewable Energy Park is situated in the western part of Debrecen, East Hungary (Figure 2) in the geographic latitude 47.530 N and longitude 21.577 E. In its meteorological station contrary to the standard meteorological stations in Hungary detailed soil temperature measurements are carried out at 9 different depths at 2 cm, 5 cm, 10 cm, 20 cm, 30 cm, 50 cm, 100 cm, 150 cm and 200 cm, in addition these data are completed with air temperature values measured at the height of 2 m as well as solar radiation values. The sensors (Table 1) are connected to CR1000 data logger produced by Campbell Scientific Ltd. Air and soil temperatures are measured by 1 second sampling and 10 minutes averaging. Some of the sensors have been in operation since September 2013, while since 1st December 2013 all sensors have been producing measured data. In some periods data logging has been suspended due to technical problems, but the number of useable data is approximately 50000 pieces per sensor.

2.2. Primer data analysis

In our approximation the values of solar irradiance have effect on the temperature of the upper soil layers, in addition the temperature of the upper soil layer can modify the temperature of the underground and also the air temperature. Two consecutive summer days and two consecutive winter days were analyzed in detail, while the

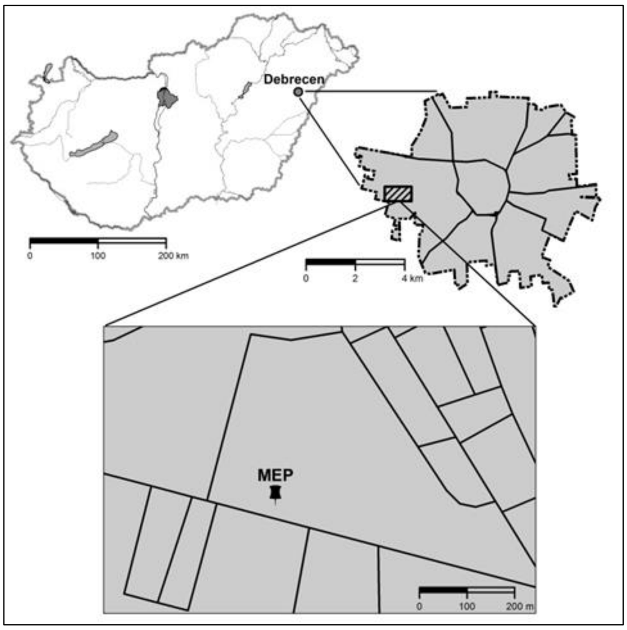


Figure 2. Location of the measuring point (MEP – Renewable Energy Park)

Table 1. The main parameters of the used sensors in the Renewable Energy Park, Debrecen

Sensor	Type	Operating temperature range	Accuracy of measurement	Measurement range
HC2S3	air temperature	–50 °C – +100 °C	± 0.1 °C	–50 °C +100 °C
DS18S20	soil temperature	–55 °C – +125 °C	± 0.5 °C	–55 °C +125 °C
CM3	pyranometer	–40 °C – +80 °C	± 5%	350–2800 nm

whole year was analyzed through the daily average temperature and irradiation values. The measured values were approximated with sinusoidal functions or temporal analysis of extreme values was carried out.

Based on theoretical considerations and measured underground temperature datasets (e.g. Adams et al. 1976, Lemmelä 1981, Smerdon et al. 2004, Koo–Song, 2008, Buday 2009, 2010) the energy flux through the surface cause temperature variation which could be approximated as a sum of sinusoidal functions:

$$\begin{aligned} T(z,t) = T_0(z=0) + Gz + A_y e^{-z\sqrt{\omega_y/2\alpha}} \cos(\omega_y t + \phi_y - z\sqrt{\omega_y/2\alpha}) + \\ + A_d e^{-z\sqrt{\omega_d/2\alpha}} \cos(\omega_d t + \phi_d - z\sqrt{\omega_d/2\alpha}) \end{aligned} \quad (1)$$

$$T(z,t) = T_0(z) + A_y(z)\cos(\omega_y t + \phi_y(z)) \quad (2)$$

$$\alpha(A) = \frac{(z_2 - z_1)^2 \omega_y}{2[\ln A(z_1) - \ln A(z_2)]^2} \quad (3)$$

$$\alpha(\phi) = \frac{(z_2 - z_1)^2 \omega_y}{2(\phi_2 - \phi_1)^2} \quad (4)$$

where: *T(z,t)*: temperature as a function of *z* and *t* (°C), *z*: depth (m); *t*: time (s); *G*: geothermal gradient (°C/m); T_0: annual mean temperature (°C); A_y, A_d: yearly and daily temperature amplitude (°C); ω_y, ω_d: yearly and daily angular frequency (rad/s), ϕ_y, ϕ_d: yearly and daily phase shift (rad), α: thermal diffusivity (m^2/s).

In the calculations the yearly and daily effects were studied independently. For the yearly calculations daily average temperature values were used, while for the daily calculations two or three days long set of data averaged in every 10 minutes were used. The best fitted functions were determined by Solver add-in in Excel.

3. Result and discussion

3.1. Daily irradiation and temperature distribution

Based on the quality and quantity of the daily datasets data of two days in July, 2014 are presented in Figure 3. Although both afternoons were cloudy, but apart from this the daylight has sinusoidal shape. The air temperature function could be divided into four sections in a regular day: fast increase in the morning, slow increase and top over midday, short decrease in the evening and moderate decrease and midnight flat. Soil temperatures at shallow depth start to increase later than air temperature and its dynamism is simpler, in addition only the more significant decrease in the radiation can cause disturbances. Below the depth of 1 m daily amplitudes cannot be detected. Based on the temperature amplitudes, thermal diffusivity is about $7.079 \cdot 10^{-7}$ m^2/s. The phase shift of the daily temperature is a half day at the depth of 0.4 m.

Winter days show slightly different correlations (Figure 5). Solar irradiance was significantly lower, however, relative air temperature increase was similar to the summer value. Shallow temperatures had lower amplitudes, in addition around 0 °C or at lower temperatures, temperature increase temporarily stopped. It was caused by the freezing of pore water (0 °C) or the water bonded weakly to the surface of the substrate (below 0 °C).

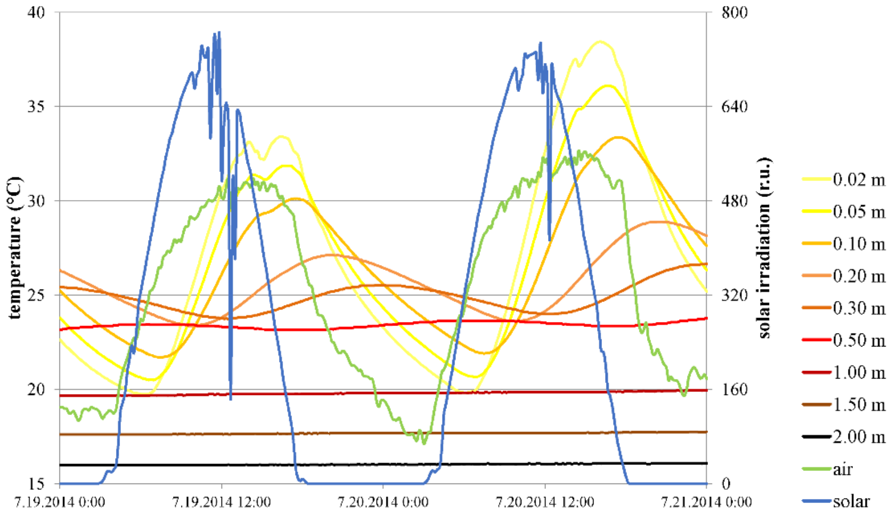


Figure 3. Measured radiation and temperatures of the Renewable Energy Park on 7.19.2014 and 7.20.2014

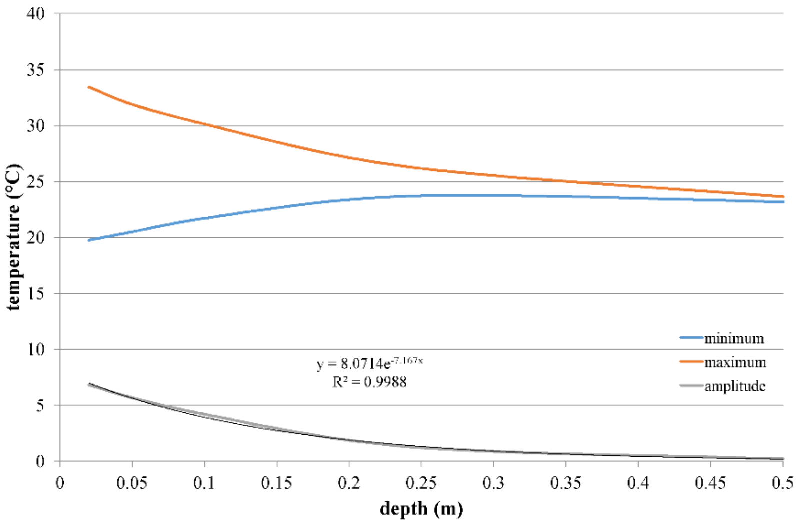


Figure 4. Daily minimum and maximum temperatures and daily amplitudes as a function of depth on 7.19.2014

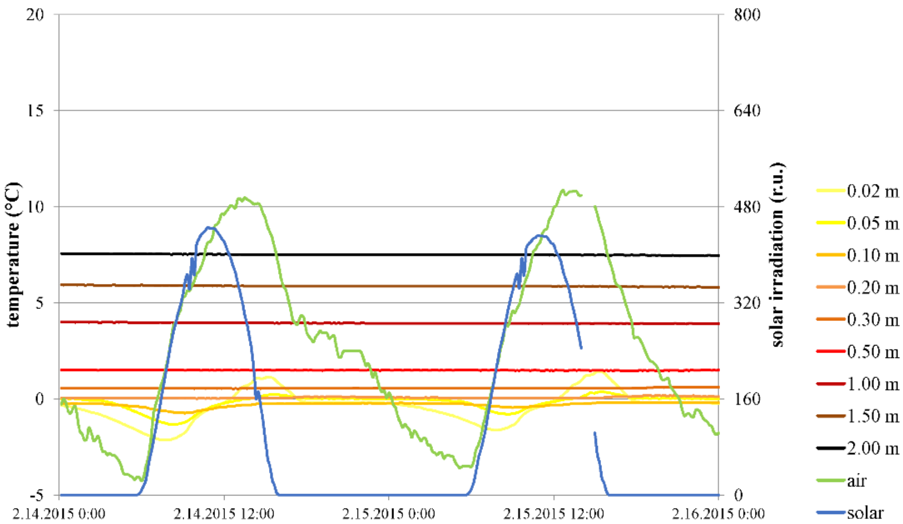
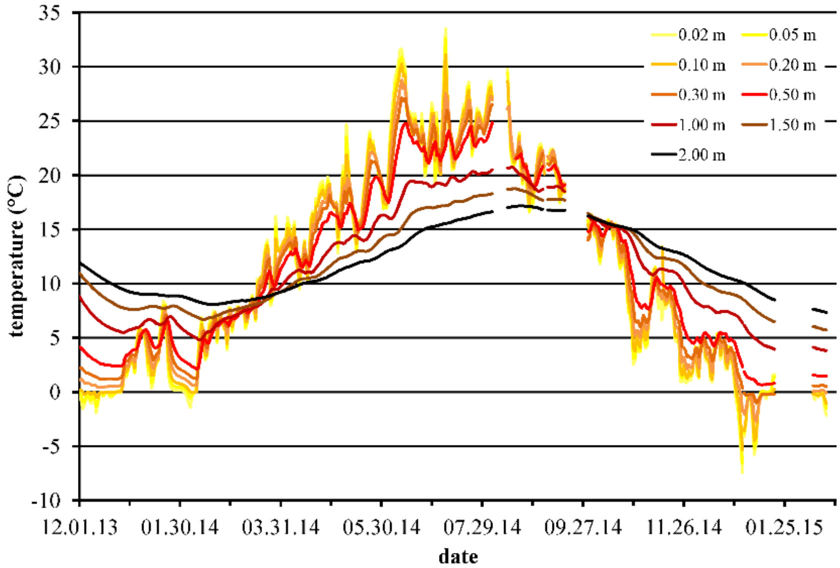


Figure 5. Measured radiation and temperatures of the Renewable Energy Park on 2.14.2015 and 2.15.2015

3.2. Yearly underground temperature distribution

The analyzed daily average temperature values at shallow depths show that longer temperature disturbances have significant effects from the surface down to 2 m. The penetration depth of the yearly changes was determined analytically. Based on the yearly analysis, sinusoidal functions could be fitted fine to data of 1 m or deeper (Figure 6), while at shallower depth the values are affected strongly by solar irradiation. For each depth interval the parameters of Eq. 1 were determined, thermal diffusivity values based on Eq. 3 and 4 were also calculated (Table 2). Parameters derived from data measured not shallower than 0.20 m were appropriate for graphical analysis as well (Figure 7). Deviations from the regression line at shallow depth may be evolved by the lack of pore water and the presence of heat convection. Based on the depth by depth and larger scale calculations, thermal diffusivity values are in the range of $2.5 \cdot 10^{-7}$ m^2/s – $2.5 \cdot 10^{-6}$ m^2/s, which is average in the lowland landscape of the Danube Region. Mean temperature values decreasing by depth could sign the increasing of the mean temperature of the surface.

Based on the fitted curves, the temperature amplitude is lower than 0.05 °C at the depth of 10 m, in addition the depth of the half period shift is 8 m.



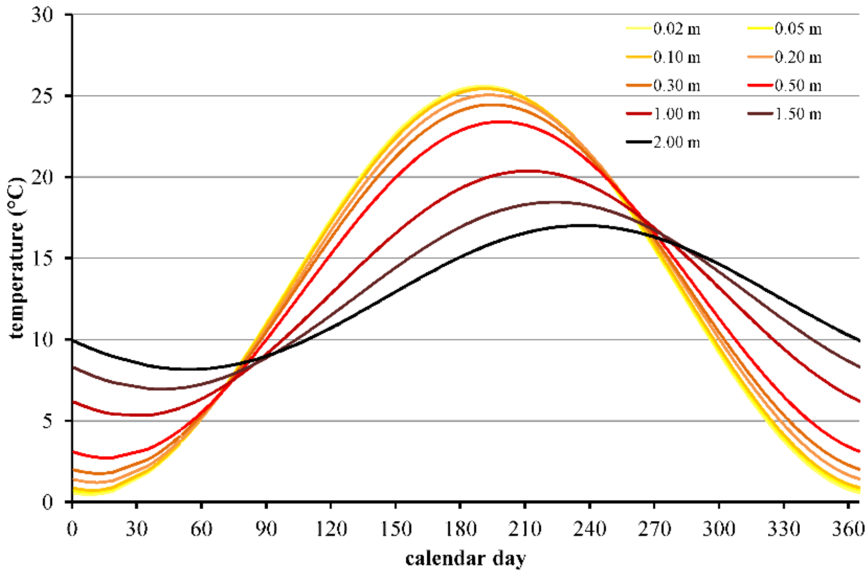


Figure 6. Measured (above) and modelled (below) temperatures of the Renewable Energy Park

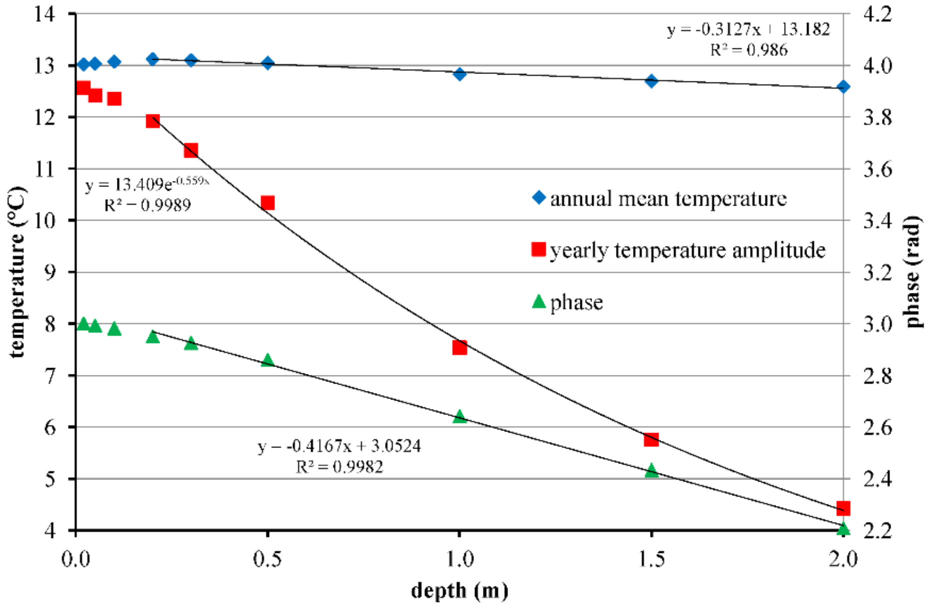


Figure 7. Parameter values of the approximate sinusoidal curves by depth with the fitted functions.

Table 2. Determined parameters of the approximate functions and the calculated thermal diffusivity values

depth	T_0 (°C)	A_y (°C)	ϕ (rad)	depth range (m)	$\alpha(A_y)$ (m²/s)	$\alpha(\phi)$ (m²/s)
0.02	13.015	12.565	3.002	0.02–0.05*	$6.623 \cdot 10^{-7}$	$1.110 \cdot 10^{-6}$
0.05	13.032	12.420	2.993	0.05–0.10*	$9.370 \cdot 10^{-6}$	$2.344 \cdot 10^{-6}$
0.10	13.074	12.356	2.982	0.10–0.20*	$7.782 \cdot 10^{-7}$	$9.931 \cdot 10^{-7}$
0.20	13.119	11.921	2.951	0.20–0.30*	$4.139 \cdot 10^{-7}$	$1.655 \cdot 10^{-6}$
0.30	13.100	11.351	2.926	0.30–0.50*	$4.588 \cdot 10^{-7}$	$9.286 \cdot 10^{-7}$
0.50	13.047	10.341	2.861	0.50–1.00*	$2.491 \cdot 10^{-7}$	$5.209 \cdot 10^{-7}$
1.00	12.826	7.537	2.642	1.00–1.50*	$3.433 \cdot 10^{-7}$	$5.735 \cdot 10^{-7}$
1.50	12.694	5.758	2.434	1.50–2.00*	$3.605 \cdot 10^{-7}$	$4.904 \cdot 10^{-7}$
2.00	12.585	4.427	2.209	*0.10–2.00***	$\mathit{3.188 \cdot 10^{-7}}$	$\mathit{5.737 \cdot 10^{-7}}$

* Based on the parameter values of the given depths and Eq. 3 or 4
** Based on the parameters of the fitted curves

3.3. Other observations

Precipitation also has demonstrable effects on shallow temperatures. Rain could infiltrate to the underground relatively quickly, and change the temperature values of the shallow depth similar to each other. Evaporation decreases the temperature of shallow zones by using heat. Snow or sleety rain is more important because of the insulation effect of snow and ice. Long spells of snow cover protect the subsurface from overcooling in winter (Figure 8).

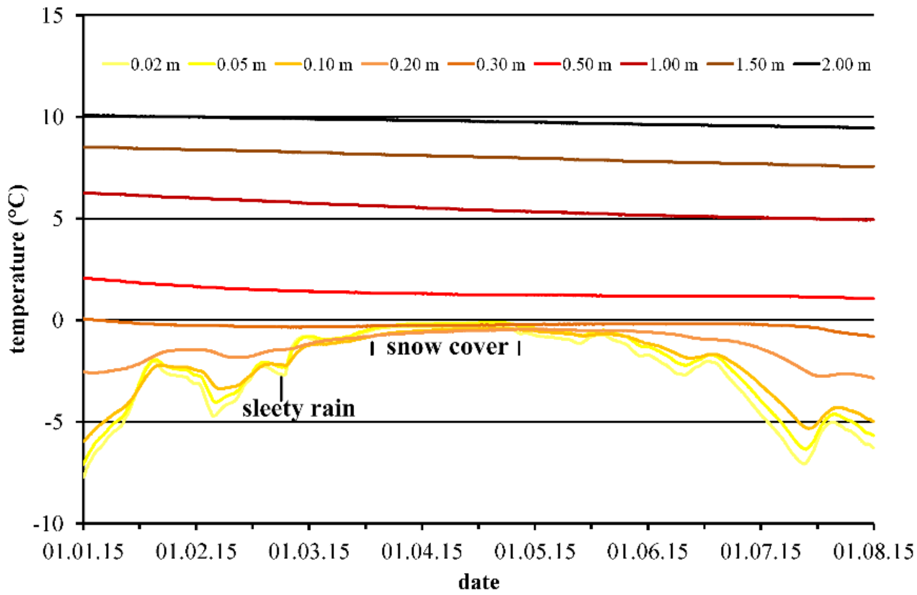


Figure 8. Measured temperatures of the Renewable Energy Park between 01.01.2015 and 07.01.2015

4. Conclusions and recommendations

Since the thermal effect of radiation in the soil can be detected only in the first few metres, it can be used only for shallow geothermal systems during recovery. Unfortunately the installation depth of these systems is small, the undisturbed underground temperature values are the lowest at the end of the heating season. This means that artificial temperature drop is intensified by natural processes and the temperature of the primer loop is lower than desirable. The most important environmental effects of this cumulate value are that soil freezing deeper, the average COP value decreasing, the operation costs increasing (Buday et al. 2014).

The effect of irradiation is not enough to supply the extracted energy, thus thermal energy storage (Lee 2013) is recommended.

Analysing the climate of the Danube region the natural supply is more effective in areas with the following characters:

– high irradiation values in both seasons and mild winter;
– high probability of long spells of snow cover during the cold winter and also of hot summer;
– higher cooling demand than heat demand with good possibilities of thermal energy storage.

The efficiency of thermal extraction and energy storage could be higher if the ground coupled loop is installed below a building. Although it keeps out the recovery effect of radiation but in a building the temperature is usually higher than the air temperature, thus the accumulated energy in the underground is higher. Other land use practice has less significant effect on energy accumulation. Shadow of nearby buildings, trees and other things decrease summer recovery (Tejedor et al. 2004), or microclimatic conditions could be also important.

The recovery of the underground is fundamental for sustainable shallow geothermal energy utilizations. These systems are environmental friendly, energy effective, but need notable capital. The investigation of the recovery in the location of an investment help to increase the efficiency of these systems, in addition best practice installations assist propagation of the technologies in less developed countries of the Danube Region also where the payback is more important due to the lack of diverse capital.

Acknowledgments

The authors would like to thank Richard William McIntosh for grammatical and technical help.

Conflict of Interest

The authors declare no conflict of interest.

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Utilizing Geothermal Energy in Hungary Today

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Current market prices for fossil and nuclear energy represent only a fraction of the true costs to society. If the external costs for environmental damage and political conflict were also considered, renewable energy would be competitive or even less expensive than conventional energy.

The ecological damage caused by the use of fossil fuels; particularly losses due to climate change and air pollution, is becoming an increasingly important economic factor, having an ever greater impact on political and economic decisions (cost of CO_2 emissions, new climate-change-related risk benchmarks for companies, agriculture etc.).

Renewable energy sources offer the possibility to meet worldwide energy needs in a climate-friendly and sustainable way.

Out of renewable energy sources, thermal energy is not very important in Hungary for the time being. A comparison with the situation in other countries offers interesting conclusions.

In Germany, the dominant renewable energy sources are those of wind and solar energy. There is, however, a range of contradictions in connection with this in German energy industry.

The solar energy plants created in Southern Germany–primarily Bavaria–with government subsidy are able to generate electric power equal to the output of 13 nuclear power plants the size of Paks.

There is, however, one problem with that: this incredible output is only achieved in sunshine. In an overcast weather or at night the performance drops to 10% or zero.

Another problem with the renewable energy sources in Germany is that the electric power generated by the wind power plants in the northern parts of the country can be fed into the national grid with considerable difficulties and at a large cost. Three new power lines, 2,700 km long each, are to be constructed.

German experts estimate that by 2020, 32–37% of the electric power will be received from renewable sources. 14% of that energy will be used for heating.

It has only been mentioned here in order to illustrate that solar and wind energy are the most commonly used sources of renewable energy. On the other hand, geothermal energy, which has immense reserves, does not develop at the rate it deserves, as pointed out by the prominent Swiss scientist, Prof. Ribach.

In Germany, shallow geothermal energy is more wide-spread than deep geothermal energy, but the latter is also significant, though far behind the shallow method. For shallow geothermal energy, they use heat pumps and distribute the energy in different ways.

There are 550 companies involved in shallow geothermic industry. They participate in manufacturing equipment for, and use of geothermal energy.

1. The Use of Geothermic Energy in Hungary

It is widely known that the well for Széchenyi Spa, made in 1878, was a world record at its time with its depth of 970,48. The temperature of the water found at that dept is 74°C. Although it was a promising start, but the hydro-geological potentials have not been fully utilised to the full ever since. It is also to be noted that at Hotel Tisza in Szolnok geothermal energy was used as early as 1930. What is more, electric power was also generated simultaneously. That was a novelty at that time, and there is no device in Hungary for generatic electric power with the help of thermal water even today (the system has long been out of use in Szolnok).

Let us also recall another world novelty when the water of the thermal fountains of Margaret Island was conducted under the Danube to the district of Budapest called Új-Lipótváros, and the entire housing estate was supplied with thermal water in 1953. The system came to be known as the “three-tap solution”. It means that one tap provided thermal water, one traditional hot water and one cold water.

In the period following the early fifties several towns made investments in order to utilize thermal water for public purposes. The city of Szeged was among the first with the system installed in its district called Odessa, but Hódmezővásárhely, Makó and other towns also introduced similar systems.

Progress in this field was not a linear process, since there were periods when very cheap fossil fuel rendered these efforts unprofitable. In other historical periods the government acted as a supporter of the introduction of renewable energy sources. When the price of natural gas grew considerably, it became an instigator of progress in renewable energy development. Government subsidy was another major factor in the utilization of renewable energy.

In the National Renewable Action Plan geothermic energy contains the following in relation to both heating and cooling: 700 new wells are planned, the amount of energy to be used for heating, cooling and hot water supply is 14,95 PJ. For electric power generation (which is going to be an interesting new feature in the Hungarian energy industry) 1.42 PJ is included in the plan. The total renewable energy usage in Hungary in 2010 amounted to a total of 4.23 PJ.

What investment does the Action Plan require for renewable energy sources? A total amount of HUF 160 billion is needed, which includes boring the 700 new wells.

2. The Exploitation of Thermal Water

In 2007, 58.3 million m^3 of thermal water was exploited in Hungary. Out of that, 12,3 million m^3 was use for energetic purposes. At that time, the remaining 46,0 million m^3 was used for other goals. It suggests that geothermic district heating systems have undergone a significant development in the past few years. Some of the early systems were mentioned previously, but even before 1990 the towns and cities of Hódmezővásárhely, Szentes, Budapest, Veresegyház, Szeged, Dunaújváros, Makó, Miskolc, Szolnok and Debrecen. In the Transdanubian areas Mosonmagyaróvár and Pécs have extensive systems. The new system of Miskolc is going to be one of the largest in the nation.

There are plans for further development, and investments are underway, for instance in Veresegyház new and new users are added to the system every year. It is therefore not easy to provide up-to-date figures about the users of thermal energy. Not only public and community institutions, (e. g. schools, hospitals, swimming pools, but business enterprises, such as the American company, the General Electric in Veresegyház. Other companies, factories, pharmacies etc.) use thermal energy.

The plans for further development are based upon the advantageous conditions at a specific area. For example, now it is the thermal energy system of Miskolc that is going to be further developed. The springs and wells located south of the city shall be used to supply the residential area on Avas Mountain, but there are plans that extend the system to the entire city.

"Advantageous conditions" primarily mean that for returning the water one well is enough for two or three wells. In the Pannonian Basin, the average is two returning wells for every one production well. Such advantageous conditions are found at places where there are karstic layers, for instance in the neighbourhood of Veresegyház. Such conditions make the utilization of thermal water extremely economical.

In the future, any responsible and far-sighted development is only possible if water exploited from the depths is returned there after utilisation. That is not only the ideal, but from an environmental point of view, the only feasible way.

SOLAR RESOURCES

Solar Energy Resources in the Danube Region

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When focusing on the availability of any renewable energy source including solar energy resources in any region including Danube region, it is first important to define the types of potentials that are considered. In the literature, various types of potentials are defined. There is no one single definition for the various types of potentials. However, one of the most usefull definition of potentials can be taken from (ECOFYS 2005) as follows:

- *Theoretical potential:* The highest level of potential is the theoretical potential. This potential only takes into account restrictions with respect to natural and climatic parameters.
- *Geographical potential:* Most renewable energy sources have geographical restrictions, e.g. land use land cover that reduce the theoretical potential. The geographical potential is the theoretical potential limited by the resources at geographical locations that are suitable.
- *Technical potential:* The geographical potential is further reduced due to technical limitations as conversion efficiencies, resulting in the technical potential.
- *Economic potential:* The economic potential is the technical potential at cost levels considered competitive.
- *Market potential:* The market potential is the total amount of renewable energy that can be implemented in the market taking into account the demand for energy, the competing technologies, the costs and subsidies of renewable energy sources, and the barriers.

For general assesment of particularly theorethical, geographical and technical potentials in the Danube region the most obvious choice is using the Photovoltaic Geographical Information System (PVGIS). Obvious reasons for using this resource according to are that PVGIS is a research, demonstration and policy-support instrument for geographical assessment of the solar energy resource combining laboratory research, monitoring and testing with geographical knowledge to analyse technical, environmental and socio-economic factors of solar (electricity) generation and that the GIS databases encompass the European Subcontinent therefore including all Danube region countries theoretical solar irradiation and photovoltaic (electricity) generation potentials presented on figure 1.

Figure 1 indicates that while the average annual global solar irradiation on the optimal plane in the European subcontinent ranges from less than 600 kWh/m^2 on the far north to the more than 2200 kWh/m^2 on the far south, Danube region lies in the area favourable for solar energy generation with global solar irradiation ranging mainly from 1100 kWh/m^2 on the northern parts (including southern Germany, country with the most PV systems installed in the World [REN21 2014]), with exception of mountain tops areas, up to 1800 kWh/m^2 on the southern parts of the Danube region with favourable Mediterranean climate conditions.

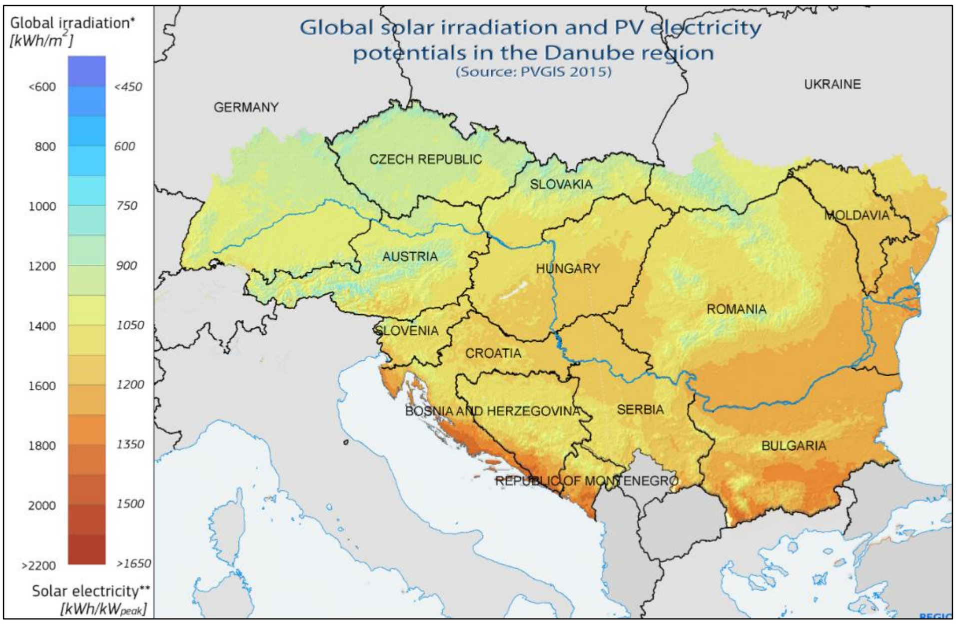

Figure 1. Theoretical solar irradiation and photovoltaic (electricity) generation potentials in the Danube region according to PVGIS

On the other hand, one of the main obstacles in using the PVGIS lies in the fact that although it is useful for assessing the theoretical potentials of solar radiation energy it is focused in terms of technical potentials only on a single technology, i.e. only on distributed photovoltaic systems. Therefore when assessing the technical potentials of the solar energy in the Danube region we should focus more on following fast developing and growing technologies according to (REN 21):

- Photovoltaic (PV) systems for solar electricity (power) generation only, with 139 GW of installed capacities by the end of 2013 out of 1560 GW for all renewable energy sources, making in the third largest renewable source in terms of installed capacities after hydro power plants (with 1000 GW of installed capacity including large hydro power plants which are considered as conventional energy source) and wind power plants (with 318 GW of installed capacity) but with the highest average annual qrowth rate of 55% in last 5 years (2008–2013)
- Concentrated solar thermal power plants (CSP) – for combined solar electricity and heat generation, with 3,4 GW of installed capacities by the end of 2013 which is negligible but with the second highest average annual qrowth rate of 48% in last 5 years (2008–2013)
- Solar collectors and heating and cooling systems (SHC) – for heat generation only, with 326 GW of installed capacities by the end of 2013 and with the fourth highest average annual qrowth rate of 14% (after wind power plants) in last 5 years (2008–2013).

For each technology there are many technical parameters and constrains to consider. Most important of all, the amount of energy being produced depends on the type of technology, configuration of the energy system and the efficiency in converting the solar irradiation to electricity and/or heat. As an example, we will consider the photovoltaic systems energy efficiency in the following.

All PV systems are in fact integrated sets of PV modules and other components, such as structure for installation (on the ground or roof), maximal power point tracker and other devices for regulation, eventual storage components (batteries, chargers etc.), DC/AC converters (inverters), cables, connectors, enabling the optimal supply of the electricity being produced from the PV modules (arrays, strings) to the network, AC or DC consumers. Two most commonly encountered configurations of PV systems are (Pelin et al. 2014): systems that feed power using DC to AC power conditioning inverter directly into the utility grid or through network connection installation such as lines and transformers (on-grid/grid-connected PV system, figure 2 and stand-alone systems with and without energy storage (batteries and chargers) (off-grid PV system), sometimes with generator back-up (hybrid PV system) (Figure 3).

Although the are other PV system losses including converter, batteries and cable losses, overall energy efficiency of the photovoltaic systems depends highly on the technology (material) of the PV modules being used. Today's market is dominated by semiconductor solar cells on the basis of mono- and poly-crystalline silicon, but new technologies based on plastics, organic materials or thin film cells with diverse semi conductor combinations are increasingly achieving marketability. In commercial application monocrystalline PV cells efficiency range between 13–19%, polycristal-

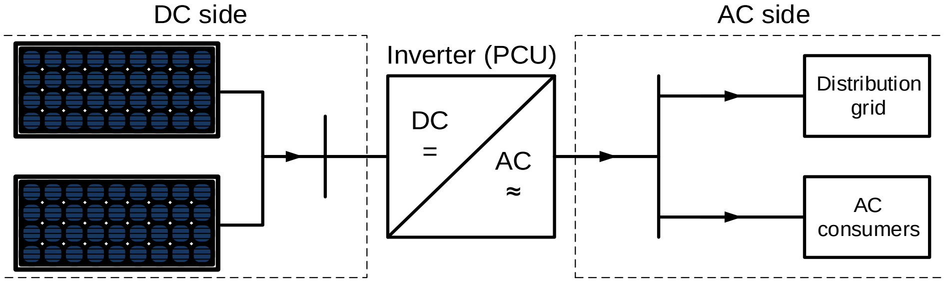

Figure 2. Typical on-grid PV system [4]

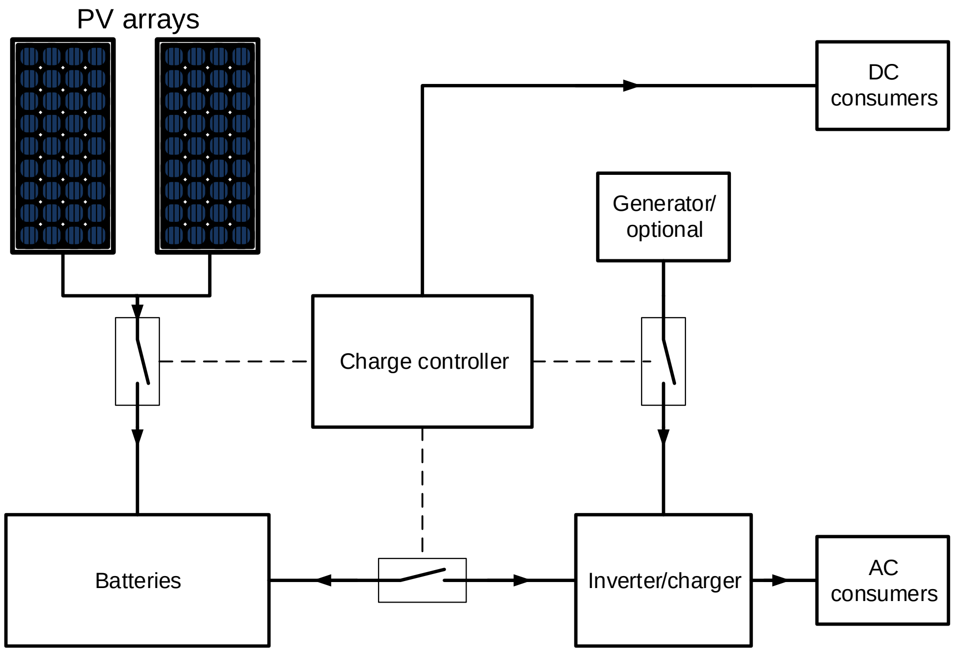

Figure 3. Typical off-grid PV system [4]

line from 11–15% and different thin film technologies with efficiency usually less than 10% (*NREL*) in so-called standard test conditions (STC). New production technologies such as are aimed at improving poor efficiency of PV cells and/or keeping production costs very low. Figure 4 presents the current best research cell efficiency chart from US NREL National Laboratory Center for Photovoltaics (*NREL*).

The investments into research focus on accomplishing more efficient transformation of sunbeams into electricity while retaining cheap materials and maintain low production costs.

Concentrated solar power (CSP) has three predominant technologies (*IEA*): parabolic troughs, linear Fresnel reflectors and towers (Figure 5) using concentrated solar irradiation for heating fluid and different thermodynamic cycles for running engine/ turbine and generator enabling combined heat and power (CHP) generation with development of thermal storage enabling usage of generated heat and electricity when demanded by consumers. A fourth type of CSP plant is a parabolic dish (Figure 5), usually supporting an engine at its focus.

CSP technology is in the early development stage meaning that there are many technical issues that needs to be addressed, such as according to (*IEA*):

– Efforts to improve linear systems (parabolic troughs and linear Fresnel reflectors) and point-focus systems, mostly towers, striving to increase efficiency in converting the energy from the sun into electricity, while reducing investment costs.

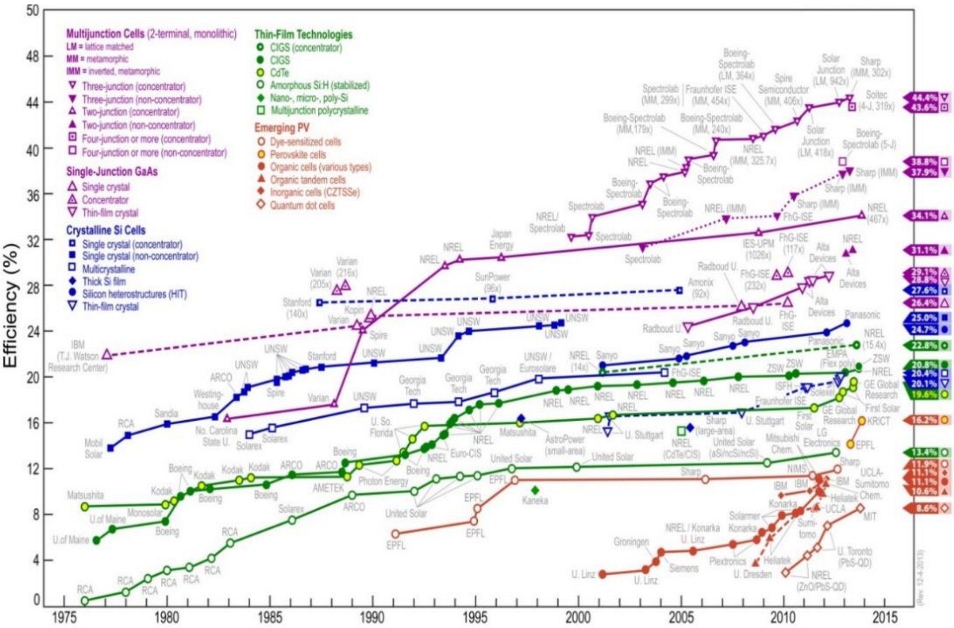

Figure 4. NREL best research PV cell efficiency (NREL)

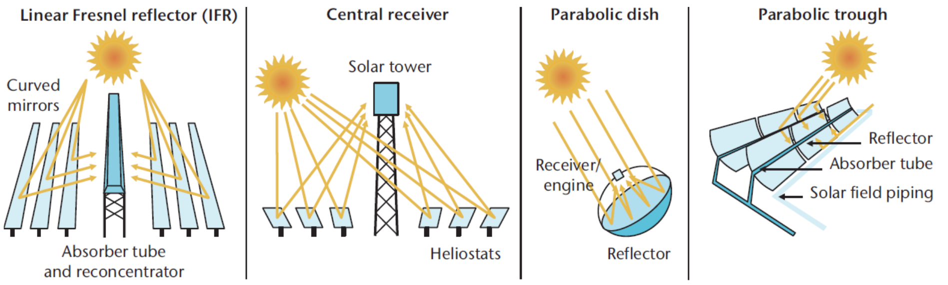

Figure 5. Main CSP technologies optical design and receivers (IEA)

- Novel optic designs are being considered, as well as new mirror materials and receiver designs. A few project are experiencing cheaper parabolic troughs of a laminated reflective components glued on aluminium sheets. Tower designers are also exploring choices relating to the type of receivers, the number and size of heliostats, the number of towers associated with each turbine, and the size and shape of solar fields.
- New thermodynamic cycles (supercritical steam cycles, Brayton cycles with a gas turbine or supercritical CO_2) can be envisioned. Higher working temperatures are key to increasing efficiency in converting the heat into electricity, reducing storage costs, lowering the cooling load and the performance penalty caused by dry cooling but on the other hand increasing the thermal losses of the receiver through convection and radiation which may require more expensive materials.
- Scaling up plants would allow reduction in the specific costs of turbines and BOP. Greater standardisation as markets mature would reduce development costs.

There are three dominant solar heating and cooling (SHC) technologies (REN21):

- glazed water collectors tubes (Figure 6) with evacuated tube water collectors (ETC) used mostly in China, while other significant SCH countries relying mainly on flat plate (FPC) collector systems
- unglazed water collectors used dominantly in USA for pool heating.

There are also many other constrains such as: limited area for installation and usage of solar energy systems (topography, geology), ecological social and political constraints, particularly in the underdeveloped countries of the Danube region as well as related economical constrains including energy market price, feed-in (incentive) and investment support policies.

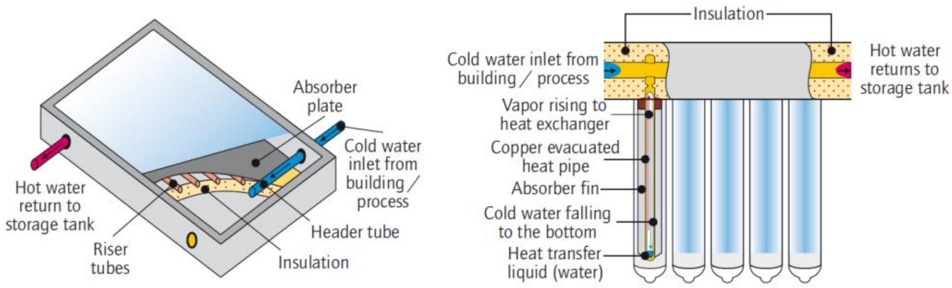

Figure 6. Flat plate collector (left) and evacuated tube collector (right) [10]

Due to high drop in PV modules and system investment costs over the last years in Europe (*EC JRC IET*) and favourable market price of electricity or PV electricity feed-in tariffs systems in most Danube region countries (REN21) (e.g. feed –in tariffs for Croatia [HROTE]) the most dominant installation up to date is in the on-grid PV systems. Currently (2014) small-scale on-grid PV system specific investment costs in Europe of 1400 €/kW (excluding VAT, because the differences in the various countries are too large) with operation and maintenance costs of 2% of investments results in the levelized costs of producing electricity (LCOE) at the average global irradiation of 1300 kWh/m^2 which is related to the situation in the most parts of the Danube region ranges from 9.18 to 13.65 €c/kWh over a financial lifespan of 20 years, depending on the return of the investment rates as presented in Table 1 (EC JRC IET).

In countries with market price higher the LCOE further installation of small-scale PV system can be expected while the incentive feed-in tariffs are necessary in less developed Danube region countries. For large scale PV system with lower specific investment of in average 1100 €/kW LCOE is even lower (at solar irradiation of 1300 kWh/m^2 from 7.21 to 10.73 €c/kWh respectively) but there are problems with high penetration of PV systems in ensuring the sufficient incentive fees for RES from the consumers of the electricity raising in electricity market price, which could result in socio-economic and political problems particularly in the less developed countries of the Danube region.

The off-grid PV systems although initially expensive can be very cost effective in remote locations where the only alternatives may be noisy, high-maintenance generators burning relatively expensive fuel, or extending the existing utility grid to the site (Pelin et al. 2014) which should be taken into consideration when accessing the solar energy potentials particularly in less developed countries/areas of the Danube region.

Table 1. LCOE of PV-generated electricity for residential systems with a system price of EUR 1400/kWp at annual generation of 1300 kWh/kWp/year and a financial lifetime of 20 years [7]

	Price (EUR/kWp)	LCOE Product (EURct/kWh)	LCOE Capital (EURct/kWh)			LCOE O&M 2% (EURct/kWh	LCOE Total (EURct/kWh)		
Return on investment		0%	3%	5%	10%		3%	5%	10%
PV module	560	2.15	0.66	1.14	2.45	0.86	3.67	4.15	5.46
Inverter	140	0.54	0.16	0.28	0.61	0.22	0.92	1.04	1.37
Balance of systems	270	1.04	0.31	0.55	1.18	0.41	1.77	2.00	2.63
Engineering, procurement & construction	300	1.15	0.36	0.61	1.31	0.47	1.97	2.23	2.93
Other (frees, permits, insurances...)	130	0.50	0.15	0.26	0.57	0.20	0.85	0.96	1.27
Total	1400	5.38	1.65	2.85	6.12	2.16	9.18	10.38	13.65

The European Union (EU28) supports a greater diversity of uses for solar thermal heating technologies than any other market. However growth contracted again in many countries, constrained by lower construction and renovation rates (due in large part to the economic crisis), pressure from solar PV and heat pumps (particularly in Austria, Germany, and France), and the reduction of support policies for solar heating (REN21). In the Danube region, Germany and Austria, the long-term EU leaders for total installations, both experienced marked declines in 2011, 2012 and 2013 (REN21). Croatia, for example, has a support policies for all RES based installation (*Environmenta*l…) enabling at least 40% support to installation costs but with limited funding cap resulting in slow growth of the SHC system installation.

Solar cooling (IEA 2012) as well as concentrated solar power (EC JRC IET) are still in the early stages of market development; costs need to be reduced through further development and increased deployment. In the Danube region firstly in the Mediterranean climate areas of the region. However, these technology should be considered for the future mid and long term energy usage in the Danube region.

Table 2. Comparison of ecological characteristics of PV modules of different technologies (Pelin et al. 2014)

	Waste disposal (direct environmental impact)	Energy consumption and CO_2 equivalent
Mono Si	High efficiency = less waste materials	High energy consumption = longer EBTP and CO_2 equivalent
CIS	Medium efficiency = more waste materials	High energy consumption = longer EBTP and CO_2 equivalent
Amorph Si	Smallest eff, shorter lifetime = the most waste, but low cell production temp results in smaller material use	Short EBTP and low CO_2 equivalent
High-eff mono Si	Even higher efficiency = even less watste materials	Short EBTP and high CO_2 equivalent
Poly Si	Similar efficiency as with mono Si	Shorter EBTP than mono Si, lower CO_2 equivalent, not containing toxic matter

Although solar energy systems are considered to have low carbon footprint during usage, there are important ecological constrains of particularly PV systems that need to be taken into considerations including extensive usage of land, long energy breaktrough period (due to high energy intensity of manufacturing solar energy systems compared to their low energy efficiency) and waste disposal after decomissioning. Table 2 presents the comparison of several PV modules technologies relating the energy breaktrough periods (EBTP) and waste disposal issues (Pelin et al. 2014).

In conclusion, when trying to assess the potentials of solar energy in the Danube region all presented teorethic, geographic, technical, economic and ecologic aspects and constrains should be taken into consideration with extreme caution following the technology development timeline and relating cost-benefit changes with adressing the RES related policies in the Danube region countries accorrdingly.

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Decreasing negative ecological impacts of PV farms: identification of suitable areas in Hungary

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Abstract: Solar photovoltaic is one of the most rapidly developing areas within the renewable electricity sector. Non-residential, utility scale PV farms became the largest segment with 37% of the European PV market in 2013, and they are expected to rise further. Hungary lags behind the trend, but it is expected that in the future investments will follow world tendencies. However, utility scale PV farms might have a negative impact on the local environment and ecological systems, such as habitat loss or fragmentation. Several studies argue that the planning phase, namely the location of the project and technologies used are the major influencing factors in these respects. This study aimed to identify degraded areas in Hungary which are likely to suffer the least adverse ecological impacts from PV farm installation. Localizing suitable areas was made by GIS analysis, combining Corine land cover, protected areas and other criteria. After the filtering process the study found that the major land cover of the remaining areas is agriculture (>99%) with additional landfills and mining areas. However, the selection of nitrate sensitive or inundation prone land can prevent conflicts with food production focusing the attention on impaired areas. Theoretical electricity generation potential was also estimated with the help of PVGIS datasets for these degraded sites. The overall potential shows that utility PV farms could supply Hungary's electricity consumption, and at the same time mitigate or avoid local ecological impacts. If agricultural areas are excluded, dump and mineral extraction sites could still significantly contribute to the electricity generation with a theoretical potential of 14–16 TWh.

Keywords: PV; ecological impacts; GIS; degraded areas, Hungary

1. Introduction

Photovoltaic (PV) applications are leading the investments in the renewable energy market together with wind power. In the European Union (EU), the Renewable Energy Directive aims to reach 20% overall energy share by 2020 from renewable energy sources (RES; 2009/28/EC. In response to this the number of PV investments rapidly increased in the EU, providing 29.7% (8 GW) of new power capacity installations in 2014, second largest share after wind power (EWEA). In Hungary, the share of PV in the electricity production is basically nonexistent, while Germany, a country in worst position when it comes to solar irradiation, provided around 6.5% of its electricity from PV in 2013(Súri et al. 2007, EPIA). The national renewable action plan (NREAP) aims to reach only 81 GWh electricity generation from PV by 2020, which would be still under 1% of the total expected electricity demand(MND). Still, even the NREAP acknowledges that with the constant development of the technology and decreasing prices, PV has great potentials, and actually can surpass the appointed goal.

Non-residential, stand-alone ground-mounted systems (PV farms) with the primary aim of electricity production became the largest segment in the European PV market with 34% share in 2013(EPIA). Although the manufacturing of PV panels requires rare and toxic materials, technological advances lowered the need for them, and as PV farms do not emit greenhouse gases during the operation phase, overall they have a positive impact on the global environment. However, they may cause adverse local ecological problems, such as habitat loss, decrease of biodiversity and alteration of local climate (Arvizu et al. 2011, Hernandez et al. 2014). Moreover, if the panels are not properly recycled and the supporting structures removed, the land may suffer further (Arvizu et al. 2011). Various studies started to explore these areas, and the latter problem seems to be solved as PV panels became 100% recyclable (Arvizu et al. 2011, Hernandez et al. 2014). As for the former point, all studies agree that proper planning, and through it the siting of the project is one of the key factors to mitigate negative impacts (Peschel et al. 2010, Wade 2011, Kelly et al. 2012, Gekas et al. 2002). Hitherto undisturbed areas are likely to suffer most, while degraded, low quality lands may even be positively influenced by the installation of PV panels.

To avoid the adverse impacts related to PV farms, this study aims to identify those areas in Hungary, which are the most suitable from the local ecological point of view for PV farm developments, i.e. degraded land. Such analysis was not carried out yet in Hungary, although choosing these areas for future installations would result in the least negative impacts. By using solar irradiation data, theoretical electricity generation potential will be also estimated for these areas.

2. Methods

2.1. Datasets used during the study Datasets used during the study

Dataset used	Source	website
– Hungarian administrative border	Global Administrative Areas	http://www.gadm.org/
– Corine land cover 2006 – Natura 2000 areas	European Environment Agency	http://www.eea.europa.eu/

Dataset used	Source	website
– Nationally designated areas		
– SRTM 30 (1 arc–second global) digital elevation	U.S. Geological Survey	http://earthexplorer.usgs.gov/
– Electric grid lines of Hungary – Hungarian road map – Excellent and good agricultural areas – Nitrate sensitive areas	Geographic Information system of Land Development and Integration [Országos Területfejlesztési és Területrendezési Információs Rendszer]	https://www.teir.hu/
– Floodplain map	Directorate of Water Management [Vízügyi Főigazgatóság]	https://www.vizugy.hu/
– Inundation map	Hungarian Catchment Management and Planning [A vízgyűjtő gazdálkodási tervezés honlapja]	http://www.vizeink.hu/
– Global yearly irradiation on horizontal and optimally-inclined surfaces	European Commission Joint Research Center, Insitute of Energy and Transport, PVGIS	http://re.jrc.ec.europa.eu/pvgis/

2.2. Analysis

The GIS analysis was carried out using ArcGIS 10.2 software. The projection of the final map product is ETRS89 LAEA (Lambert Azimuthal Equal Area, EPSG: 3035).

The filtering process was divided to three parts. In part one, the areas suitable for PV installations were identified. In part two, the selection was narrowed down to areas likely suffering the least negative impacts. During the installation of PV panels the vegetation has to be cleared and the soil leveled. Because of this any site richly vegetated prior to the installation will suffer negative impacts, with higher sensitivity of naturally forested habitats, grasslands, wetlands. Part two was aimed to find those areas which due to past/present human activities are already disturbed, so using them would result in less negative impacts. Finally, in part three, degraded lands were highlighted from the result of Part two. The main steps of the process are summarized in Figure 1.

In the final step (Step 9), by using the PVGIS database, the irradiation values of the degraded areas (Step 8) were obtained. Estimation of electricity generation (E, kWh) was made by using the following equation (Súri et al. 2007):

$$E = P_k \times PR \times G \qquad (1)$$

Where P_k is the unit peak power (assumed to be 1 kW_p), PR is the performance ratio (assumed the value of 0.75 [Súri et al. 2007]), and G is the mean of the yearly total irradiation on horizontal or optimally inclined plane of Step 9 products (kWh/m^2). The unit number of 1 kW$_p$ systems were calculated from the area of Step 8 products divided by the different system requirements (hybrid monocrystalline 5 m^2, monocrystalline 6.7 m^2, polycrystalline 7.2 m^2, thin film 10 m^2 for 1 kW$_p$ systems (Manap).

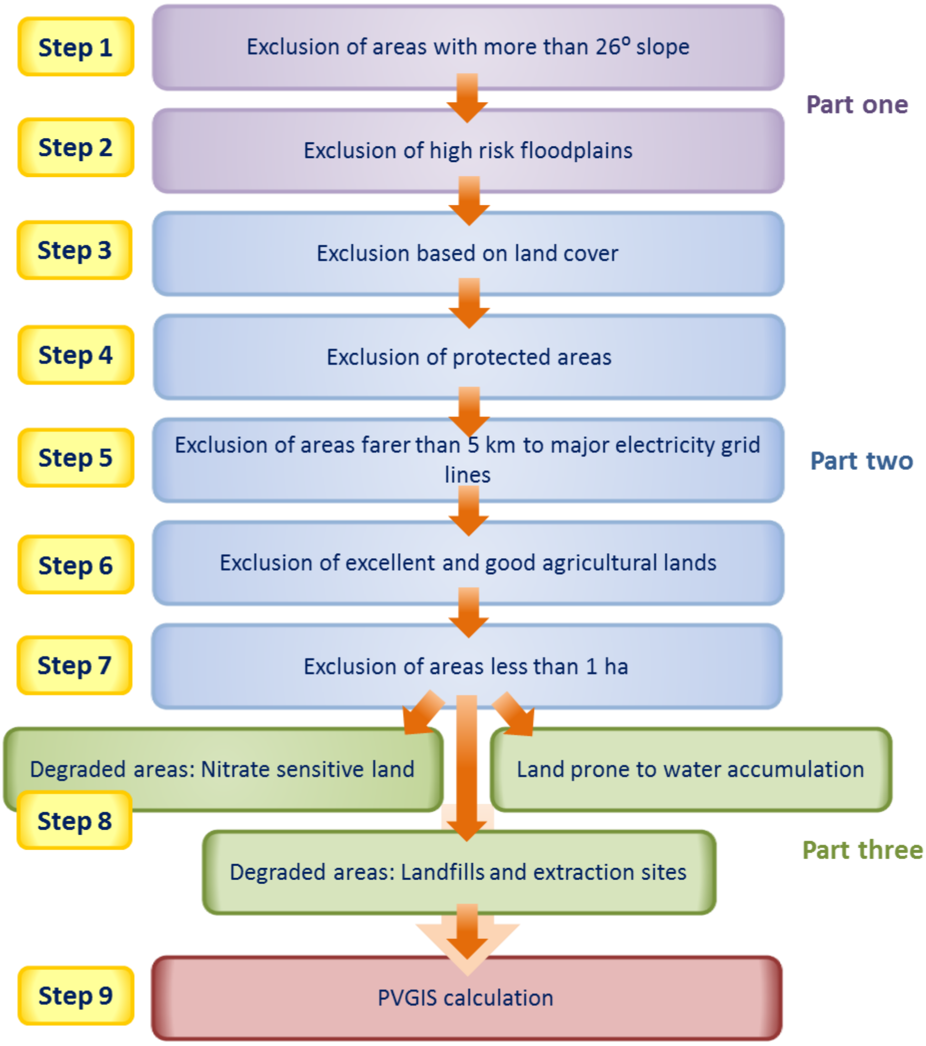

Figure 1. Filtering process of the analysis

3. Result and discussion

3.1. Part one, identification of suitable areas

This study did not take into consideration the economic costs of installation and operation; therefore no areas were excluded based on limited irradiance due to aspect or shading. Also land ownership was not taken into consideration. In Step 1, the physical possibility of installations was examined, through the degree of slope, derived from the SRTM-30 digital elevation model. Areas of higher slope than 26° (moderate and steep slopes 91 [Anbalagan 1992]) were excluded, due to construction difficulties and landslide hazards. In Step 2, areas associated with higher risk of natural catastrophes were excluded. Hungary has a low frequency and intensity of earthquakes, landslides and severe storms due to its geological position. However, flooding pose a risk at certain areas, which could destroy or damage PV modules. Therefore high risk flood plain areas were excluded.

3.2. Part two, exclusion of areas likely to suffer excess adverse impacts

The following steps refined the suitable areas based on the ecological impact, according to the order of importance. Step 3 excluded areas based on the Corine land cover map. Urban and urban green areas, industrial and construction areas, sports and leisure facilities which are not suited for utility scale PV plants were excluded. Forested areas, wetlands, natural grasslands, vineyards, tree plantations and complex cultivation patterns were also excluded, as using hitherto undisturbed and forested areas results in excess CO_2 emission due to the disturbance of the upper soil layer (Hernandez et al. 2014). Protected areas do not have to be 100% excluded, as the presence of PV panels can co-operate with habitat protection measures. Still, as this study used a conservative approach to avoid conflicts, Step 4 eliminated all National parks, Natura 2000 areas and other nationally designated areas.

Large scale PV farms not only impact their local surroundings, but lands have to be cleared to build access roads and transmission lines. After examining the Hungarian roadmap, it can be said that almost every area is reachable without the need of large scale construction. Therefore road connection was not considered as a limitation factor. However, transferring the electricity to major electric grid lines was a restrictive factor, hence areas farer than 5 km to major gridlines were excluded in Step 5. This step is highly conservative, as local gridlines can be also made suitable to supply the electricity into the grid.

Examination of the suitable areas after Step 5 revealed that the major land use form was agriculture (99%). To avoid conflicts between food production and electricity generation, the next step (Step 6) were aimed to exclude agricultural areas of high and good quality. Concentrating on lesser quality land from the point of view of agriculture can create an incentive for farmers to use or lease their land for electricity generation, if suitable policies and support programs are in place.

Step 7, the final step of second part, excluded areas smaller than 1 ha, being unsuitable for large scale installations.

3.3. Part three, highlighting ecologically degraded areas

The remaining areas (in total 11 923 km^2; Table 1) theoretically satisfied the search requirements of the study, namely they did not have high natural value in their recent state and were already subjected to anthropogenic disturbance. But to further refine the search, Step 8 was aimed to highlight those areas, which were influenced by other degrading factors. Identifying degraded areas is challenging without local field trips to characterize the environment. In the present study three parameters were used to select degraded sites. Two of these factors were based on major anthropogenic disturbances, while the third factor identified areas which are prone to yield damage, and therefore their agricultural value is lower.

Table 1. Remaining and excluded areas during the filtering process Degraded areas cover Dump and mineral extraction sites, nitrate sensitive land and areas prone to inundation

<table>
<tr><td colspan="2"></td><td colspan="2">km^2</td><td colspan="2" rowspan="7">additional area if nitrate sensitive good quality agricultural land is considered</td></tr>
<tr><td colspan="2">Hungarian land area (without water bodies)</td><td>91,152</td><td>Excluded area</td></tr>
<tr><td rowspan="10">after</td><td>Step 1</td><td>91,011</td><td>−141</td></tr>
<tr><td>Step 2</td><td>86,616</td><td>−4,395</td></tr>
<tr><td>Step 3</td><td>54,202</td><td>−32,414</td></tr>
<tr><td>Step 4</td><td>47,605</td><td>−6,597</td></tr>
<tr><td>Step 5</td><td>16,766</td><td>−30,839</td></tr>
<tr><td>Step 6</td><td>11,930</td><td>−4,836</td><td></td><td>1,695</td></tr>
<tr><td>Step 7</td><td>11,923</td><td>−7</td><td rowspan="2">Degraded areas from Step 7</td><td>1,694</td></tr>
<tr><td rowspan="3">Step 8</td><td>6,741</td><td>−5182</td><td>98</td></tr>
<tr><td>674,094</td><td colspan="2">ha</td><td>9,845</td></tr>
<tr><td>7,265</td><td colspan="2">Dump and mineral extraction sites (ha)</td><td>54</td></tr>
</table>

From the two anthropogenic factors, the first was based on land use, highlighting landfills and excavation sites, while the second identified nitrate sensitive areas, a likely result of damaging agricultural activities. The third factor was based on the inundation risk map, and selected those areas which fell into the medium or high risk category. Water inundation is relatively frequent event in Hungary, causing damage to farmers by destroying crops. By identifying areas subject to frequent inundation, the conflict between electricity and food production can be avoided, as abandoning agriculture in favor of electricity production on these lands could generate more stable income for farmers than yields. The united land area of these categories was 6741 km^2, 56.5% of the total areas after Step 7. Although high and good quality areas were excluded in Step 6, if they are considered in the case of nitrate sensitivity (35% of all high and good quality land), they could support an additional area of 9845 ha.

Dump and mineral extraction sites were also highlighted on their own right (7265 ha, 1% of total Step 8 areas), as these areas are the most altered and degraded due to human activities, often seriously polluted, and do not conflict with agriculture. German examples show that PV farm deployment can be united with prior revitalization measures and positively enhance the quality of the land and its surroundings by recreating grassland habitats (Peschel 2010). These areas, if found suitable after appropriate further monitoring by field trips and consultation of local authorities should be the most encouraged sites for PV farm installations.

3.4. Discussion and Step 9-PVGIS analysis

Step 8 highlighted degraded areas based on three criteria. The use of additional factors (e.g. heavy metal pollution, former military grounds) could have helped to further filter Step 8 products and reach higher accuracy. Data was not available for these at the time of the study, or field visits would have been required to survey them. There were also not enough data to distinguish abandoned and still operating dump and mineral extraction sites, limiting the findings of the study.

In Step 9, the area of Step 8 product and also separately the area of dump and mineral extraction sites were compared with yearly irradiation data on horizontal and optimally inclined surfaces from the PGVIS database to estimate how much electricity could be generated in the theoretical case of 100% module coverage (Figure 2). Four PV technologies were examined: hybrid monocrystalline, monocrystalline, polycrystalline and thin film, whose outputs can be seen at Table 2. The real world distances between the PV modules and the slightly changed area coverage in the case of inclined panels were not taken into account, thus the estimation is positively biased. In 2013 the net electricity demand of Hungary was 36,269 GWh [14]. Even if just 1% of the identified areas (67 km^2) would be used for PV farms, 18–41% of the electricity consumption could be covered, depending on the technology. Looking only at the dump and mineral construction sites and counting with 50% coverage, the contribution of PV farms could be between 9.7–22%.

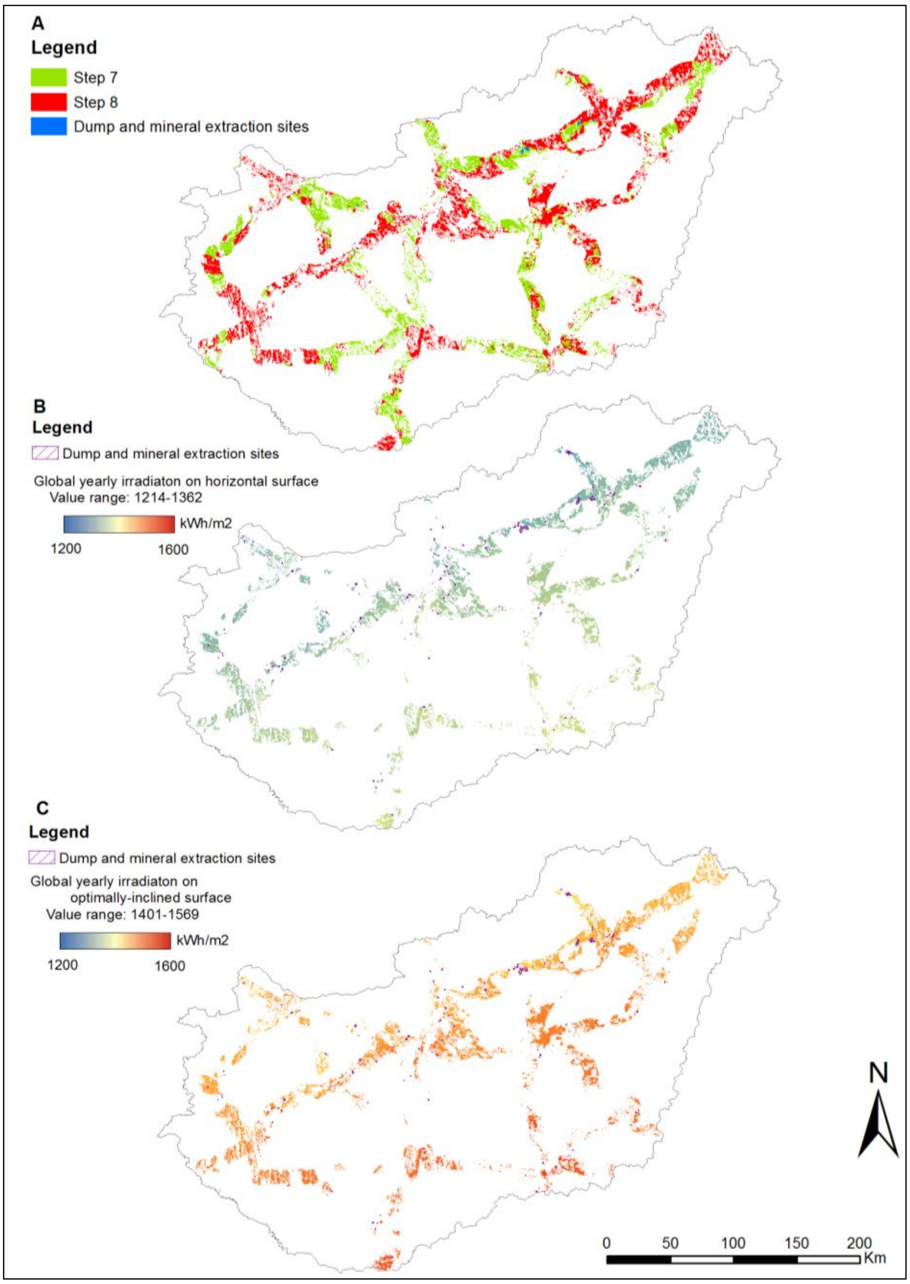

Figure 2. **(a)** Suitable areas after the selection; Step 7 contains Step 8, Step 8 contains dump and mineral extr. sites **(b)** and **(c)** Irradiation map of Step 8 areas, dump and mineral extr. sites highlighted

Table 2. Theoretical electricity generation based on PVGIS irradiation data
Dump, Min. stands for dump and mineral extraction sites

technology (m^2/kW_p)	TWh			
	Horizontal surface		Optimally inclined	
	Step 8 973.5 kWh/kW_p	Dump, Min. 960.75 kWh/kW_p	Step 8 1119.75 kWh/kW_p	Dump, Min. 1105.5 kWh/kW_p
hybrid monocrystalline (5)	1,309.16	13.98	1,507.88	16.03
monocrystalline (6.7)	976.99	10.43	1125.28	11.96
polycrystalline (7.2)	909.14	9.71	1047.14	11.13
thin film (10)	654.58	6.99	753.94	8.01

4. Conclusions

This study was limited to an overall country analysis, without the support of field trips and knowledge of local circumstances, which can further alter the suitability of an area. The study was aimed to show that there are sufficient possibilities to deploy PV farms and at the same time avoid the most negative local ecological impacts, by choosing degraded areas instead of ecologically valued natural lands. The results prove that this is achievable, especially if degraded agricultural areas are taken into consideration. Land use change of former agricultural areas to PV farms, if correctly installed and maintained, can have a positive effect on the local ecological interactions and at the same time contribute to global environmental advantages.

Utilizing urban areas by encouraging residential and non-residential rooftop installations or building integrated systems also have a large potential, without negatively influencing natural areas. Rooftops can provide 84.19–107.75 km^2 area countrywide (Munkácsy 2011, Kassai-Szoó 2014, KSH), slightly more than landfills and mining areas. Their theoretical potential ranges from 8–24 TWh (from horizontal thin film to optimally inclined hybrid monocrystalline, calculating with 1294 and 1489 kWh/year global irradiation for urban areas respectively). This number would be further reduced because of shading, sharing the area with solar collectors, public acceptance and technological difficulties. Developments in this direction should be highly supported, as they decrease the need for PV farm installations. Still, as the number of PV farms are expected to rise in the future, we should be prepared to minimize their local ecological impacts. One of the key factors to do so is choosing the appropriate site, which the study intended to highlight.

Acknowledgments

I would like to express my gratitude to Tsuyuzaki Shiro and the German Federal Environmental Foundation who supported my work. I am also grateful for Takeshi Kuramochi and Kazuhisa Koakutsu, as the research carried out with their help inspired the idea of the current study.

Conflict of Interest

The author declares no conflict of interest.

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Cost-Benefit Analysis of Different Photovoltaic Systems in Croatia, Hungary, Serbia and Slovenia

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Abstract: The aim of paper is evaluation of different categories and different solar cell technologies of photovoltaic systems. Therefore, two types of user categories are considered: solar home system users (i.e. small scale system) and energy producer investors (i.e. large-scale system) as well as five modules technologies, more specifically: monocrystalline, polycrystalline, CIS, amorphous and high-efficiency monocrystalline. In order to perform cost-effectiveness calculations for four countries in Danube region (Croatia, Hungary, Serbia and Slovenia) the technical data and relevant prices were based on measurements, regulations as well as available web-database.

Keywords: cost-benefit analysis, PV systems, net present value, investment, specific profit

1. Introduction

In the past 10 years, photovoltaic systems (PV systems) have experienced significant growth, due to the intensive growing of the global PV industry and important decreasing of the PV module cost. By the end of 2012, the cumulative-installed PV capacity overtook more than 100-gigawatt installed power, reducing more than 53 million tons of CO_2 per year (Masson et al. 2013). The penetrations of PV-systems in power system generally are developing in two directions (de Brito et al. 2011). The first direction is related to small-scale PV systems installed on the roof of houses and buildings. The second direction is belonged to large-scale grid-connected PV systems.

Researchers have been conducted on the economic evaluation of different scale PV systems to understand the impact of different parameters to investment (Meisi 1993, Liyanage–Rajakaruna 2011, Mao–Jin–Xu 2014). The most of these papers are mainly concentrated on the cost-benefit analysis of different PV system regarding scale size which is determined by national legislative (Muneer–Bhattacgarya–Canizares 2011, Suh–Kim–Kwon 2012, Šljivac et al. 2014).

The paper introduces the study of two research teams of different research profile. In the paper it is tried to research regional impact of different PV system in Drava region related to different module technology. Therefore the authors of the paper working together on the bilateral project of cross-border Hungary-Croatia program in the field of renewable energy sources obtained detailed cost-benefit analysis of chosen PV systems in order to develop an optimal photovoltaic system for cross-border region (Pelin et al. 2014). The small-scale PV system was installed in Osijek, Croatia and regional impact is studied for Pécs, Hungary. The calculation is extended for Novi Sad, Serbia and Maribor, Slovenia in this paper. It can be noticed that Osijek, Pécs and Novi Sad have the similar intensity of solar radiation, whereas Maribor, Slovenia have better conditions regarding solar radiation.

2. Model and evaluation methodology

In the aspect of set up reliable model, one of main factors in determining of the average solar radiation data at specific location is usage solar database (REGPHOSYS 2014). Although, PVGIS evaluation of solar radiation is very precise, the average annual energy production is verified on installed PV system at location in Osijek by measurements for two months and all measurement data are recorded in database (PVGIS 2012). The annual sum of global irradiation in Pannonian part of Croatia, Serbia and Hungary is about 1300 kWh/m^2 and for Slovenia this value is approximately 1500 kWh/m^2 (PVGIS 2012).

The next specificity regarding installed PV system was choice of the particular PV modules of different types of semiconductor materials (i.e. different technologies). The following photovoltaic modules were installed at the roof of Faculty of Electrical Engineering building in Osijek, Figure 1.

1. monocrystalline technology; BISOL, BMO250, 250W,
2. pokycrystalline technology BISOL, BMU250, 250W,
3. CIS technology; SOLAR FRONTIER, SF-150, 150W,
4. amorphous technology; MASDAR MPV100-S, 100W,
5. high-efficiency monocrystalline technology PANASONIC, VBHN2450SE10, 245W.

For the purpose of the technical evaluation of the PV system, the choice of particular scale of photovoltaic system is done. Two types of PV systems are chosen regarding researching feed-in tariffs in the Croatian and Hungarian legislation and then the study is extended for Serbia and Slovenia:

– *solar home system users*: It is small scale PV system. In this case, solar panels are installed on the roof structure of houses (mini home power plants), by which the complete photovoltaic system attains capacity of the order of 4 kW.

In this category of users, regulations set forth the stipulation that only surplus generated over energy demand can be fed into the central network in Hungary. For Serbia, Croatia and Slovenia the situation where the PV users must by own consumption from central network after the selling of own energy production was analysed.

– *energy investors:* This category involves big business enterprises which establish large-scale PV parks and feed electric energy produced by them into the central mains system which very well is corresponded to large-scale PV system. Power plants operated by such enterprises have an output of several hundred kilowatts, whereas, Hungarian regulations set forth 500 kW as maximum installed capacity. Since in Croatia the upper limit to solar power plant capacity is 300 kW, calculations for both countries were performed with 300 kW (Kovács and Suvák 2014).

Figure 1. Installed PV modules on the roof in Osijek

A research is based on a two-dimensional model, which, on one hand operates by the application of PV modules of varying sizes and types and, on the other hand, also researches a range of diverse application techniques. Our objective is to enable the economically most appropriate technology to be selected from among possible alternatives along the two dimensions. In order to perform cost-effectiveness calculations a considerable number of data is needed, Table 1. The model data are listed into two categories: technical data and technical parameters as well as the relevant prices for chosen equipment of PV system. The calculations were partly based on the measurement results and experience obtained on the PV-system installed in the Osijek (capacity, life-cycle), and on the other, on the data (costs) provided by the business undertakings executing the construction of photovoltaic systems, as well as on the set of data supplied by energy authorities.

Table 1. Dataset of the Model

Denomination of data	Applied Source:
Technical data, parameters	
Average annual energy production	Measurement results by the University of Osijek, ETFOS
PV panel capacity	Technical specifications
PV panel unit price	Price offers
Inverter unit price	Based on the Photon GmbH dataset (Photon GmbH 2014*)*
Panel life-cycle, capacity reduction	Based on the study by Jordan and Kurtz (2013)
Inverter lifetime	Based on technical parameters 12.5 years
System installation costs	Practical experience
Cost charged for central network connection	Price fixed in Croatia (223 EUR/kW) and Slovenia (130 EUR/kW) while no such cost exists in Hungary and Serbia
Internal system, cost of system construction	Experience-based determination (by business undertakings executing construction) of 20% of the cost incurred for the complete system
Annual maintenance costs	Experience-based determination (by business undertakings executing construction) of 15% of annual revenue
Price-type data	
Retail price of electricity	Electricity price trends, regulations
Electricity transmission rates	National legal regulations, directives (HR Official Gazette 63/2012; Vlada Republike Srbije, 99/2009; MEKH 2014; Borsen 2014)
Other data	
Annual inflation rate	Long-term forecasts of Eurostat, OECD and national banks (HR: 0.5%; HU: 0.4%; SLO: 0.5%; SRB: 1.6%)
Real interest rate	Long-term forecasts of Eurostat, OECD and national banks (HR: 5%; HU: 5%; SLO: 2.5%; SRB: 6.5%)
Whole investigation period	According to long-term vision 25 years

Source: Kovács and Suvák 2014.

2.1. Evaluation Methodology

In the interpretation of the described set of data, our model allows for the performance of several economic calculations, out of which hereby we use four indicators to enable us to evaluate the panel-choice alternatives for electricity producers (Kovács and Suvák 2014).

Eliminating the shortcomings of the real profit indicator (it assumes zero inflation) we used the *inflation-adjusted or deflated profit*: it eliminates the drawback implied by the above indicator, more specifically, it is suitable for long-term investigations and its calculation allows for the comparison of not only specific years but also a period of several years.

$$\Pi_t^D = \frac{\Pi_t}{(1+i)^t} \tag{1}$$

$$T\Pi^D = \sum_{t=1}^{n} \Pi_t^D \quad \text{(cummulated form)} \tag{2}$$

where:
Π_t – total profit
TR_t – Total income for the year
TC_t –Total expenditure for the year
p – Acceptance price
Q_t– Generated electrical energy surplus, amount fed in the mains network
c_t – Annual energy demand
P – Consumer electricity price
t – Number of years (1–25)
i – inflation rate (Kovács and Suvák 2014)

The *net present values* (NPV): It indicates the value of a given investment in year "t". It is defined as sum of the present values (PVs) of incoming and outgoing cash flows over a period of time. Incoming and outgoing cash flows can also be described as benefit and cost cash flows, respectively. We can talk about return on investment if it results in 0 NPV. This indicator extends the previous indicator by the mathematical operation of deducting the sum invested in year 0 from the inflation-adjusted profit (Talavera et al. 2011; Kovács and Suvák 2014).

$$NPV = PV_{\,0} - C_0 \tag{3}$$

$$NPV = \sum_{t=1}^{n} \frac{\Pi_t}{(1+r)^t} - C_0 \tag{4}$$

where:
PV_0 – Present Value
C_0 – Investment value
r- Real interest rate

Levelized cost of electricity (LCOE): The another modified formulate of LCOE[1] is used. In this case, it indicates the ratio of total expenses and income/savings in a longer time period. Therefore, it can be interpreted as a type of cost-effectiveness, cost-benefit indicator (IRENA 2012, Pawel 2014).

$$LCOE_m = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + O_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t + S_t}{(1+r)^t}} \qquad (5)$$

where:
LCOE – Levelised Cost of Electricity Generation
I_t – Investment cost
M_t – maintenance cost
O_t – Other costs
E_t – income from feed into network
S_t – Cost benefits generating from self-supply (IRENA 2012; Kovács and Suvák 2014).

3. Technical and economical evaluation of a 4 kW solar home system users

Regarding annual capacities, for an average family house, self-consumption from the energy generated is defined in 4.430 kWh (PORTFOLIO.HU). The incentive price which is taken into calculation for Croatia is 0.25 EUR/kWh, 0.21 EUR/kWh for Serbia, 0.42 EUR/kWh for Slovenia and 0.11 EUR/kWh for Hungary (HR Official Gazette 63/2012, Vlada Republike Srbije, 99/2009, MEKH 2014, Borsen 2014). This is the point where there is a sharp boundary between the Croatian, Serbian and Slovenian and the Hungarian relations. For all three countries the solar electricity transmission prices are considerably higher than electricity consumer prices, consequently, it is more profitable to sell as much solar electricity as possible at the incentive prices (i.e. there is a possibility to sell all the produced energy). As opposed to this, in Hungary feed-in-tariff, which is lower than consumer price (85% of the latter), discourage investments, also legal regulations stipulate that only surplus remaining after the use of own consumption can be fed into the system.

Results of the cost-benefit analysis and simulation for period of 25 years are given in Figure 2. analysed countries.

[1] In the basic formulate of LCOE, the net present value of investment and other costs is the numerator and the yearly electricity production is the indicator's denominator, and the LCOE shows the unit cost of PV system in EUR/kWh [20]. In our modified formulate of the LCOE, the denominator is a net present value of all incomes of PV-system.

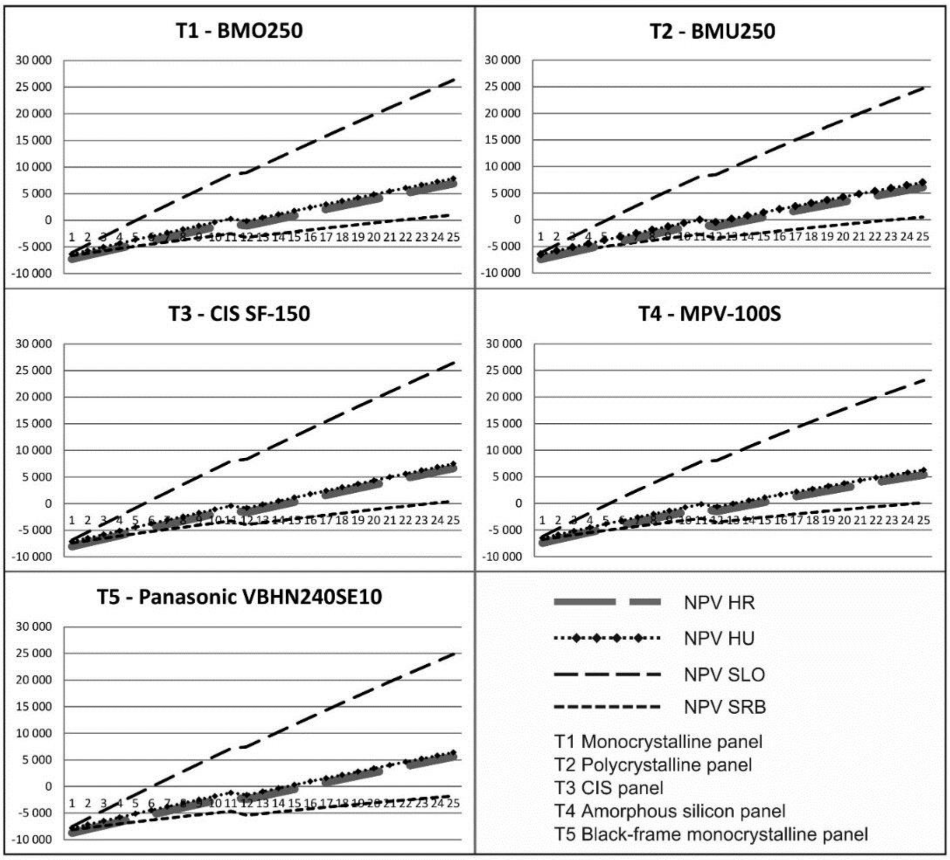

Figure 2. The net-present value regarding five technologies for Croatia, Hungary, Slovenia and Serbia
Source: Calculations based on Kovács and Suvák 2014.

The shortest payback time can be attributed to monocrystalline panels, Figure 2. In this context the best choice for solar home system user is the monocrystalline module (T1). In terms of the unit cost indicator, it is also the monocrystalline technology that is considered to be the most appropriate investment in all countries. On the Croatian side, in a timeframe of 25 years, all the cost factors related to this technology account for 68.7% of the income, while, due to lower-level revenue opportunities, this percentage value reaches 65.7% in Hungary. In contrast, black-frame panels (T5) amount to as much as 77.2% of revenues and have cost factors constituting 78.0% of the income as shawn in Table 2. In relation to polycrystalline and amorphous silicon panels, the order of priorities also shows a discrepancy between the two countries. By comparing all four countries, the long payback is calculated for Serbia, then for Hungary, Croatia and the best result are calculated for Slovenia due to the highest incentive price.

The specific investment cost and profit for all 5 module technologies are shown in Table 3. According to the results, the most expensive investment is calculated for Panasonic modules (2345 EUR/kW) in Croatia. The low specific investment is obtained for monocrystalline technology (1767 EUR/kW) in Serbia and Hungary. The most profitable technology is CIS technology (8953 EUR/kW) for Slovenia.

In context of profitability, the countries are very different, but the investment costs for different technologies are similar. The Hungarian and Serbian specific investment data are similar, and the Slovenian values are better than Croatian. The specific profit's country ranking is the following: Slovenia, Croatia, Hungary and Serbia.

Table 2. The unit price indicators regarding solar home system users for all countries

$LCOE_{T1, HR}$	0.687	1.	$LCOE_{T1, HU}$	0.657	1.	$LCOE_{T1, SLO}$	0.290	1.	$LCOE_{T1, SRB}$	0.780	1.
$LCOE_{T2, HR}$	0.696	2.	$LCOE_{T2, HU}$	0.668	2.	$LCOE_{T2, SLO}$	0.295	2.	$LCOE_{T2, SRB}$	0.828	2.
$LCOE_{T3, HR}$	0.737	4.	$LCOE_{T3, HU}$	0.718	4.	$LCOE_{T3, SLO}$	0.317	4.	$LCOE_{T3, SRB}$	0.840	3.
$LCOE_{T4, HR}$	0.697	3.	$LCOE_{T4, HU}$	0.669	3.	$LCOE_{T4, SLO}$	0.295	3.	$LCOE_{T4, SRB}$	0.867	4.
$LCOE_{T5, HR}$	0.780	5.	$LCOE_{T5, HU}$	0.772	5.	$LCOE_{T5, SLO}$	0.340	5.	$LCOE_{T5, SRB}$	1.089	5.

Source: Calculations based on Kovács and Suvák 2014.

Table 3. The specific investment cost and profit for five different PV modules (EUR/kW)

PV system economic characteristcs	Mono Si Bisol BMO250	Poly Si Bisol BMU250	CIS Solar Frontier SF-150	Amorph Si Masdar MPV-100S	High-eff mono Si Panasonic
Specific investments – *SLO*	1,897	1,930	2,092	1,933	2,260
Specific investments – *SRB*	1,767	1,800	1,961	1,803	2,129
Specific investments – *HU*	1,767	1,800	1,951	1,803	2,112
Specific investments – *HR*	1,990	2,023	2,174	2,026	2,345
Specific profit in 25 years – *SLO*	8,732	8,353	8,953	7,973	8,732
Specific profit in 25 years – *SRB*	2,283	2,189	2,338	2,095	1,949
Specific profit in 25 years – *HU*	2,933	2,823	3,003	2,704	2,936
Specific profit in 25 years – *HR*	2,956	2,848	3,051	2,734	2,991

Source: Calculations based on Kovács and Suvák 2014.

4. Technical and economical evaluation of a 300 kW PV system for energy investors

The incentive price which is taken into calculation for Croatia is 0.20 EUR/ (kWh), 0.16 EUR/ (kWh) for Serbia, 0.42 EUR/ (kWh) for Slovenia and 0.11 EUR/ (kWh) for Hungary HR Official Gazette 63/2012, Vlada Republike Srbije, 99/2009, MEKH 2014, Borsen 2014).

In the case of energy producer investors profit indicators – although with significant differences – show the same ranking, namely CIS panels with the highest costs and with the lowest amortisation are the most favourable and the amorphous one is the least profitable.

Considering net present values, no significant difference between user dimensions can be demonstrated, Figure 3. Similarly, for solar energy production-based power stations, the shortest payback time and the highest net present value are ascribed to monocrystalline modules technology. However, in view of this indicator, rankings are exactly the same in all countries; which appears in the sequence of T1, T2, T4, T3, T5.

Unit cost calculations produced relatively more interesting results since the order of rankings show, Table 4. The differences both in terms of countries and in user dimensions are recognised. In Croatia, Slovenia and Serbia, regarding energy generating and investment-focused installations, the smallest unit cost is ascribed to monocrystalline panels, whereas in Hungary the smallest unit cost is attached to amorphous silicon panels. However, in Hungary the order of rankings is blurred inasmuch as the difference between the best and the worst values does not reach 0.5%. Therefore, for energy investors in Croatia, Serbia and Slovenia, the installation of monocrystalline modules it provided to be the best alternative, as a contrast, in this respect such unambiguous statement cannot be made in Hungary.

The shortest payback time can be attributed to monocrystalline panels, Figure 3. and Table 4. So, the lowest payback time is obtained for Slovenia, 3.9 years, then for Croatia 7.2 years, then goes Serbia with 7.35 years and Hungary at last with 12.6 years.

The specific investment cost and profit for all 5 module technologies are shown in Table 5. According to the results, the most expensive investment is calculated for Panasonic modules (1883 EUR/kW) in Croatia. The low specific investment is obtained for amorphous technology (1897 EUR/kW) in Hungary. The most profitable technology is CIS technology (8701 EUR/kW) for Slovenia.

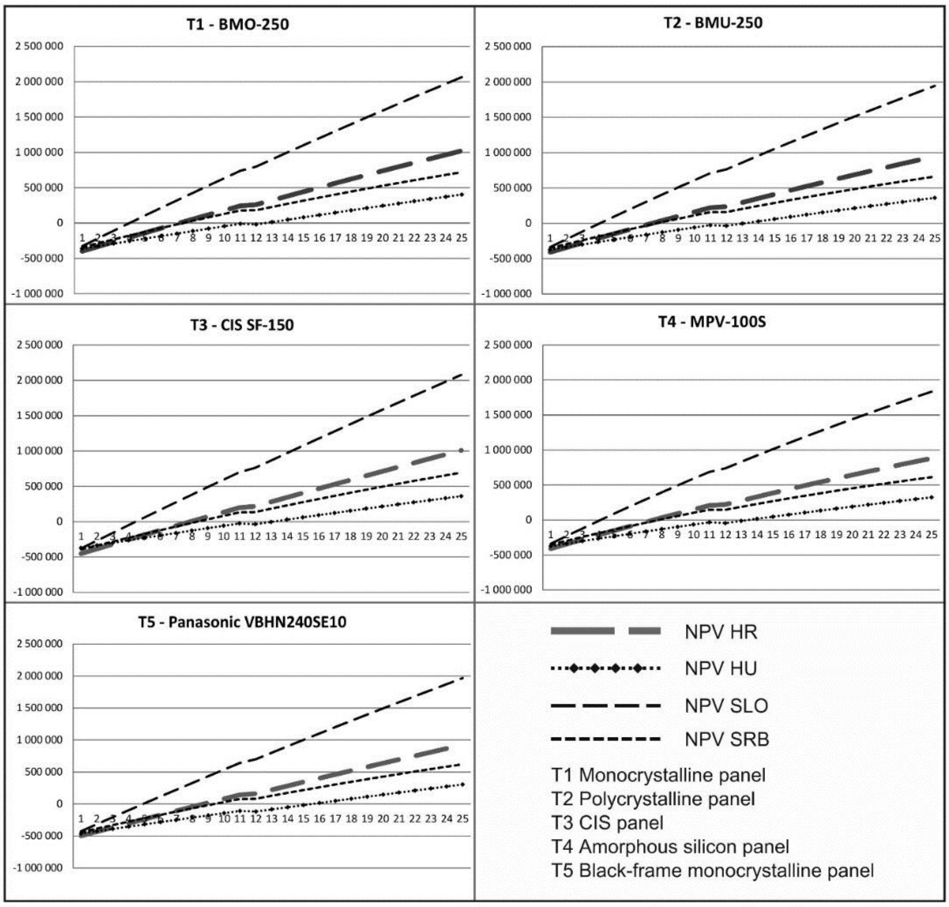

Figure 3. The net-present value regarding five technologies for Croatia, Hungary, Slovenia and Serbia

Source: Calculations based on Kovács and Suvák 2014.

Table 4. The unit price indicators regarding PV system for energy investors for all countries

LCOE $_{T1, HR}$	0.568	1.	LCOE $_{T1, HU}$	0.7592	5.	LCOE $_{T1, SLO}$	0,340	1.	LCOE $_{T1, SRB}$	0,574	1.
LCOE $_{T2, HR}$	0.574	2.	LCOE $_{T2, HU}$	0.7542	2.	LCOE $_{T2, SLO}$	0,344	2.	LCOE $_{T2, SRB}$	0,587	2.
LCOE $_{T3, HR}$	0.599	4.	LCOE $_{T3, HU}$	0.7542	3.	LCOE $_{T3, SLO}$	0,361	4.	LCOE $_{T3, SRB}$	0,641	4.
LCOE $_{T4, HR}$	0.574	3.	LCOE $_{T4, HU}$	0.7541	1.	LCOE $_{T4, SLO}$	0,344	3.	LCOE $_{T4, SRB}$	0,588	3.
LCOE $_{T5, HR}$	0.627	5.	LCOE $_{T5, HU}$	0.7543	4.	LCOE $_{T5, SLO}$	0,380	5.	LCOE $_{T5, SRB}$	0,700	5.

Source: Calculations based on Kovács and Suvák 2014.

Table 5. The specific investment cost and profit for five different PV modules (EUR/kW)

PV system economic characteristcs	Mono Si Bisol BMO250	Poly Si Bisol BMU250	CIS Solar Frontier SF-150	Amorph Si Masdar MPV-100S	High-eff mono Si Panasonic
Specific investments – *SLO*	1,460	1,494	1,636	1,496	1,790
Specific investments – *SRB*	1,330	1,364	1,506	1,366	1,660
Specific investments – *HU*	1,330	1,364	1,506	1,366	1,660
Specific investments – *HR*	1,553	1,587	1,729	1,589	1,883
Specific profit in 25 years – *SLO*	8,486	8,118	8,701	7,749	8,486
Specific profit in 25 years – *SRB*	3,871	3,711	3,964	3,551	3,871
Specific profit in 25 years – *HU*	2,059	1,981	2,108	1,897	2,061
Specific profit in 25 years – *HR*	4,109	3,955	4,201	3,798	4,103

Source: Calculations based on Kovács and Suvák 2014.

5. Conclusions

The photovoltaic system with technically the best high efficiency mono-crystalline modules is indeed the one with the highest and therefore least favourable specific investments, regardless of the system size.

The system with the multilayer Copper-Indium-Selenium (CIS) modules, which has moderate specific investments and medium efficiency with regard to the tested technologies, displays the highest expected electricity production as a result of the use of different materials and better usage of the sun radiation spectrum (confirmed additionally by measurement), as well as by far the lowest expected annual capacity loss results, along with the highest expected long-term specific profit during the 25-year (duration of module warranty) lifecycle of the photovoltaic system. Thus, based on the techno-economic cost-benefit analysis, this technology would be the one to recommend among the five tested technologies.

Additionally, amorphous silicon is the technology that, due to its lower efficiency, should result in lower specific investments, but its lower market availability results in similar specific investments as for the crystalline silicon technologies. Because of the significantly higher expected capacity loss during its lifecycle, it results in the smallest expected deflated profit.

The cost-benefit analysis also resulted in a lower expected investment cost for larger systems (up to 300 kW), but due to the respective lower incentives compared to the small systems (up to 10 kW) it still results in lower expected specific deflated profit.

The model uses a large variety of economic and technical data, Table 1, so the outcomes are relevant for a specific time when these data were valid. However, the technology is in constant change, as well as the renewable energy policy all over the world and in the chosen countries. To make estimations for hypothetical situations caused by the change of the circumstances, a sensitivity analysis was carried out for the most important input data. An array of possibilities for reasonable economic and efficiency modifications has been investigated. The increase in the consumer prices of energy, the decrease in transmission prices and the impact of technological development were examined ceteris paribus. According to the results the model is sensitive to each of the three changes investigated. The pay-back time depends on these data-changes as follows: technological development and the increase in consumer prices exert positive influence by decreasing payback time since technological progress results in the reduction of annual costs and the increase in consumer prices entails savings generated from self- consumption. As opposed to this, the decline in transmission prices induces lower levels of annual revenues, i.e. it results in prolonged payback time.

Acknowledgments

This research has been founded by the REGPHOSYS project of the Hungary-Croatia IPA Cross-border Co-operation Programme 2007–2013 (HUHR/1101/2.1.3./0002), co-financed by the European Union in the framework of the aforementioned programme. A part of this work has been supported under OTKA - Hungarian Scientific Research Fund grant #NK 104985 (New driving forces of spatial restructuring and regional development paths in Eastern Europe at the beginning of 21st century).

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Applying Solar Energy for Water Heating – a Case Study at a Secondary School in Croatia

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Abstract: The paper describes an example of solar energy usage for water heating. Solar energy is suitable for application in Croatia, considering a number of sunny days and high average temperatures in Croatia. Described weather conditions results in high efficiency of heating systems based on solar energy. The most important advantage of solar energy heating, in comparison to other heating systems, is in environmental sustainability. Solar system, applied for water heating, can save an average of 50–60 % annual energy needs. During almost all the year (except winter conditions with extra low temperatures), additional conventional water heating systems work on a minimum power, thus eliminating harmful emissions (CO_2), which occur as a by-product from burning conventional fuels. By transforming solar energy to water thermal energy, considerable financial resources are saved. Investment's repayment of this solar heating system can be observed through the reduction of energy consumption (e.g. natural gas) during the preparation of consumable hot water (CHW) and/or space heating.

Key words: solar thermal energy, heating system, savings, emissions

1. Introduction

There are many energy sources applied by mankind but renewables are our future. Solar energy is one of the base points of renewables because of its natural transformations in other renewable energy sources indirectly used by engineers to produce applied energy, such as wind energy, water energy, biofuels, energy of tide, sea currents and waves. Also, solar energy is directly transformed to produce electricity (PV distributed generation) and heating energy. Today, climate changes have reached concerned level caused by burning of fossil energy sources which produce harmful emissions of greenhouse gas (CO_2). Mankind vision of possible ways to lead out of this crisis is based on returning to use less detrimental energy sources.

The main energy sources during last two centuries were non-renewable energy sources such as coal and petroleum.

The main problems of non-renewable energy sources are their limited quantity and great amount of environment pollution which very likely causes global temperature increment on the Earth. Renewable energy sources are long term sustainable but with other technical problem – unbalance of energy generation and energy consumption time scheduling.

Renewable sources have an enormous potential, but the present technological development does not make it possible to rely only on these sources. Renewable energy, excluding hydropower, still meets a negligible share of total energy demand. In the near future, this share should be significantly increased due to the known reasons related to non-renewable sources. The Sun delivers to the Earth 15.000 times more energy than mankind's needs. Also, the world distribution of energy consumption is unequal – areas (continents) with high density of energy generation and consumption and areas with neglected energy consumption although there are energy needs. It implies that renewables can and must be better used and that our civilisation should not be depended only on fossil fuel energy. The development of renewables is very important for several reasons:

a) Renewables play an important role in the reduction of CO_2 emission into the atmosphere. This green policy has been accepted by the European Union and Croatia as well.
b) Increased share of renewables improves energy system sustainability. Also, it improves energy supply security by reducing dependence on imported energy resources and electricity.
c) It is expected that renewable energy sources to become economically competitive regarding the conventional energy sources in the medium to long term period.

Several technologies, especially wind energy, small hydro power plants, biomass energy, geothermal energy and solar energy are economically competitive by feeding tariffs usage. It guaranties to attract new investments in renewable energy sources development.

The intensity of solar radiation comprises consists of different wave lengths. The most part (99%) of the solar radiation are in range of wavelengths from 0,275 μm to 4,6 μm. Radiation that reaches the Earth surface consists mainly of invisible ultraviolet range (0,12–0,4 μm) and it is represented by 9%, of the visible range (0,4–0,75 μm) represented by 41,5 %, then invisible infrared range (greater then 0,75 μm) represented by 49,5% of the global energy of solar radiation Knezevic–Zidar (n.d.). Due to the Earth spherical shape, its elliptical orbit around the Sun, the inclination against orbital plane and rotation around its own axis, energy coming from the Sun is not uniformly distributed on the surface of the Earth and it changes year-round and during the day. In fact, the Sun's altitude on the horizon is changed, which implies the change of the solar radiation angle on the ground, furthermore, the day length and finally the distance between the Earth and the Sun. As all these changes are well known, solar radiation could be calculated at any period of the day or at any position of the upper atmosphere boundaries. The total solar radiation on the Earth surface consists of direct, diffused and reflected radiation. The sum of these radiation components form the total radiation, presented on Figure 1.

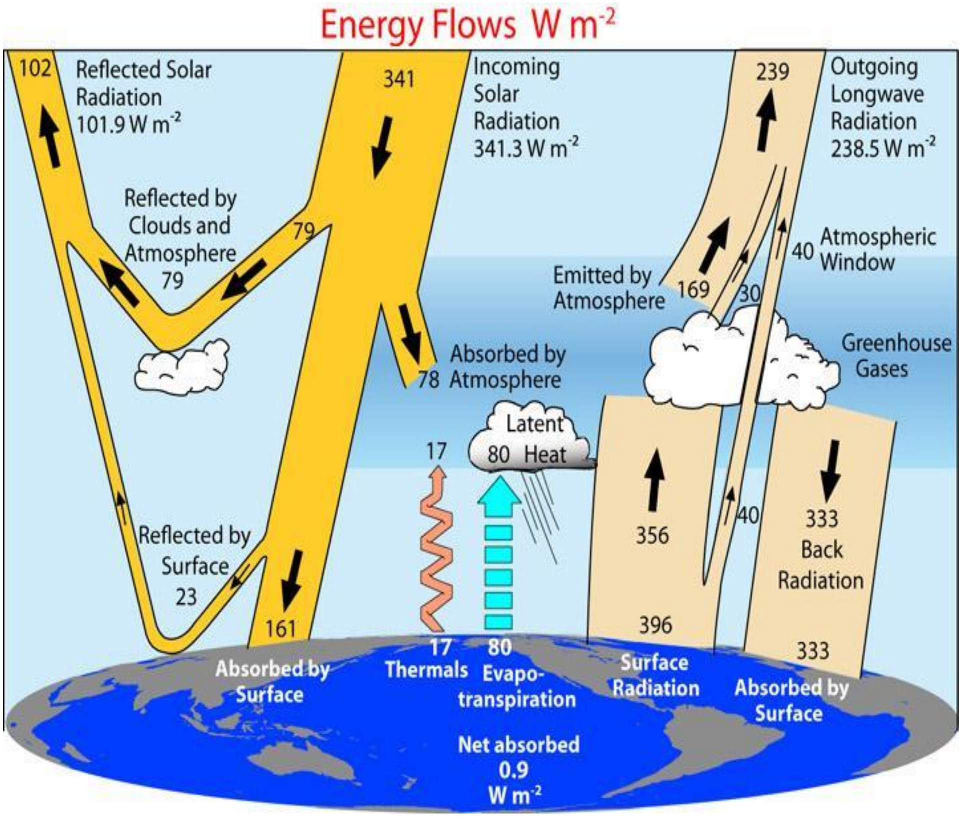

Figure 1. Solar radiation on the Earth (Google images…)

2. Solar radiation in the south east Europe (Danube Region)

Approximation of the available solar potential for a certain location is facilitated by the data bases (for example PVGIS, NASA, Meteonom database), which contain data on the solar radiation intensity, ambient temperature, average daily temperature etc.

All given data from data bases have been calculated based on satellite measurements of extraterrestrial radiation above the Earth atmosphere.

Most often used tool for cost-effective exploitation of solar energy is an irradiation maps, which show the level of irradiation of a certain areas on the Earth. Thus, by observing the irradiation map of south – east Europe (Figure 2), it is obvious that the total annual amount of solar radiation increases from the northwest to the southeast, which is in accordance with the latitude change. According to the PVGIS (Photovoltaic Geographical Information System) data, the optimal annual angle is also changed. It should be noted that the optimal angle changes day by day during the year due to a seeming Sun movement (PVGIS).

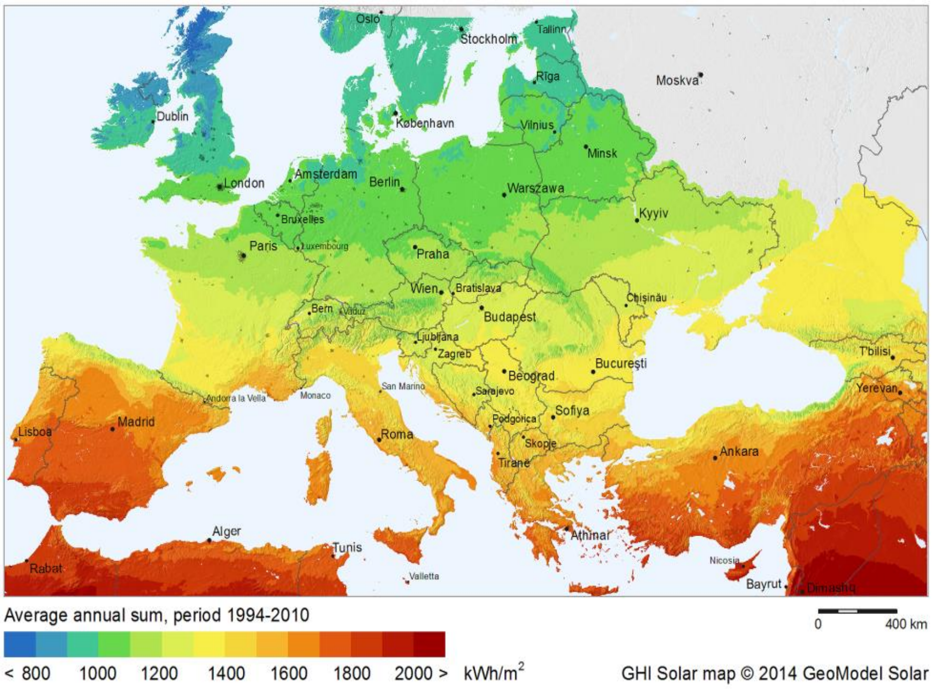

Figure 2. Total annual irradiation on horizontal plane (PVGIS)

3. Solar heating energy system

3.1. Collectors of solar radiation

Collectors that directly convert the energy of solar radiation into thermal are presently the simplest and the most applicable devices for a wide-ranging usage from the technical, technological and economic standpoint. They could be roughly classified into two categories, depending on the temperature the operating medium could achieve:

- low-temperature collectors – this group includes all collectors, which have the temperature of the operating medium up to 200°C, but usually it is bellow 100°C;
- high-temperature collectors – they use bigger surfaces for focussing on a smaller surface whereby, very high temperatures are achieved, depending on the construction, even up to several thousand °C.

Collector construction has resulted in various approaches, but basically the attempt is to obtain maximum exploitation of solar energy. The simplest device for conversion of solar energy into thermal is the flat-plate collector. The production technology for these collectors has been completely adopted, it has been used worldwide and many factories produce and sell these collectors commercially. Shapes, dimensions and positions of the parts are determined by installation, namely by conditions under which the collectors will function. In the same way the applied materials are determined by new knowledge and production technologies.

3.2. Thermal energy tanks

Thermal energy tanks should be chosen in accordance with the planned thermal energy consumption, based on the number of persons and their needs and/or based on the requirements of the heating/cooling system. Renewable energy tanks accumulate (store) heat because solar radiation varies during the day or year due to intermittent characteristic of solar energy.

Installation of accumulation tanks, thermal energy tanks, increases the efficiency of the solar energy system because they save thermal energy, collected during the day, to be used either at night or in the following few days or weeks without sufficient solar energy.

4. Application of solar energy system – case study

4.1. Secondary school Valpovo

The school building was built in 1967 and in 1992 it was modernized and enlarged. This provided optimal space conditions for the normal realization of an educational process. Optimal layout of the school requires specific energy consumption and this means specific financial sources, as given in Table 1. The table presents gas consumption in the period of 2007 until 2009 (*Srednja*…).

Significant thermal energy consumption, as shown in Table 1, refers to gas consumption from 2007 to 2013. Temperature changes, both monthly and daily, determine varied gas consumption used for school premise heating.

Usage of solar energy to obtain thermal energy is recommendable in transitional periods. In the winter, however, solar energy can be used as a backup power system, namely as a parallel energy source besides the major source, which is natural gas. There are various factors, which determine availability of thermal energy production by using solar energy: number and type of collectors, thermal energy tanks, possibility of adapting collector's direction etc.

Table 1. Overview of natural gas consumption V (m^3) per months from 2007 to 2013 (*Srednja*…)
(The table does not provide gas consumption for metalworking in the workshop)

Month	Average	2007	2008	2009	2010	2011	2012	2013
	V (m^3)							
January	17,557.86	11,181	20,295	15,438	17,543	19,952	20,151	18,325
February	13,523.57	11,803	14,540	13,927	12,852	14,231	13,987	13,325
March	11,268.71	9,853	11,611	11,197	10,835	11,562	12,035	11,788
April	5,127.57	4,276	7,532	4,060	4,652	4,951	5,124	5,298
May	1,629.57	1,490	1,619	1,785	1,645	1,712	1,543	1,613
June	1,192.71	1,309	1,256	1,027	1,123	1,254	1,201	1,179
July	1,070.17		1,279	904	1,002	1,120	1,097	1,019
August	1,041.33		1,030	952	987	1,102	1,086	1,091
September	2,648.30	1,546	3,113	2,871	2,718	2,914	2,875	2,501
October	6,768.86	7,098	7,085	6,328	6,283	6,814	6,901	6,873
November	12,657.43	15,675	10,005	11,093	11,688	13,541	13,848	12,752
December	17,234.71	15,215	18,428	17,109	17,654	17,988	17,530	16,719

During the day, some real measurements were performed at school once per hour. Based on the results given in Table 2 and graphic presentation in Figure 3, it is possible to conclude that with minimum conditions and equipment, solar energy could be used for heating (water heating system and/or as a backup power system). The measuring equipment, used in this case, could be bought in any technical equipment shop without any problems or personally made. Steel plate with a fixed temperature indicator, used for the measurement, was placed in an isolated chamber. The upper side of the steel plate was used to place in the glass plane. As two sets were made, simultaneous measurements for comparison of the different conditions were possible. During the measurement, one measurement set was used without glass and the other was used with double-isolated glass. Each time the ambient temperature was measured (in a shade, at 2 m height). Weather conditions were also recorded. Equipment for temperature measurement consists of steel plate 200 × 300 × 18 mm, 2 pieces and digital thermometer Metalflex DT 850. There are 3 measurement points (dimensions of 400 × 500 × 180 mm): MP0, without cover glass; MP1, with single glass and MP2, with double glass. Here in Table 2, there are measured temperatures for two measurement points MP0 and MP2.

It is easy to see from Table 2 and Figure 3 that despite the clouds in the sky, a certain amount of energy input was received at the measurement points, which led to temperature rise.

5. Solar energy applied for heating

The secondary school must be heated in the long period (October – March at least) together with the gym and it causes significant costs for space heating and water heating during the school year. The present system of central heating, based on natural gas, meets the school needs. Installation of solar collector system applied for solar water heating and as a backup of present space heating system, could decrease consumption of conventional energy sources, namely natural gas, and decrease CO_2 emission into the atmosphere. Natural gas consumption varies during the year and it is significantly higher during winter period.

The solar heating system could be designed in such a way that solar energy is applied in summer months to meet demand for water heating (sport activities) and in transitional periods to meet demand for space heating and/or for solar water heating. During the winter period (shorter periods of solar radiation), solar thermal energy is insufficient, Therefore, it is necessary to use the conventional energy source (like natural gas) in order to meet demand for space heating and water heating. Of course, if solar heating system is additionally applied for apace/water heating, needs for natural gas decrease.

As an example, fluctuations in gas consumption during March are presented with the average temperature oscillations during the day. The solar heating system for heat water production is designed according to school daily needs for hot water (per single user). Hot water accumulation tank's volume (V_s) is calculated to be between minimum and maximum volume:

$$V_{S\min} = 1{,}5 \cdot W_h \tag{5.1}$$

$$V_{S\max} = 2 \cdot W_h \tag{5.2}$$

Table 2. Example of temperature measurements during the day, 18th April 2010

	Ambient temperature / °C	Weather conditions	MP0 / °C	MP2 / °C
7:00	7,3	Clear	8,8	10,8
8:00	9,1	Clear	10,6	13,5
9:00	10,2	Clear	19,2	23,1
10:00	13,1	Clear	30,1	43,8
11:00	15,5	Clear	43,9	70,3
12:00	16,8	Clear	47,8	88,9
13:00	17,1	Cloudy/nimbuses	49,4	102,1
14:00	19,1	Cloudy/nimbuses	51,3	108,6
15:00	20,2	Cloudy/rain	51,6	110,9
16:00	23,8	Cloudy/nimbuses	52,3	114,9
17:00	22,9	Cloudy/rain	41,8	102,4
18:00	21,1	Cloudy/nimbuses	26,4	73,4
19:00	20,1	Cloudy/nimbuses/sunset	22,1	56,1
20:00	18,2	Cloudy/nimbuses	18,7	43,3

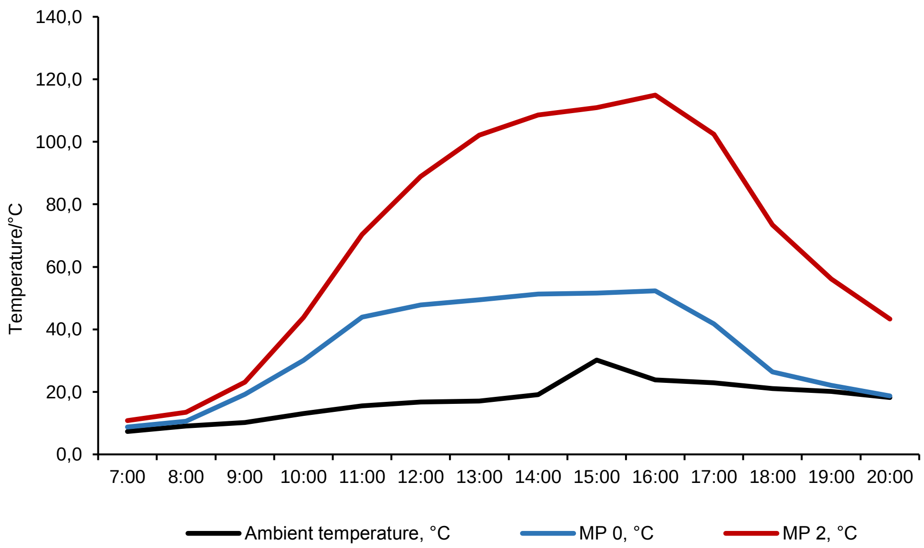

Figure 3. Comparison of measured temperatures during the day, April 18th 2010

Further on, total number of collectors depends on collector's surface P_k as a function of volume of hot water accumulation tank and it should be between minimum and maximum values:

$$P_{k\,\min} = 1{,}25 \cdot \frac{V_s}{100} \tag{5.3}$$

$$P_{k\,\max} = 1{,}65 \cdot \frac{V_s}{100} \tag{5.4}$$

Designed solar heating system consists of 30 m^2 solar collectors and heating accumulation reservoir of 1500 l. Design surface of solar collectors is increased to satisfy hot water demands during the winter and additional sport activities in gym which are not included in daily school hot water needs. Vacuum tube collectors has parameters: F_R ($\tau\alpha$) = 0.76 and F_{Rk} = 1.6 W/m^2K. Vacuum tube collector is selected due to better performances during low solar radiation.

In the calculation performing, an assumption is adopted that thermal water consumption was 1500 l per hour and the initial water temperature was 20 ºC. Also, water temperature was 80 °C on leaving the reservoir. All calculated data were presented in Table 3 with notified changes during the day. In Table 4, the data for two systems were compared in one day, week and month – the first system used a combination of gas and solar energy for solar water heating and as a backup to conventional heating, while the second used only natural gas (Majdandžić 2008).

In order to make an easy comparison, the collector heat (Qk) was expressed as a gas equivalent in m^3 (fuel value of natural gas ranges from 34 to 38 MJ/N·m^3) (Majdandzic 2008, *Seminar*…).

As the obtained data for energy needs of analyzed building in March, it is possible to do the same for the whole year (Hornung et al. 2010). Calculated data could be compared with the average gas consumption during 2007–2013 and expressed in percentages, as shown in Table 5 and in Figure 4, shows the coverage of natural gas consumption by equivalent solar energy.

If calculated data for the average gas consumption over the years (2007–2013) are analyzed, for the whole year (2008), an average of 91,720.8 m^3 of gas is spent. If solar energy were used to heat DHW and central heating backup, average of 91,720.8 m^3 of natural gas could be saved throughout the year, which in this example is 23.67%. In the same way, a comparison of energy demands for the same object located in several cities in Europe (Danube region) is made. The secondary school building in Valpovo (26 km from Osijek) is compared with the same object (geometry and energy demands) located in different cities of Europe.

Table 3. Water temperature in accumulation reservoir and equivalent of gas consumption during the day

Time	Q_k – collector heat / MJ	q_s – reservoir temperature / °C	Gas equivalent / m^3
8:00	25,6497	24,08	0,71
9:00	55,4480	28,82	1,54
10:00	93,0541	34,81	2,58
11:00	135,0478	41,49	3,75
12:00	178,1075	48,34	4,95
13:00	218,8039	54,81	6,08
14:00	253,8021	60,38	7,05
15:00	280,0535	64,56	7,78
16:00	294,8696	66,92	8,19
17:00	296,8712	67,23	8,25
18:00	288,0049	65,82	8,00

Table 4. Comparison of gas consumption in March

Time period	I (Gas + equivalent solar energy), gas / m^3	II (Gas) / m^3
Day	56.13 + 58.88	115.01
Week	392.87 + 412.17	805.04
Month	1,683.72 + 1,766.43	3,450.15

Table 5. Coverage of gas consumption by equivalent solar energy

Month	Consumed natural gas / m^3	Daily production / m^3	Weekly production / m^3	Percentage / %
January	17,557.90	13.98	433.29	1.62
February	13,523.60	28.14	787.86	4.80
March	11,268.70	58.88	1,825.31	11.18
April	5,127.57	73.97	2,218.97	23.99
May	1,629.57	91.43	2,834.34	159.02
June	1,192.71	96.00	2,880.01	213.06
July	1,070.17	102.60	3,180.55	237.09
August	1,041.33	100.41	3,112.78	278.16
September	2,648.29	67.74	2,032.21	64.12
October	6,768.86	46.38	1,437.78	17.26
November	12,657.40	21.31	639.41	4.74
December	17,234.70	10.66	330.49	1.23
Total	91,720.80		27,712.98	

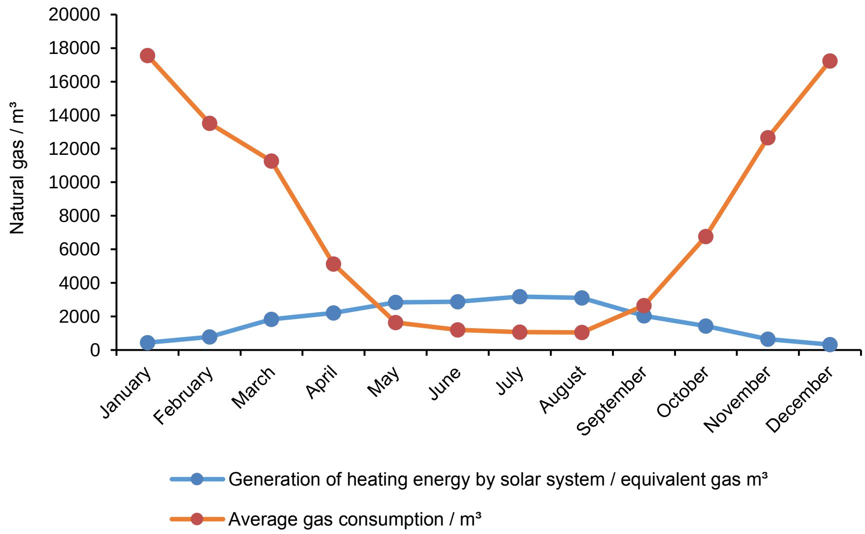

Figure 4. Coverage of gas consumption by equivalent energy production based on solar system

In Figure 5, energy savings are shown for one day in March with installed solar heating system. In Figure 6, there are calculated data of gas cumulative consumption for the same purpose (heating provided hot water) as comparison.

Solar system for domestic hot water (DHW) and / or central heating backup mainly consists of collectors, heat storage, radiator, or the corresponding heaters, automation and control system, as well as classic heater that provide heating energy when solar energy is not sufficient. The system also allows obtaining hot water by means of suitable heat exchangers. Conventional heating device must be sized to meet the needs when the solar contribution is insufficient.

6. Conclusion

Solar heating is suitable for climate area in Croatia, especially in south parts, with plenty of sunshine and relatively high average temperature, and results in greater efficiency of the heating system. The advantage of solar heating compared to other methods is its eco-friendliness, and also in its autonomy (this is applicable in areas without municipal infrastructure). The solar system for heating a building may save 50–60% annual energy needs of the object. During the summer months, the conventional system for hot water producing can be reduced to a minimum or completely shut down and thus remove the harmful emissions (CO_2), formed from the combustion of fossil energy sources. Significant savings of material resources can be achieved by thermal solar energy production.

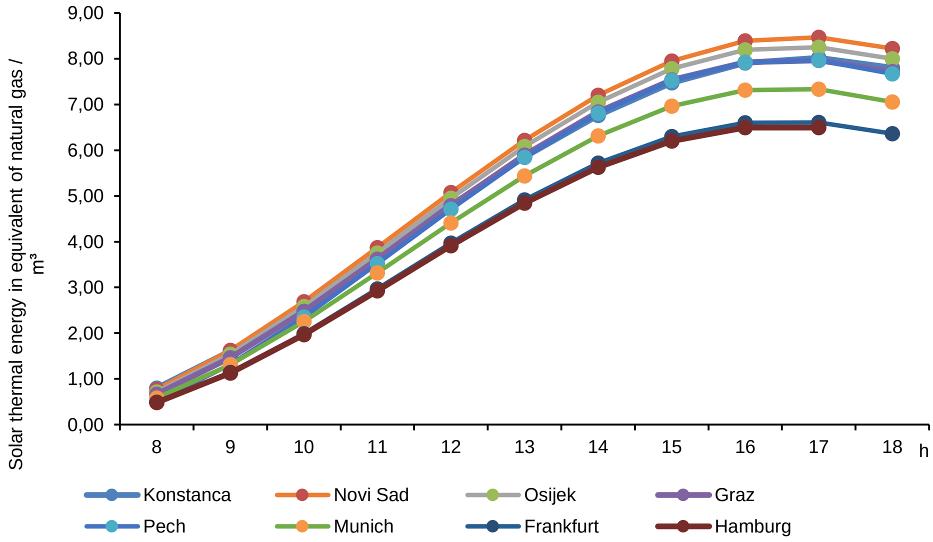

Figure 5. Generation of solar heating energy – equivalent of natural gas / m³

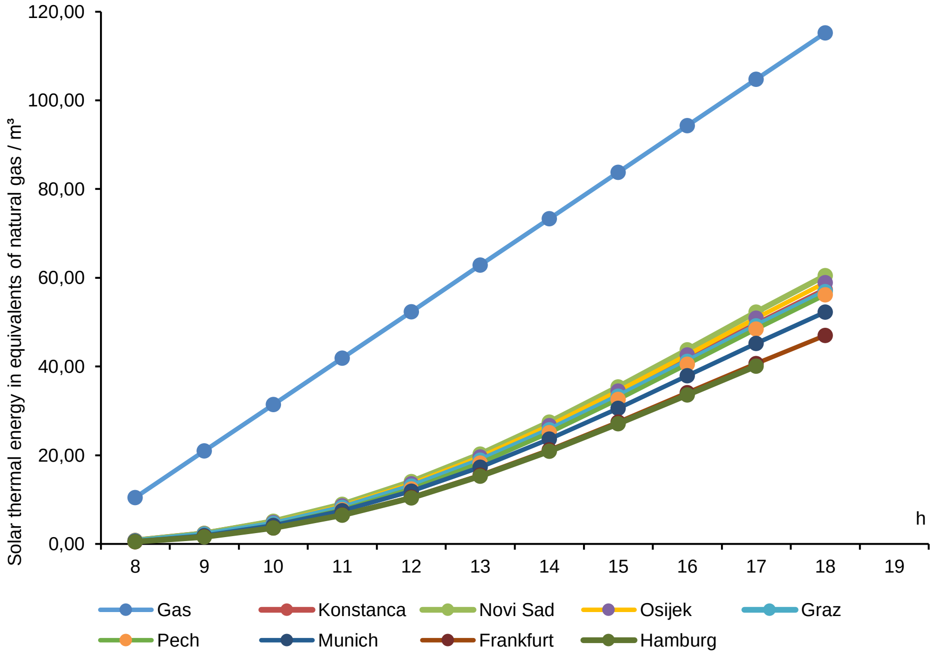

Figure 6. The required amount of natural gas and generation of heating energy of solar system in equivalent m³ of natural gas

Repayment of the solar system is made through the reduction of energy consumption (eg. natural gas) when DHW and/or energy for space heating. Proper size design and settings of the basic heating system, solar thermal energy can be used for partial or complete energy independence of the building. Designing of the solar thermal system should take into account day energy needs to determine the maximum installed heating power of the system, better to say day periods with direct usage of hot water and day periods with postpone usage of hot water (hot water accumulation storage tank).

Conflict of Interest

The authors declare no conflict of interest.

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BIOMASS RESOURCES

Sugar Beet as a Potential Energy Crop in the Danube Region

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Abstract: Currently in the Danube Region Germany, (Bayern), Austria, Czech Republic, Slovakia, Romania, Croatia, Serbia und Hungary in total 600–650.000 ha cultivate sugar beet. In the last few years sugar beet is also considered as base material of bio-fuels. In 2012 Germany produced 321.3 million litre and Czech Republic 110.4 million litre agrar–ethanol. Wastes – remnants – of sugar/ethanol production are applicable for biogas production, like in Hungarian sugar factory in Kaposvar. It should be pointed out, that sugar beet is one of the most competitive energy plants in our climate among the cultivars on arable land. In the countries with sugar beet cultivation of Danube Region sugar beet yields average about twice the amount of bioethanol per hectare than corn and three times than wheat. In addition to ethanol production, other components of the sugar beet plant (marc, top, tail) can be used advantageously for biogas production. From 1 ton of sugar beet approximately 50 m3, 50% CH4 containing biogas can be obtained by the anaerobe fermentation of the mentioned organic wastes. If this amount of biogas is burnt in a cogeneration power plant, the energy (ca. 240 kWh/t beet) is more than enough to cover the energy (heat and power) demand of the ethanol production or also that of other processing technologies (biorefinery).

Cultivation of sugar beet plays important role in sustainable agriculture. Its specific advantages are: sugar beet reduces the problems caused by diseases and pests in crop rotation (lower risk caused by chemicals). It increases the fertility and water-holding capacity of the soil and improves its structure due to it's more than 1 metre long tail-roots. It helps to maintain the flora and fauna biodiversity, and eliminates the disadvantages of the single-crop system. The net GHG (green house gas, that is CO_2) balance of sugarbeet is better than most of the energy plants.

In this paper the possibilities of "energy beet" production in Danube Region are discussed.

Keywords: sugar beet, bioenergy

1. Introduction

The area covered by EUSDR ranges from the Black Forest (Germany) to the Black Sea (Romania–Ukraine–Moldova), covers parts of nine EU countries (Germany, Austria, Hungary, the Czech Republic, Slovakia, Slovenia, Croatia, Bulgaria and Romania) and five non-EU countries (Serbia, Bosnia and Herzegovina, Montenegro, Ukraine and

Figure 1. Countries of Danube River Basin
Soure: JRC Science and policy report.

Moldova) and includes more than 100 million inhabitants. More than 90% of countries such as Hungary, Austria, Romania, Serbia and Slovakia being part of the Danube area (Figure 1.), while other countries are less involved, down to Germany (where 16.8 % of the country is in Danube river basin) and Ukraine (5.4%) (*European Commission*…).

In 2020 biofuels use in transport sector in EU countries of Danube Region is foreseen to double their absolute contribution reaching 358 PJ from 172.6 PJ in 2010. Bioethanol use in 2020 is expected to reach 71.3 PJ with an average increase of 7.9 % per annum. Other biofuels (biogas, vegetable oil, etc.) are expected to have the second highest relative increase with 9 % per annum in average reaching 14.5 PJ in 2020 (Banja et al. 2014).

The Danube region has a large natural potential for bioenergy development in all three main feedstock categories (agriculture, forestry and waste). In EU countries of Danube Region the forestry is still expected to be the largest component of domestic biomass supply for energy production in 2010 with 980.4 PJ (54.5% in contribution). About two-third of this contribution is expected to come from direct supply of wood biomass from forests (Banja et al. 2014).

The biomass supply from agriculture (agricultural by-products /processed residues and fishery by-products) will be the second source of domestic biomass supply in 2020 with 689 PJ (38.3% in contribution) increasing by an average 16.5%

per annum from year 2010. The main contribution in agricultural supply is expected to come from agriculture crops and fishery products with 442 PJ (65 % in share) while agricultural by-products and residues will cover the remainder part of 247 PJ (35%) (Banja et al. 2014).

Among the agricultural crops sugar beet gives the higest energy per hektar. This energie is mostly in the form of bioethanol and biogas.

In this study the potential of bioethanol and biogas production from sugar beet in Danube Region are demonstrated.

2. Methods

The study is based on data from the yearly booklets of Sugar Economy of Europe and European Statistical Office (Eurostat). Using the basic yield data of Eurostat and literature sources in related bioenergy topics (Gilbert 2005), the potential biothanol, biodiesel and biogas yield pro hectare was calculated for different energy plants. The advanteges of sugar beet in sustainable agriculture are collected from brochure of International Confederation of European Beet Growers (Cibe).

3. Result and discussion

Sugar beet production potential in Danube Region

In the Danube Region Austria, Bulgaria, Czech Republic, Germany (Bayern), Croatia, Hungary, Romania, Slovenia, Slovakia, Moldavia and Serbia have produced sugar beet. But due to EU Sugar Reform the production had stopped in Bulgaria and Slovenia and reduced in the other EU countries. Without Ukraine (because his sugar beet fields are not in Danube Region) total 600–650,000 ha sugar beet are cultivated in Danube Region countries (Figure 2) and from this about 350,000 ha in Danube region. However the potential could be about 1 million ha if we take into account the maximum area of sugar beet in this region (Table 1). In the last few years sugar beet is also considered as base material of bio-fuels. In 2012 Germany produced 321.3 million litre and Czech repuplik 110.4 million litre agrar-ethanol.

4. Potential and benefits of sugar beet ethanol production

From one ton sugar beet average 108 l boethanol can be produced (Gilbert 2005). If we count with the average sugarbeet yield of last 14 years (51 t/ha) in the recent 350,000 ha 1.87 million m^3 bioethanol could be produced. However in the potential 1 million hektar cc. 5 million m^3 bioethanol is realistic (Table 2).

The biofuel production from sugar beet are encreasing. In 2012 Germany produced 321.3 million litre and Czech repuplik 110.4 million litre agrar-ethanol.

In the future the production expected to develop, due to lots of benefits of sugas beets as raw material. These benefits are the followings:

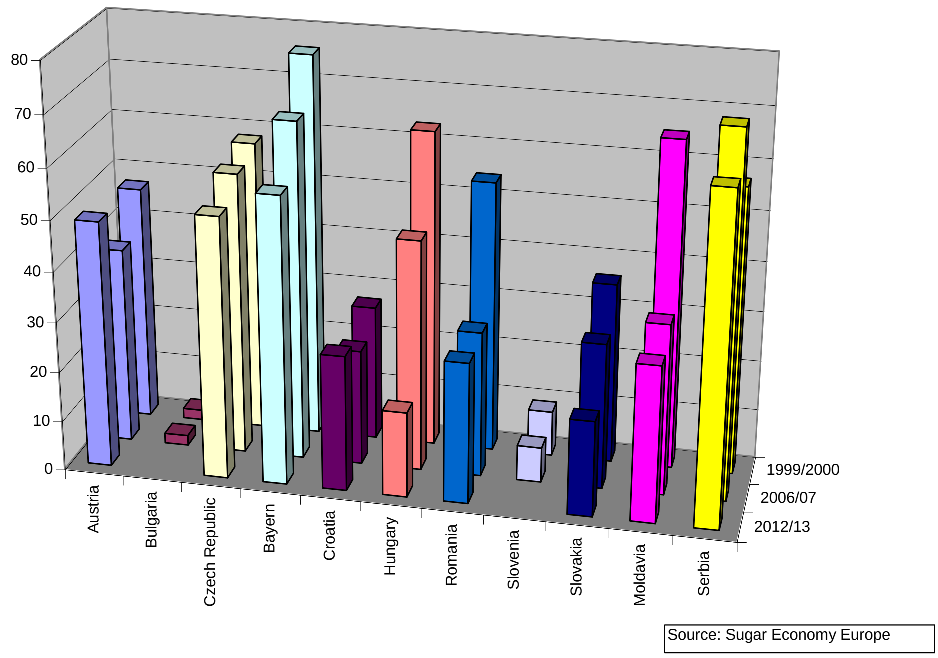

Figure 2. The changing of sugar beet growing area in Danube Region from 2000

Table 1. Maximum growing area of sugar beet during the last 27 years in Danube Region.

Country	Examination period	Maximum growing area (ha)
Bulgaria	1987–*2007*	41,0
Czech Republic	1987–2014	138,0
Bayern	1993–2012	82,6
Croatia	2000–2014	34,3
Hungary	1987–2014	161,0
Austria	1987–2014	53,8
Romania	1987–2014	260,0
Slovenia	1991–2006	10,8
Slovakia	1987–2014	54,7
Macedonia	1991–2009	3,0
Serbia	2006–2013	81,0
Moldavia	2006–2013	34,0
Total		954,2

Source: Eurostat and Sugar Economy.

Table 2. The potential bioethanol yields in Danube Region. Counted from the data of Eurostat

	From 1991	From 2001	From 2011
Average sugar beet yield (t/ha)	44	51	56
Average bioethanol yield (l/ha)	4,765	5,356	6,039
Bioethanol production in 350,000 ha (million m^3)	1.67	1.87	2.11
Bioethanol production in 1 million ha (million m^3)	4.76	5.36	6.04

4.1. Energy balance

The energy balance of sugar beet ethanol production is significantly positive: based on lifecycle assessments (from cultivation to distribution): 1 unit of energy is used to produce between 2 and 2.5 units of renewable energy. This balance is particularly positive when compared to that of gasoline, where 1 unit of energy is used to produce only 0.85 units of fossil energy.

In addition, the energy balance of beet ethanol is expected to constantly improve in the coming years. This will also be achieved thanks to the implementation of several current projects concerned with the diversification of energy sources used in beet processing, namely through the replacement of traditional fossil energy with biogas.

The energy balance of beet ethanol is particularly impressive in the cultivation phase, for example when compared to wheat ethanol.

Furthermore, energy consumption is being reduced in all phases of beet ethanol production, from the cultivation of sugar beet (as shown) to its processing into ethanol.

4.2. Land use efficiency

Based on the average national beet yields from Eurostat the sugar beet has the highest biothanol production in Danube Region during the last 28 years. (Almost double than the other plants is used for bioethanol production). Last years about 6000 litres of bioethanol have been produced from 1 hectare of beet (compared to 2000 for wheat and 3000 for maize).

As a consequence, the current beet yields in Danube Region countries are able to produce beet ethanol above 6500 litres per hectare (Figure 3).

After the counting in every country sugar beet produced much higher ethanol yield than other crops.

The highest ethanol yield was in Austria, they can produce about 8000 l ethanol from 1 hectare of beet in the national average (Figure 4).

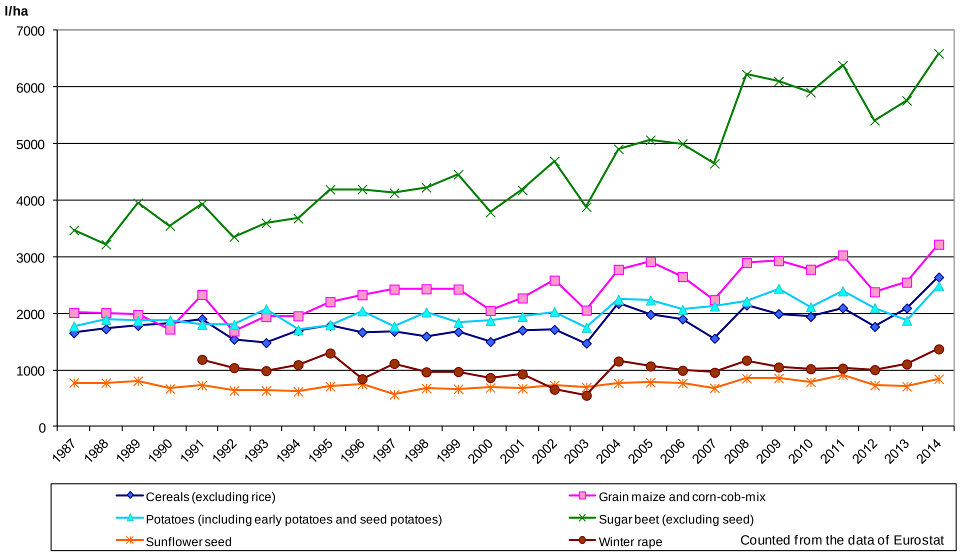

Figure 3. The potential bioethanol and biodiesel yield of different plants in Danube Region countries from 1987 to 2014. Counted from averages national yield data of Eurostat.

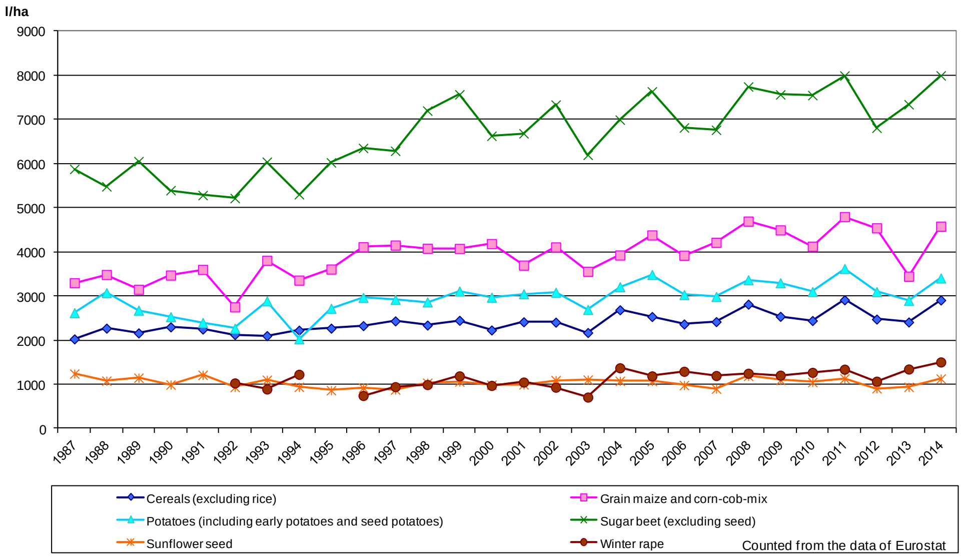

Figure 4. The potential bioethanol and biodiesel yield of different plants in Austria from 1987 to 2014. Counted from averages national yield data of Eurostat.

In addition, land used for beet growing has been under arable cultivation for decades, and most of the ethanol beet suppliers are long established farmers. Beet growing provides two types of raw material for ethanol production, beet juice and beet molasses.

Beet molasses is one of several valuable co-products from beet sugar production. Therefore, its production does not require dedicated land, but comes from the same beet area also used for sugar, and does not reduce the sugar yields per hectare.

Even better, EU beet ethanol production has positive indirect land use change effects. In fact, vinasse and pulp are co-products derived from beet ethanol production and can be used for animal feed, releasing land used for the production of traditional feed crops.

In particular, the production of bioethanol from 1 hectare of beet provides an amount of animal feed co-products corresponding to 1.3 hectares of traditional feed crops, namely soybean and fodder barley.

In fact, processing the beet harvested on 1 hectare of land into ethanol, co-produces vinasse in a quantity which, based on its useful protein content, corresponds to the soy meal produced from over 0.73 hectares of soybean.

At the same time, processing the beet harvested on 1 hectare of land into ethanol, co-produces pulp in a quantity which, based on its metabolic energy, corresponds to the fodder barley produced on over 0.6 hectares (source: Crop Energies).

This means that the production of beet ethanol can release more area than it uses.

The other by-products are valuable renewable energy sources, vinasse and pulp can also be used to produce biogas. In addition to vinasse for animal feed and biogas, other co-products are obtained from beet ethanol production: plant residues and lime are used as organic fertiliser; betaine as fish feed; low temperature heat for district heating and greenhouse horticulture; and electricity. In factories applying the poly-generation biorefinery concept, it is possible to produce all these co-products and at the same time sugar and ethanol (CTBE and CFS).

5. Biogas from sugar beet

As shown by recent developments in Austria, Germany and Hungary sugar beet is ideally suited for biogas production, thanks to its fast fermentation, high yield and cost effective substrate.

The yield of beet biogas depend on the usage of whole plant or defoliated / topped root. From this point view the potential of average biogas yields are between 5800 and 8750 m^3/ha in Danube Region (Table 3).

If we count with the average sugarbeet yield of last 14 years (51 t/ha) in the recent used 350,000 ha 2.35; 2.64 and 2.78 million m^3 bioethanol could be produced. However in 1 million hektar cc. 6.73; 7.56 and 7.96 million m^3 biogas is the potential.

Table 3. The potential biogas yields of sugar beet in Danube Region. Counted from the data of Eurostat

Raw material for biogas	From 1991	From 2001	From 2011
	Average biogas yield m³/ha		
Topped roots (without crown and leaves)	5,838	6,559	7,399
Defoliated roots (without leaves)	6,554	7,362	8,307
Whole plants (root + leaves)	6,899	7,749	8,744

With the increasing of averages national yields per hektar the potentials of biogas production are increase too (Figure 5).

To compare with other raw material, the yield of biogas from silo maize are similar than from sugar beet root, especially in developed countries, like Austria. But by using the tops and leaves sugar beet has higher potential every year and country (Figure 6).

In sugar factories in addition to using the whole beet for beet sugar and bioethanol, biogas could be also a co-product by using residues such as pulp and vinasse.

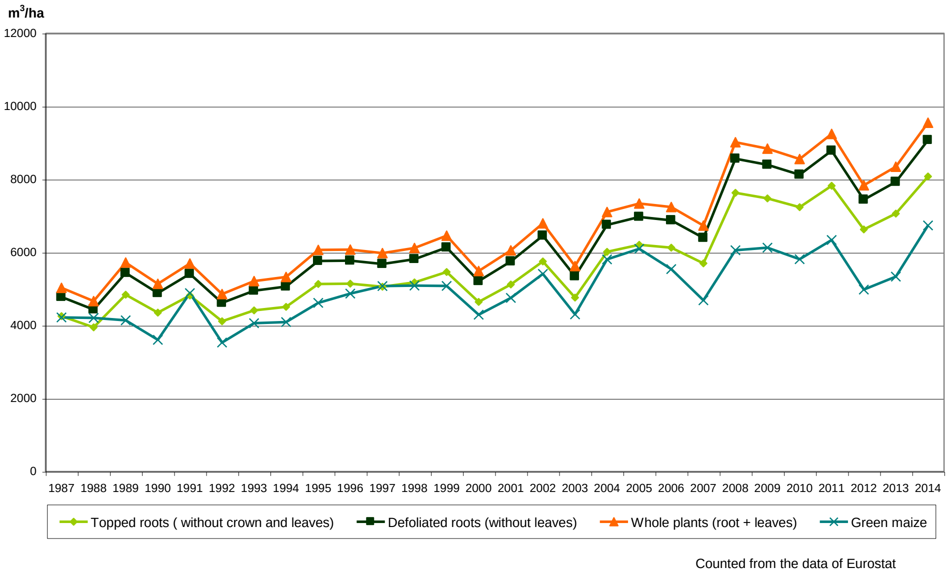

Figure 5. The potential of biogas from sugarbeet and green maise in Danube Region countries from 1987 to 2014. Counted from averages national yield data of Eurostat

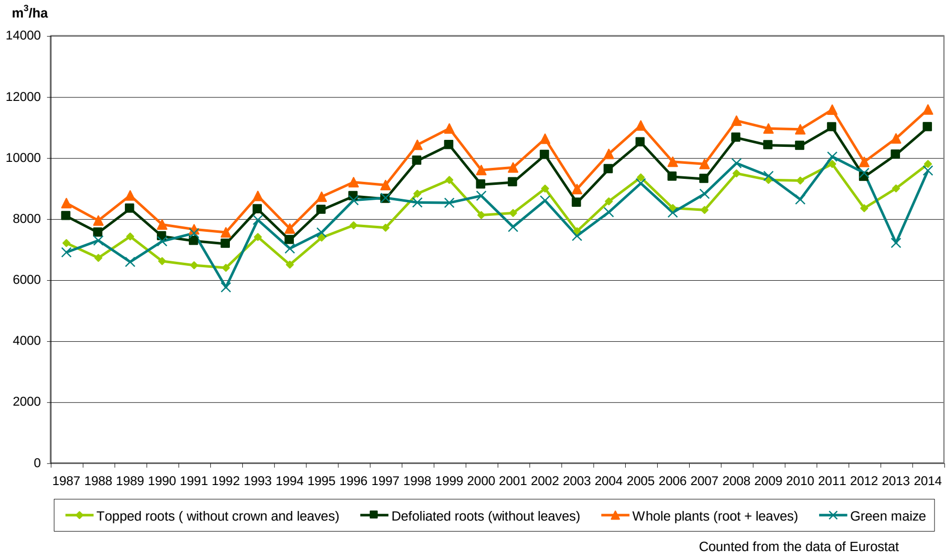

Figure 6. The potential of biogas from sugarbeet and green maize in Austria from 1987 to 2014. Counted from averages national yield data of Eurostat.

In countries where pressed pulp or dried pulp cannot be sold as cattle feed, production of biogas from pressed pulp on an industrial scale is one alternative. For example, a sugar plant in Kaposvár, Hungary, substitutes more than 50% of its demand for primary energy with this new ecological coproduct.

In countries where pressed pulp or dried pulp cannot be sold as cattle feed, production of biogas from pressed pulp on an industrial scale is one alternative. For example, a sugar plant in Kaposvár, Hungary, substitutes more than 50% of its demand for primary energy with this new ecological coproduct.

Beet biogas is mainly, but not only, used for heating purposes. Biogas is also a valuable renewable fuel supplement which helps reduce fossil energy consumption and associated emissions.

In a number of countries, fossil fuels are increasingly replaced by biogas. Some experts maintain that by 2030 biogas could replace 25–35% of fossil fuels used for road transport in Europe (CTBE and CFS).

6. Function of sugar beet in sustainable agriculture

Cultivation of sugar beet plays important role in the sustainable agriculture and protection of the environment. Its specific advantages are: sugar beet reduces the problems caused by diseases and pests in crop rotation (lower risk caused by chemicals). It increases the fertility and water-holding capacity of the soil and improves its structure due to it's more than 1 metre long tail-roots.

It helps to maintain the flora and fauna biodiversity, and eliminates the disadvantages of the single-crop system. Especially the high photosynthetic activity of sugar beet should be emphasized, because of the high surface area of the leaves and long duration of vegetation necessary to accumulate the amount of sucrose as storage carbohydrate. The net GHG (green house gas, that is CO_2) balance of sugar is better than other cultivated plants, including corn and especially rapeseed. Cultivation of sugar beet helps to fight climatic changes – the frightening fact of the present.

All the lifecycle calculations show that sugar beet ethanol/ biogas reduces GHG emissions by at least 60% when used instead of fossil fuel, thereby going beyond the sustainability threshold of 35% set by the EU Renewable Energy Directive.

When compared to other crops, sugar beet has the best performance in terms of low GHG emissions, especially in the cultivation phase (Figure 7).

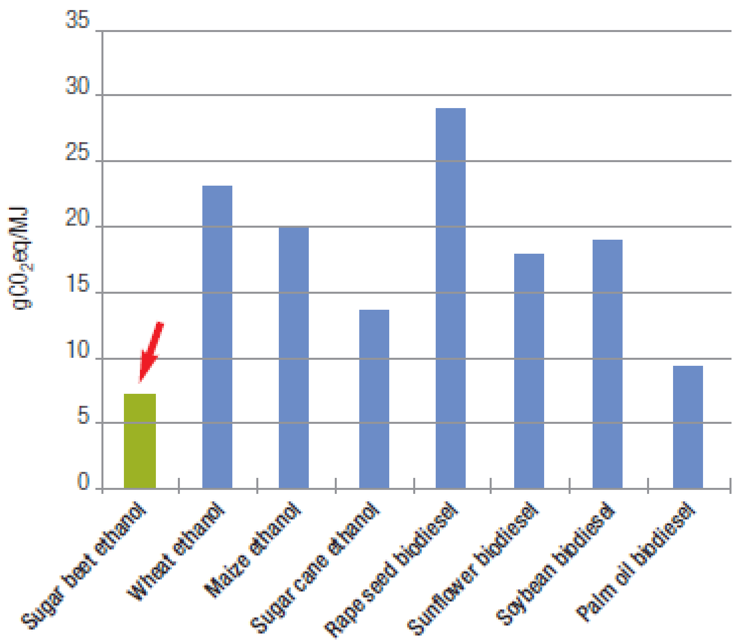

Figure 7. GHG emission of different energy crops
Source: CIBE

7. Conclusions

It is clear, that sugar beet is one of the most potential energy plants in our climate among the cultivars on arable land. In Danube Region sugar beet can yield average about twice the amount of bioethanol per hectare than corn and three times than wheat. In addition to ethanol production, other components of the sugar beet plant and residues of sugar/ethanol production can be used advantageously for biogas production. It appears the most economical potential to produce bioenergy (bioethanol and biogas) from sugar beet in or beside sugar factories.

Conflict of Interest

"The authors declare no conflict of interest".

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Reed as a Biomass Resource in the Danube Region – An Assessment of Potentials and Different Utilization Possibilities for Energy Production in Austria

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Abstract: Reedbeds are spread all over Europe and represent a large biomass potential, which hardly has been used until now. Especially for the Danube Region reed could be a future biomass source for energy production. The area of the Danube Delta und Lake Neusiedl represent the largest reed potentials in Europe.

The aim of the Project ENEREED (Sustainable Energy Conversion from Reed Biomass) is to analyse the supply-chain of reed biomass from harvesting to thermal utilization in different conversion paths. The focus of the project is on the specific circumstances of the reed-belt at Lake Neusiedl (Austria) which offers the largest connected reed potential in Central Europe (area 18,000 ha; 84,000 t total biomass potential).

To investigate the different conversion possibilities, field tests in harvesting, chopping and thermal conversion in large-scale plants (district heating and cement production) as well as laboratory experiments in combustion in domestic boilers are carried out.

The requirements in harvesting technology merge from conventional technology, how it is used for harvesting of reed for construction usage, to technologies with a higher degree of mechanisation and less demand of manpower for operation. Combustion experiments show, that reed can be utilised in a wide range of technologies. In some cases, there is a need to adapt the machinery equipment because of the fuel characteristics of reed.

Keywords: reed, energetic utilization, fuel properties, harvesting.

1. Reed biomass potentials in the Danube Region

Reed biomass areas of different size are spread all over Europe. In addition to the conventional use as construction material, there are several projects investigating reed as biomass resource for energetic purposes. An early potential analysis is published by Rodewald-Rudescu (1974), see Table 1.

As an excerpt of different projects from the past years, some facts about reed biomass in the Danube Region, focused on the Danube Delta and Austria, are shown.

Table 1. Reed Potentials, according to Rodewald-Rudescu (1974)

Area	Area (ha)
Former Sowjet-Union	5,500,000
Danube Delta	200,000
Poland	60,000
Hungary	26,200
Lake Neusiedl	15,000

1.1. Reed biomass at Danube Delta

The largest reedbeds in Europe are located in the Danube Delta, transnational at Rumanian and Ukrainian territory (see Figure 1). The annual biomass growth is up to 15 t_{db}/ha. A study explores the reed potentials in the Ukrainian part of the Danube Delta with satellite images and data field studies. It assesses total phytomass resources of 1,300,000t. The total amount of available pythomass for energy purposes in the investigated area Vilkovo town is estimated with about 125,000t/a. (Zhmud 2012)

1.2. Reed biomass at Lake Neusiedl

The largest connected reed belt in Middle-Europe surrounds the Lake Neusiedl. About 10,000 ha of the reed belt is located in Austria, 8,000ha in Hungary (see Figure 2).

Studies show a total biomass potential of ca. 84,000t at the western side of the reed belt on Austrian territory (Gamauf 2000). This biomass potential is available for harvesting, principally. Other areas, especially in the eastern part of Lake Neusiedl, are protected through nature conservation laws (National Park Neusiedlersee – Seewinkel). In spite of this significant potential of biomass, only small areas of the reed belt is annually cut and used as quality reed for construction purposes.

The main portion of fully-grown reed (with a plant age > 3 years), cannot be utilised for construction purposes. This biomass remains at the reed belt, the died-off plants lead to deterioration of the water quality due to the increased nutrification as well as to the silting-up of the lake. Nature protection authorities as well as landowners and environmental protection organizations promote a sustainable utilisation of reed with focus on the biodiversity in the reed belt.

2. Overview of investigated utilisation paths within the project ENEREED

Within the project ENEREED, different utilisation paths are investigated (see Figure 3). Each of the utilisation paths start with the harvesting and logistics of the reed material, followed by the fuel processing (chopping, pelleting) to different types of conversion. As result, each single step in the supply- and utilisation chain is evaluated after economic, ecologic and technical points of views.

The evaluations are summarised and lead to an implementation suggestion. The concept based on the principles mentioned above, should enable and promote the exploitation of the regional renewable biogenic energy resource.

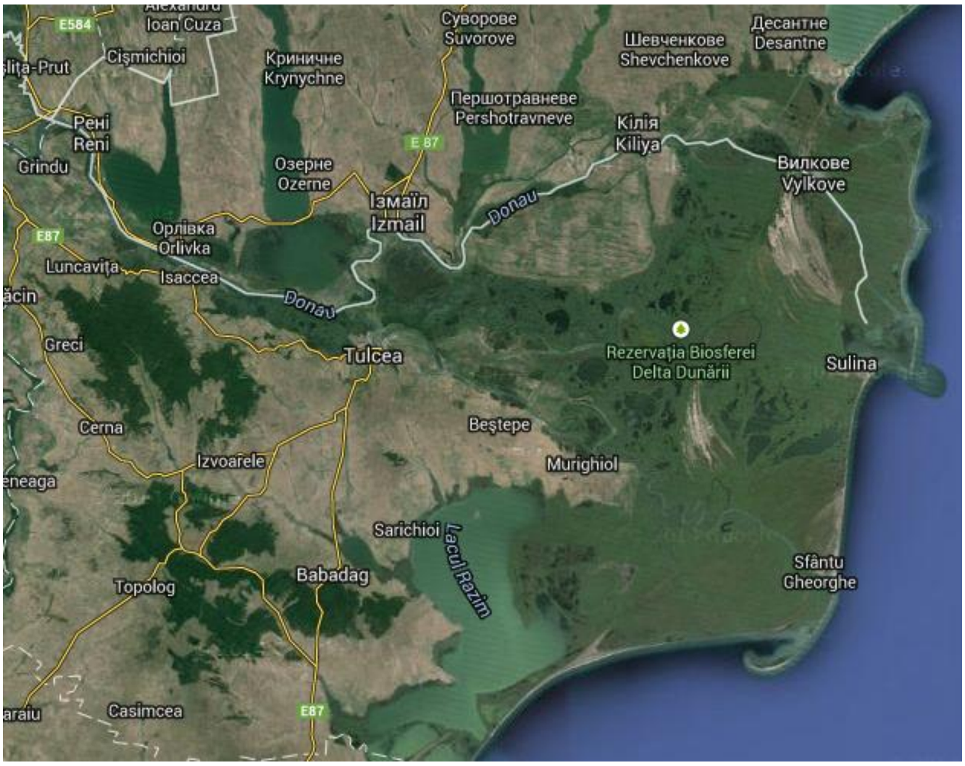
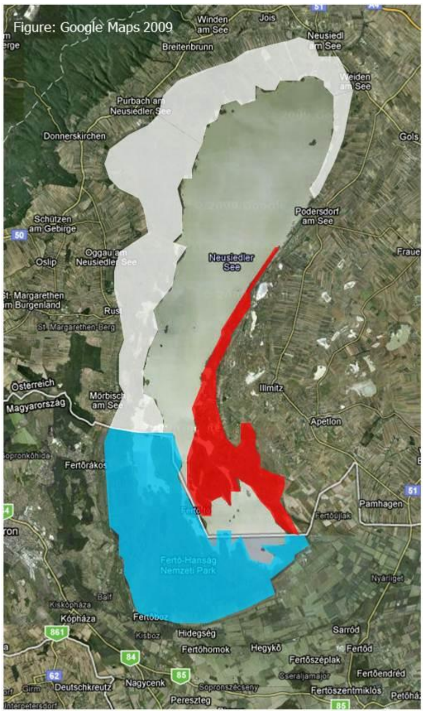


Figure 1. Map of Danube delta (Google Maps, 2015)



White areas: Austrian territory, mostly available for harvesting
Red areas: Austrian territory, national park area
Blue areas: Hungarian territory

Figure 2. Map of Lake Neusiedl, reed areas dyed according to territory and possibility for utilisation, modified from Google Maps (2009)

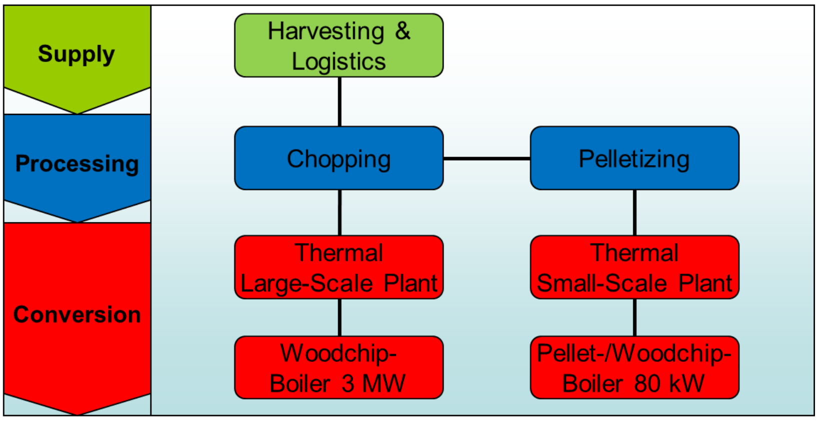


Figure 3. Conversion paths investigated within the project ENEREED
Source: own work.

3. Fuel characteristics of reed

3.1. Materials and Methods

To evaluate the fuel properties, proximate as well as ultimate analyses are carried out. The fuel characteristics of the reed plant at Lake Neusiedl are investigated habitat-specific with a range of samples from different areas. The parameters, listed in Table 2, are analysed.

A qualitative comparison of the fuel characteristics of reed to other types of biomass show, that the critical elements (N, S, Cl), which lead to air pollution are mostly in a lower level in comparison to other agricultural biomass, but in a higher level in comparison to woody biomass (see Table 3). On the other hand, the ash-content of the compared biomass is in a lower/much lower level than the ash content of reed with a mean value of all the analysed samples of 7.47%. The sintering and softening temperature of the ash from reed biomass is rather high in comparison to woody as well as agricultural biomass.

Table 2. Analysed fuel properties

Parameter	Unit	According to standard
Upper heating value	MJ/kg	OENorm EN 15400 (2011)
Water content (related to the moist material)	$\%_{wb}$	CEN/TS 15414-1 (2010)
Ultimate analysis: C- , H- , O- , N- , S- and Cl-content	$\%_{db}$	
Volatiles	$\%_{db}$	DIN 51720 (2001)
Ash content	$\%_{db}$	DIN 51719 (1997)
Sintering- and softening temperature	°C	DIN 51730 (2007)

Source: Own work.

3.2. Results fuel characteristics

A qualitative comparison of the fuel characteristics of reed to other types of biomass show, that the critical elements (N, S, Cl), which lead to air pollution are mostly in a lower level in comparison to other agricultural biomass, but in a higher level in comparison to woody biomass (see Table 3). On the other hand, the ash- content of the compared biomass is in a lower/much lower level than the ash content of reed with a mean value of all the analysed samples of 7.47%. The sintering and softening temperature of the ash from reed biomass is rather high in comparison to woody as well as agricultural biomass.

Table 3. Qualitative comparison of fuel properties of reed to different types of biomass

	Unit	Reed		Woody biomass [2]		Straw [2]		Grain whole crops [2]		Grain [2]		Grasses [2]	
Ultimate analysis (dry mass)													
C-Content	$\%_{db}$	45.48	[7]	↑↑	[113]	↔	[128]	↓	[60]	↓↓	[65]	↔	[128]
H-Content	$\%_{db}$	5.84	[7]	↑↑	[76]	↑	[112]	↑↑	[57]	↑↑	[55]	↑↑	[158]
O-Content[1]	$\%_{db}$	40.52	[7]	↑	[–]	↓	[–]	↑↑	[–]	↑↑	[–]	↓↓	[–]
N-Content	$\%_{db}$	0.47	[7]	↓↓	[133]	↓	[146]	↑↑	[66]	↑↑	[94]	↑	[204]
S-Content	$\%_{db}$	0.07	[7]	↓	[119]	↑	[141]	↑↑	[62]	↑↑	[66]	↑↑	[173]
Cl-Content	$\%_{db}$	0.15	[7]	↓↓	[122]	↑↑	[116]	↓	[56]	↓↓	[55]	↑↑	[116]
Proximate analysis (dry mass)													
Ash-Content	$\%_{db}$	7.47	[7]	↓↓	[120]	↓	[145]	↓↓	[67]	↓↓	[64]	↓	[201]
Volatiles	$\%_{db}$	76.98	[7]	↑	[86]	↓	[76]	↔	[52]	↑↑	[49]	↓↓	[159]
Lower heating value $H_{u,p,db}$	MJ/kg	16.38	[7]	↑↑	[115]	↓↓	[126]	↓↓	[58]	↓↓	[68]	↓↓	[218]
Ash melting behaviour													
Sintering temperature SIT	°C	1409	[7]	↓↓	[29]	↓↓	[48]	↓↓	[19]	↓↓	[13]	↓↓	[50]
Softening temperature SOT	°C	>1500	[7]	↓	[34]	↓↓	[59]	↓↓	[19]	↓↓	[14]	↓↓	[62]

↔ Basic value / equal to
↓ | ↑ Value lower (↓) / higher (↑) than basic value (basic value inside the typical range)
↓↓ | ↑↑ Value much lower (↓↓) / much higher (↑↑) than basic value (basic value outside of the typical range)
[1] Calculated value as residual value (100% minus average content ash, C, H, N, K)
[2] Analyses from (Hartmann, H. et al. 2000)
[###] Number of analysed samples

Source: Own work.

4. Harvesting technology

4.1. Materials and Methods

Reed cutting at the Lake Neusiedl is carried out since ages, but it used to be focused on young grown reeds, needed for the fabrication of constructions materials. Following the aims of the project, already available and applied harvesting machines has been investigated with respect to its suitability, performance, strengths and weaknesses, development and optimisation potential. Harvesting trips under real conditions concerning the harvesting period during the wintertime, the climate and ground conditions as well as the botanic demands have been carried out.

The harvesting machine, called “Paul 1” (see Figure 4), is equipped with a binder to produce bundles. It is the adequate machine to harvest young grown reed needed as construction material. Its operation is rather manpower consuming (the crew consist of one driver and 4 workers).

For the intended energetic use, fully-grown (more than three years old) reeds should be used and more advanced harvesting technologies are requested. The harvesting machine “Sumo-Quaxi” (see Figure 5) is equipped with a press to produce round bales. A carrying device is able to take three bales (see Figure 6), whereas the fourth bale stays within the press, until the discharging place is reached. The crew consists of the driver and allows a second person to go with the driver in the operator’s cab.

Figure 4. Harvester for young grown reed “Paul 1”; harvesting on ice
Source: own photo.

Figure 5. Harvester for fully grown reed "Sumo-Quaxi", during the harvesting operation
Source: own photo.

Figure 6. Harvester for fully grown reed "Sumo-Quaxi" at the discharging place
Source: own photo.

The output of both machines were determinate by the ratio of reed weight to duration per route. In order to get a more detailed knowledge about the performance influencing parameters, the whole track has been monitored by GPS-System. Figure 7 shows the track of a typical route with a predominate mowing route and a short return route, resulting in a penetration depth of the reed belt of approximately 300 m due to the limited storage capacity of only four bales.

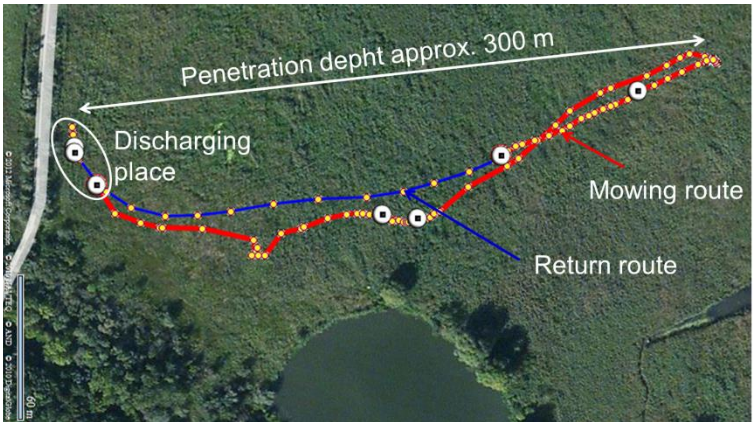


Figure 7. Harvesting route of the "Sumo-Quaxi"
Source: own work

4.2. Results harvesting

Table 4. shows the technical data of the two regarded harvesting machines. Both machines are tailor-made, to meet the requirements of the Lake Neusiedl. Each of the machines uses a chain-type chassis of a snow groomer and a conventional sickle bar.

The Table 5 summarizes the performance figures of both harvesters as mean values from a number of test routes.

Table 4. Technical data of the two considered harvesting machines

Performance data (mean values)	Unit	Reaper-binder "Paul 1"	Reaper-baler "Sumo Quaxi"
Manufacturer		Erwin Sumalowitsch, Podersdorf	
Year of construction		~2000	2004
Crew	men	5	1 … 2
Weight empty / maximum	kg	4500 / 6500	9800 / 11500
Chain: axial distance * width	m	3,33 * 1,00	4,73 * 1,00
Chain area	m^2	6,66	9,46
Maximum soil pressure	kg/cm^2	0,098	0,122
Overall length * width * height	m	6,80*3,00*2,85	9,43*3,10*3,67
Power of Diesel-engine	kW	118	142
Fuel consumption	litre/h	6,3	10,0
Feed width of mower	m	2,85	2,85
Shape of harvested reed		bundles	round bales
Bundle or bale size: Diameter * Length	m	~0,2 * reed L	1,2 * 1,2
Bale volume	m^3		1,36
Bundle or bale weight	kg	3 …4	191
Bale density	kg/m^3		141
Storage capacity = harvest per route	kg/route	1850	764

Source: Own work.

Table 5. Performance data of the harvesting machines

Technical data	Unit	Reaper-binder "Paul 1"	Reaper-baler "Sumo Quaxi"
Speed, during mowing / without mowing	km/h	1,2 / 3,8	0,8 / 2,7
Route-duration, with mowing / total route	h	1,00 / 1,33	0,55 / 0,69
Penetration depth	m	1.130	345
Hourly harvesting output (wet base)	t/h	1,39	1,11
Daily harvesting output (8h/d, wet base)	t/d	11,13	8,86
Aerial mowing performance	ha/route	0,336	0,123
Aerial yield (wet base)	t/ha	5,5	6,2

Source: Own work.

Both harvesting machines exhibits an output in the range of 1.25 t/h resp. 10 t/d at an aerial yield around 6 t/ha.

"Paul 1" works flexible and reliable. A fundamental increase of the performance seems to be unrealistic, because the limiting factor is the men power.

The concept of the harvester "Sumo-Quaxi" is technical feasible. Its output was expected to be higher. The low storage capacity on the harvester (see Table 4), results in time-consuming return routes.

Some improvements are certainly possible:

- An increase of mean velocities leads to a better output
- An larger sickle-bar (above 3m) increases output
- An increase of bale density and capacity (higher pressure technologies, more than 4 bales) shortens the duration of the return route
- Shuttles avoid the necessity of the return routes of the harvester.

Fundamental improvements can only be realised with new harvesting designs and probably new concepts.

5. Thermal utilisation small-scale plant (Pellets-/woodchip boiler – domestic heating)

5.1. Materials and Methods

To analyse the combustion behaviour of reed pellets during a combustion process in a conventional biofuel boiler, combustion experiments have been carried out. Therefore reed pellets and wood pellets (both pure and in different mixtures) as well as wood chips (for reference) have been tested under standardised testing conditions at a boiler test stand (see Figure 8) according to OENorm EN 303-5 (1999).

The combustion experiments have been carried out with a pellet-/woodchip boiler with moving grate and a nominal capacity of 80 kW. To handle the rather big amount of ash from the combustion process, some adaptations have to be done at the ash discharging system.

The test stand is equipped with about 70 measuring points and a data logging in a one second interval. The collected data are processed to 1 min mean values and used for the calculation of heat power, boiler efficiency and emission coefficients. Particulate matter is analysed by increment samples (measuring duration 15 min) during the test run.

5.2. Results thermal utilisation small-scale plant

Figure 9 shows the results of the analyses of the average heat power output as well as the results of the boiler efficiency. The best results could be achieved during the combustion experiment with 100% wood pellets. Therefore, a heat power of nearly

1) Boiler 2) Biofuel container	3) Flue pipe 4) Emission measuring instruments	5) PM measuring instruments 6) Buffer tank

Figure 8. Experimental setup – boiler test stand
Source: own work.

95 kW was achieved. The generated heat power decreases proportionally when the mass fraction of the reed pellets increases. With 100 % reed pellets an average heat power of 40 kW was achieved. By the use of wood chips, a heat power output of 77 kW was measured.

With a boiler efficiency of 92%, the test run with 100 % wood pellets obtained the best results. The experiments with wood chips and with a 50/50% wood pellets/ reed pellets mixture showed nearly similar results (87 and 88 % boiler efficiency). By the use of 100 % reed pellets, a boiler efficiency of 78 % was detected.

The measurement of gaseous emissions (see Figure 10) were taken during stable condition and do not include start-up, shut-down or ash- discharging phases.

The highest CO emissions with about 28 mg/m_N^3 (at 13% O_2 reference) occurred at the combustion 100% reed pellets. The evaluation of the other three test runs showed, that the measured CO emissions were generally lower than 10 mg/m_N^3.

By the analysis of the SO_2 emissions it was detected, that the value of SO_2-emissions raises proportional to the mass portion of reed. The test runs with wood chips and wood pellets show mean values of the SO_2 emissions less than 10 mg/m_N^3, the SO_2 emissions of 100% reed pellets raises up to 98 mg/m_N^3.

The lowest value of NO_X emissions was determined by burning wood pellets (120 mg/m_N^3). A higher mass fraction of reed increases NO_2 emissions proportionally. The combustion of 100 % reed pellets emitted 330 mg/m_N^3 NO_X to the atmosphere. This emission value is twice as high as the emissions by burning wood chips (160 mg/m_N^3).

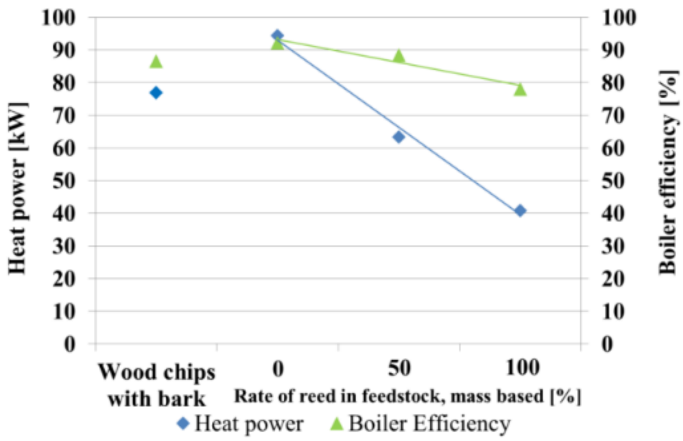


Figure 9. Heat power and boiler efficiency pellets-/woodchip boiler
Source: Own work.

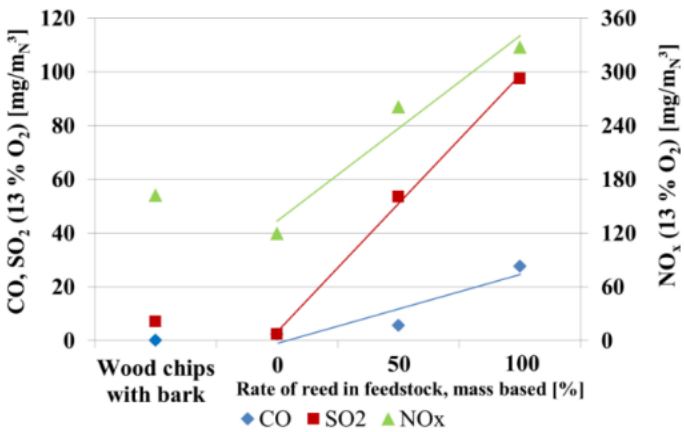


Figure 10. CO, SO_2 and NO_x emissions pellets-/woodchip boiler
Source: Own work.

The emissions of particulate matter were measured with a cascade impactor. With this type of measurement method the particles were separated into three fractions: <2.5 µm, 2.5–10 µm and >10 µm.

As expected, the combustion of 100 % wood pellets produced the lowest particulate emissions with a mean value of 15.4 mg/m_N^3 (see Figure 11). As previously seen by other measurement values, particulate emissions increased as the share of reed pellets increased. The combustion of 100 % reed pellets caused 30.8 mg/m_N^3 particulate matter, a value that can be compared with the particulate emissions from wood chips with a mean value of 27.8 mg/m_N^3.

In the sector of ultrafine particles (<2.5 µm) the test run with a share of 50/50% wood to reed pellets achieves the best results (11.8 mg/m_N^3), followed by the test run with 100 % wood pellets (14.5 mg/m_N^3). Like at the total amount of particulate matter, the test run with wood chips and with 100 % reed pellets show nearly similar results. During both test runs about 22 mg/m_N^3 of particles <2.5 µm were detected.

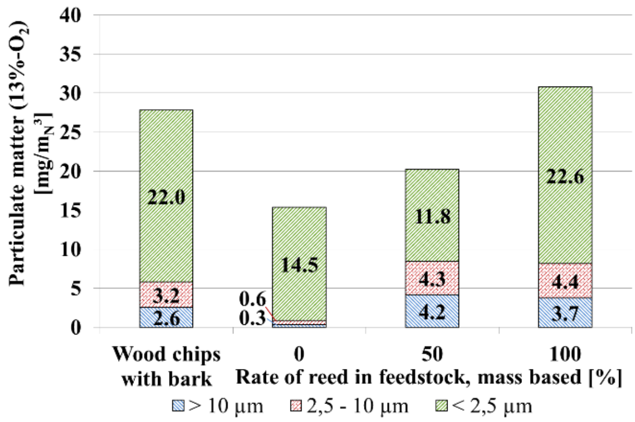


Figure 11. Particulate matter emissions pellets-/woodchip boiler
Source: own work

6. Thermal utilisation large-scale plant (Woodchip boiler – district heating)

6.1. Materials and Methods

Within the project ENEREED, 11 tons of reed were burned in a commercial district heating plant over four test runs. The standard fuel for the plant is wood chips and the standard input power is 3 MW_{th}. To investigate the combustion of reed different mixtures of reed with wood chips were burned. The used reed was harvested in February and had a water content of ca. 12.5 % whereas the water content of the wood chips was about 44 %. After harvesting, the reed was chopped in pieces of a maximum length of 10 cm. The chopped reed was mixed with wood chips and fed to the district heating plant. A basic flow sheet of the district heating plant is shown in Figure 12.

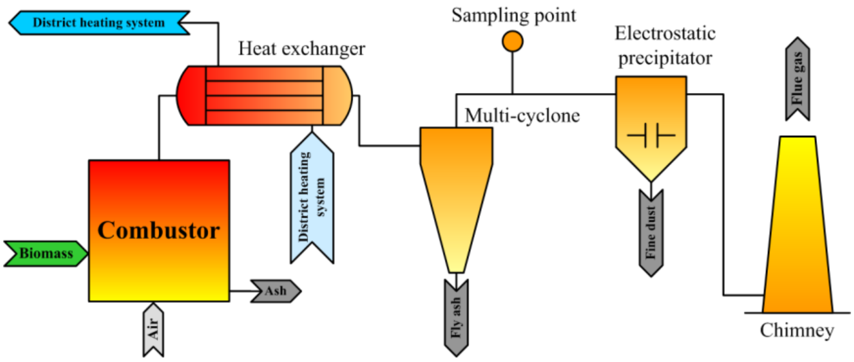


Figure 12. Basic flowsheet of the 3 MW_{th} district heating plant in Güssing, Austria
Source: own work.

Biomass, in this case different mixtures of reed and wood chips, is burned in a conventional grate combustor. The biomass enters the combustor with a push-floor transport system. It is combusted on an inclined stationary grate with three different zones. In the first zone, biomass is dried and devolatilised. In the second zone, biomass is burned at high temperatures. The third zone is important for complete combustion. The third zone ensures very low carbon contents in the remaining ash. To control the combustion temperature as well as the emissions in the flue gas, secondary and tertiary air is blown into the combustion chamber. In addition, a flue gas circulating system is installed. This ensures low emissions (especially NO_x-emissions) and helps for part-load operation of the heating plant. After the combustion chamber, the hot flue gas is led through a tube bundle heat exchanger. The gas temperature before is about 850°C and behind about 250°C. On the further downstream way, the flue gas is cleaned with a multi-cyclone and an electrostatic precipitator before it is transported over the chimney in the atmosphere. The sampling point for analysis the composition of the flue gas is located between the multi-cyclone and the electrostatic precipitator as shown in Figure 12.

Most of the gas measurements is done online. Therefore, Rosemount Multicomponent Analysers –NGA 2000 – measures via a small side stream the flue gas concentration of CO, CO_2, NO_x, SO_2 and O_2 continuously. The content of HCl was measured discontinuously with impinger bottles and IC analysis. For the organic carbon content a flame ionic detector was used. Dust content, heavy metals and dioxides and furans were measured discontinuously in according to the waste incineration regulation (AVV-Novelle 2010) valid in Austria. The dust and mercury content were sampled over half an hour and heavy metals were sampled over 90 minutes whereas the dioxins and furans were measured over 6 hours.

6.2. Results thermal utilisation large-scale plant

The series of test runs lasted 4 days and 11 tons of reed were burned. At the first day only wood chips (0% reed) were burned to verify a reference point. At the second day 50% reed with 50% wood chips and at the third day 30% reed with 70% wood chips were examined. All mixtures are calculated on an energy basis. At the fourth day 100% reed was burned in the heating plant. On each day, the measurements started at 9 a.m. and ended at 5 p.m. In this time period, the power of the plant varied between 1.5 MW_{th} and 3 MW_{th}, depending on the heat supply demand of the district heating system. To evaluate the system performance, illustrated in Table 3, periods of 1 to 2 hours with nearly constant conditions were used.

Table 3 present also the emissions dependent on the ratio (in wt %) of reed in the feedstock. The SO_2 and HCl contents are obviously increasing with increasing reed ratio. This is explainable by the fact that the sulphur content as well as the chlorine content is higher in reed than in wood chips.

Table 3. Operation and measurement data from the test runs

System data	Unit	0% reed, 100% wood chips	30% reed, 70% wood chips	50% reed, 50% wood chips
Power	kW	2800 ± 430	2660 ± 180	2630 ± 240
Combustion temperature	°C	880	836	934
Flue gas temperature	°C	202	205	206
CO_2 content	vol $\%_{db}$	8.37	8.89	9.20
C_{org} content	$mg/m_N{}^3{}_{db}$	1.1	3.0	0.7
HCl content	$mg/m_N{}^3{}_{db}$	0.8	1.4	1.7
SO_2 content	$mg/m_N{}^3{}_{db}$	9.3	16.3	27.3
NO and NO_2 content as NO_2	$mg/m_N{}^3{}_{db}$	272	207	231
CO content	$mg/m_N{}^3{}_{db}$	30.5	30.2	14.4
Dust content	$mg/m_N{}^3{}_{db}$	209	71.3	84.8
Hg content	$mg/m_N{}^3{}_{db}$	0.0004	0.0004	0.0004
Σ Cd, Tl	$mg/m_N{}^3{}_{db}$	0.006	0.007	0.007
Σ Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn	$mg/m_N{}^3{}_{db}$	0.489	0.127	0.165
Dioxins and furans	$ngTE^*/m_N{}^3{}_{db}$	0.0276	0.0092	0.0307

*nano gram tar equivalent
Source: Own work.

All emissions are below legislation limits for waste incineration in Austria (AVV-Novelle 2010), which is in good agreement with European legislation limits. In order to allow comparison with other combustion plants, all measured emissions shown in Table 3 are calculated referred to an oxygen content of 13% in the flue gas. The test runs showed, that the level of dioxins and furans are merely increasing with increasing chlorine content.

After the test runs with mixtures of reeds and wood chips, a short run with 100% reed was carried out. There were feeding problems during this run since the hydraulic push floor, which transports the fuel from the bunker to the combustion chamber, blocked. The reason is that the feeding system is designed for wood chips and not for reed, which has a lower volumetric energy density. It would be necessary to adapt the feeding system if 100% reed should be used. No operational problems for the combustion occurred even when the plant was operated with 100% reed.

7. Result and discussion

The results of the lab-scale and field tests show, that reed can be used as alternative biofuel in a wide range of conversion paths. The bottleneck for a commercial utilisation for heating purposes is still the proper harvesting technology. In this field, prototype harvesting machines are available, but still the concepts have to be improved and developed further. One of the limiting factors is the low material storage capacity of the harvesting machines that leads to limited penetration depths into the reed belt and high transportation requirements of the harvested reed.

The results of the plant operation tests for heating purposes show, that the limiting factor for small scale plants is the high ash content of reed in comparison to standardised fuels, like wood- pellets. A mixture of 50% reed pellets and 50% wood pellets, shows good results even in small scale combustion units. The results can be compared with the combustion experiments carried out with wood-chips.

In large scale boiler equipment, the high ash content is no limiting factor in combustion. The test runs with mixtures up to 50% chopped reed and 50% wood chips shows good results in boiler operation. The measured emission meet the national emission limits. For the combustion of 100% reed, the feeding equipment has to be adapted to handle the chopped material.

8. Conclusions

Following the results of the project ENEREED, it is possible to use reed as an energy carrier for heating purposes in domestic heating or in district heating systems. Because of the specific fuel properties, a co-combustion with conventional fuels, like wood-chips or wood- pellets is recommended. For commercial utilisation, further developments have to be done in the segment of harvesting technology. Therefore, special harvesting equipment, which meets the requirements of different habitats, like Lake Neusiedl or Danube Delta, has to be developed. This would be an essential step to make the reed resources utilisable for the Danube Region.

Acknowledgments

Research Partners in this project are the University of Applied Sciences Fachhochschule Burgenland GmbH (project leader), Vienna University of Technology and the civil engineering consulting company TB Dr. Beckmann.

The project is realised in cooperation with (in alphabetical order): Esterházy Betriebe GmbH, Government of the Province of Burgenland, Güssinger Fernwärme GmbH, Herz Energietechnik GmbH, Lafarge Zementwerke GmbH and WWF - World Wide Fund for Nature. The project is funded by the Austrian "Klima- und Energiefonds" (carried out within the research promotion scheme "NEUE ENERGIEN 2020") and co funded by the Government of the Province of Burgenland, Lafarge Zementwerke GmbH and Herz Energietechnik GmbH.

Conflict of Interest

The authors declare no conflict of interest.

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Evaluating the Market Competitiveness of Reed Based Biofuels

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Abstract: The aim of the Project ENEREED (Sustainable Energy Conversion from Reed Biomass) is to analyse the supply-chain of reed biomass from harvesting to thermal utilisation in different conversion paths. The focus of the project is on the specific circumstances of the reed-belt at Lake Neusiedl (Austria) which offers the largest connected reed potential in Central Europe (area 18,000 ha; 84,000 t total biomass potential).

To review the market competitiveness of reed based biofuels, an economic assessment of the supply chain, starting with harvesting, fuel logistics and storage up to fuel processing to chopped material and reed pellets is carried out. The production costs are compared to market prices of other biofuels.

In the case of industrial utilisation of reed in co-combustion in cement production, the marginal abatement costs are evaluated.

Keywords: Reed; economic assessment; fuel market.

1. Introduction

Within the project ENEREED, reed from Lake Neusiedl in Austria is examined as an energy source for thermal utilization. The Lake Neusiedl is surrounded by the largest connected reed belt in Middle-Europe with 18,000 ha in total (Austrian and Hungarian territory). In spite of this significant potential of biomass, only small areas of the reed belt is annually cut and used primary for construction. The reason is, besides nature conservation laws, missing succession of reed harvesting companies.

The aim of the project is to investigate methods for using reed as a renewable fuel for combustion processes in industry (cement production), biomass power plants and biomass boilers. Therefore the supply chain of reed biomass from harvesting to thermal utilization is analysed for the different conversion paths. To investigate the different conversion possibilities, field tests in harvesting, chopping and thermal conversion as well as laboratory experiments in pelletizing are carried out. After the technical evaluation of the thermal utilisation methods an economic assessment is done.

2. Methods and material

Reed can be used for energy generation in different forms. Therefore an objective in this work is to examine the cost structure of reed chopped short and pellets produced from reed. Chopped reed has its main use in big industrial boilers. Reed pellets can be used in small scale boilers in domestic heating. The combustion experiments show that reed can be used in a wide range of technologies from a technical point of view. Not all these options make sense from an ecological or economic point of view. The economic evaluation is carried out for the best technical and environmental options (Krail et al. 2013).

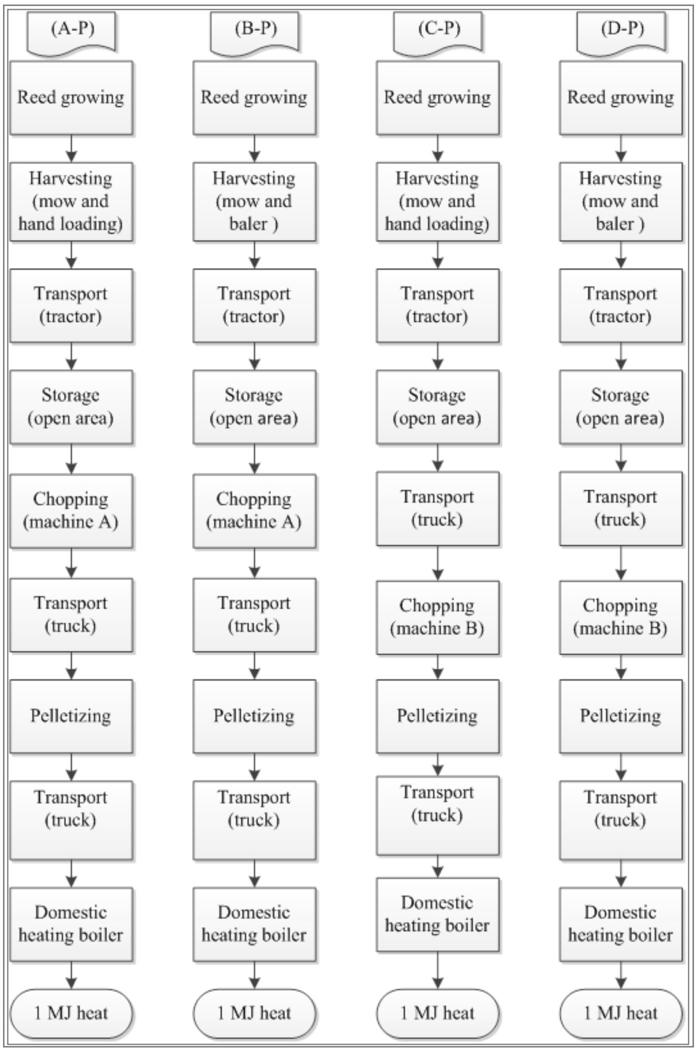
2.1. Supply chain structure

Different utilisation paths are investigated (see Figure 1). The supply chains of reed biomass with harvesting and fuel logistic have to be evaluated. Each supply chain starts with the harvesting and logistic of the reed material which is followed by fuel processing (chopping and pelleting) and storage. Between each step transportation is necessary, this is done with tractor or truck.

This study analyses and compares two types of harvesting equipment. The first type of harvester is an ordinary harvester with mow and hand loading. This conventional technology is used for harvesting of reed for construction usage and needs a lot of manpower. The second technology is a harvester with mow and baler. This machine is a prototype and has a higher degree of mechanisation and therefore less workers are needed. Although this machine has a worse economic performance at the moment. Further development is necessary to raise the harvesting capacity per hour. Several transport and storage possibilities are investigated too, as a variation within the supply chains (Krail et al. 2013).

To find the best option, different supply chains are examined. Figure 1 shows four different supply chains for producing pellets (A-P to D-P) and four different for producing chopped reed (A-C to D-C). The differences are in the harvesting technology, the chopping technology and where transportation is placed in the production chain. The first two supply chains in each category (pellets or chopped material) use the mow with the baler for harvesting (A-P, B-P and A-C, B-C) the others use the machine which produces bundles and needs hand loading. So for the first transportation step round bales or bundles are transported which makes a difference in transportation capacity of the vehicle.

For chopping two machines are used, machine A and machine B. As machine B has not such a good economic performance it is only used in two supply chains (C-P and D-P). There is a difference if transportation takes place before or after chopping. The transportation after chopping is chosen for the two pellets supply chains A-P and B-P as well as for the two supply chains C-C and C-D for producing chopped material. How and how often the material is stored has also an impact on the results. Within the supply chains A-C and B-C an additional storage is placed and its influence on the path is evaluated.



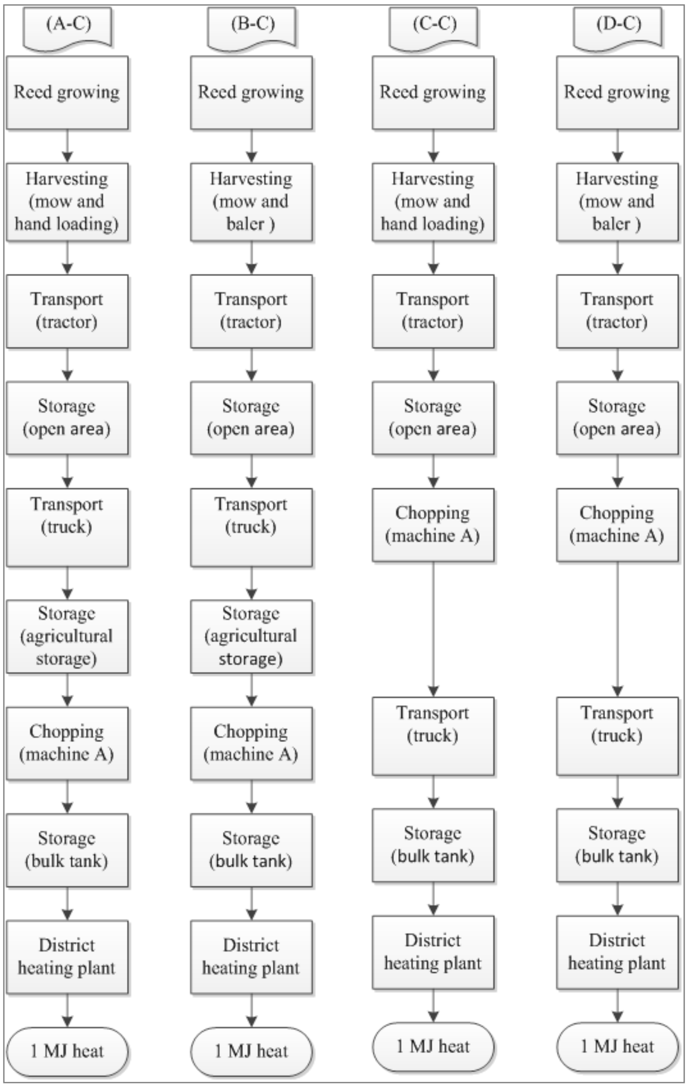


Figure 1. **(a)** Supply chains– reed pellets (A-P to D-P). **(b)** Supply chains– chopped reed (A-C to D-C)

Source: Own work.

2.2. Direct costing approach

For the economic evaluation the different process steps of the supply chain are calculated separately as cost objects. The total supply chain with different harvesting technologies, the fuel logistics and fuel processing as well as the thermal utilisation is included for calculation. Costing is done for fixed and variable costs. The fixed costs include capital costs (depreciation), interest on the tied capital, insurance and maintenance expenses. The variable costs consist of expenses for personnel, fuel and operating materials.

The following table (Table 1) shows the cost model after that the calculation of the individual costs of each process step is conducted. This model is applied to process steps: harvesting, chopping, pelletizing, transport and storage.

For calculation, data from producers, field tests, literature or own estimations is used. To get a good comparability all costs are indicated for 1t of reed (dry after harvesting).

For land use no costs are included in the calculation – no lease or tax on land. The fixed costs of the chopping machines cannot be attributed to 100% to reed production, since this machines are used for chopping wood as well. Therefore the depreciation is charged only for the proportion of annual operating hours, which is necessary for the processing of reed. The same is done with the costs for the tractor. The tractor is needed to transport the reed and for the storage and retrieval. It is estimated that 25% of its annual work hours, the tractor is used for the processing of reed, which is why 25% of fixed costs are allocated.

Table 1. Calculation scheme for fuel production costs (according to KTBL, 2012)

Costs for equipment (investment)	Depreciation (residual value=0) Insurance Interest
Costs for equipment (operating)	Operating materials Repair and wear Rent
Labour costs	Wages seasonal workers
Costs for building and infrastructure	Depreciation Structural maintenance Insurance Interest
Surface fee	Lease Tax on land

2.3. Marginal abatement costs cement industry

The evaluation of reed used in small and medium heating boilers is different to the economic evaluation for using reed in the cement production process. Here the marginal abatement costs are determined (Ragoßnig et al. 2012).

The determination of marginal abatement costs for fossil-CO_2 allows an economic comparison of different emission reduction possibilities for participants in emissions trading schemes. A comparison of the costs for internally realised emission avoidance with the costs of purchasing emission allowances is also possible (Spangardt and Meyer 2005).

There are some facts that make this evaluation difficult. First the costs of avoiding any extra ton of fossil CO_2 rise with every ton. And second every actions affect not only on the emission, a reduction of energy demand and a change of fuel used may lead to changed fuel production costs. A change in fuel may cause adaptations of technology like change in fuel logistics. To be able to evaluate this complex system a comprehensive approach is necessary. To allow statements about the economic impact and the meaningfulness of the implementation of the different scenarios.

For calculation, data from own calculation of material production is used. In this case the costs for the supply of chopped reed, supply chain C-C, is taken into account. Then scenarios which take CO_2 saving costs into account are evaluated.

3. Result and discussion

The supply chains for the production of chopped reed and reed pellets are economically evaluated and compared. The reason for evaluating reed based fuel once chopped and once palletised is that so two kinds of costumers can be served: industrial customers with big boiler technology and domestic with small scale boilers.

3.1. Supply chain

The results for the production are calculated for the land side area of the reed belt. So there is no extra distance for transportation of the harvested reed within the reed belt. If harvesting is done in the centre of the reed belt or at the lake side an additional transportation has to be calculated as well.

The economic evaluation of the supply chains shows that the supply chain with mow and hand loading in combination with the chopping machine A and no additional storage got the lowest overall costs (see Table 2 and Table 3). The supply chains with the lowest total costs for pellets (A-P) and chopped material (C-C) are marked in grey.

Table 2. Production costs for different supply chains (reed pellets)

A-P	[€ / t]	B-P	[€ / t]	C-P	[€ / t]	D-P	[€ / t]
Harvesting (mow, hand loading)	60.81	Harvesting (mow, baler)	91.89	Harvesting (mow, hand loading)	60.81	Harvesting (mow. baler)	91.89
Transport (tractor)	11.70	Transport (tractor)	11.85	Transport (tractor)	11.70	Transport (tractor)	11.85
Storage (open area)	0.35	Storage (open area)	0.35	Storage (open area)	0.35	Storage (open area)	0.35
Chopping (machine A)	11.57	Chopping (machine A)	11.57	Transport (truck)	24.17	Transport (truck)	27.62
Transport (truck)	11.60	Transport (truck)	11.60	Chopping (machine B)	19.01	Chopping (machine B)	19.01
Pelletizing	38.27	Pelletizing	38.27	Pelletizing	38.27	Pelletizing	38.27
Transport (truck)	4.64	Transport (truck)	4.64	Transport (truck)	4.64	Transport (truck)	4.64
Sum	139.00	Sum	170.00	Sum	159.00	Sum	194.00

Source: Own work.

Table 3. Production costs for different supply chains (chopped reed)

A-C	[€ / t]	B-C	[€ / t]	C-C	[€ / t]	D-C	[€ / t]
Harvesting (mow, hand loading)	60.81	Harvesting (mow, baler)	91.89	Harvesting (mow, hand loading)	60.81	Harvesting (mow, baler)	91.89
Transport (tractor)	11.70	Transport (tractor)	11.85	Transport (tractor)	11.70	Transport (tractor)	11.85
Storage (open area)	0.35	Storage (open area)	0.35	Storage (open area)	0.35	Storage (open area)	0.35
Transport (truck)	24.17	Transport (truck)	27.62	Chopping (machine B)	11.57	Chopping (machine B)	11.57
Storage (agricultural storage)	6.83	Storage (agricultural storage)	9.18	Transport (truck)	11.60	Transport (truck)	11.60
Chopping (machine A)	11.57	Chopping (machine A)	11.57				
Sum	115.00	Sum	152.00	Sum	96.00	Sum	127.00

Source: Own work.

3.2. Competitiveness of reed as fuel

This results in Table 2 and Table 3 are compared with other fuels (wood chips and wood pellets) which are typically used in the observed fields. With this information a calculation of the maximal costs for harvesting is done to evaluate the ability to be competitive at the market. In the case of harvesting costs, the biggest potential for getting a better economic performance is estimated. To make the supply chain more efficient, it is considered to design a new harvesting machine. As part of this consideration maximum harvesting costs for reed are calculated. The determination of this maximum costs are based on reference prices for wood chips and wood pellets.

In case of producing pellets, reed is already competitive to the market price. In fact harvesting could cost up to 112 €/t_{wb} which is above the costs for harvesting of both investigated technologies (compare Table 2 and Table 4). Still, reed pellets are not used as fuel yet. In this field of operation a proper boiler technology has to be developed to handle the specific fuel properties of reed pellets (e.g. high ash content). Because of an increased operation and maintenance effort which can be expected, the use of reed pellets is rather in medium scale boiler technology for district heating systems.

From demand side, the use of chopped reed is more interesting. Medium and large scale boilers are able to handle this special type of fuel. But here the price is not competitive at the moment. As shown in Table 4 the upper price limit for harvesting is about 49€/t_{wb} at the moment the cheapest way of harvesting is about 60€/ t_{wb} (compare Table 3 and Table 4).

Table 4. Upper price limit for harvesting depending on fuel. (Source: own work)

	Unit	Chopped reed	Reed Pellets
Upper price limit for fuel (adjusted to heating value)	[€/twb]	84.00*	190.00**
Transport (tractor)	[€/twb]	11.70	11.70
Storage (open area)	[€/twb]	0.35	0.35
Chopping	[€/twb]	11.57	11.57
Transport (truck)	[€/twb]	11.60	11.60
Pelletizing	[€/twb]	–	38.27
Transport (truck - pellets)	[€/twb]	–	4.64
Maximal costs for harvesting of reed	[€/twb]	49.00	112.00

Source: *prices for wood chips in Burgenland: (Landwirtschaftskammer, 2012); ** average pellet prices 2003 to 2013 (Pro Pellets Austira, 2013).

3.3. Marginal abatement costs

The calculation of the marginal abatement costs of fossil CO_2 is done for different scenarios of fuel mixes in the calcinatory. The reference scenario uses 100% petrol coke. Then scenarios are evaluated where different percentages of petrol coke with some alternative fuel like reed (scenario A), sludge (scenario C) or waste (scenario B) are used (see Figure 2).

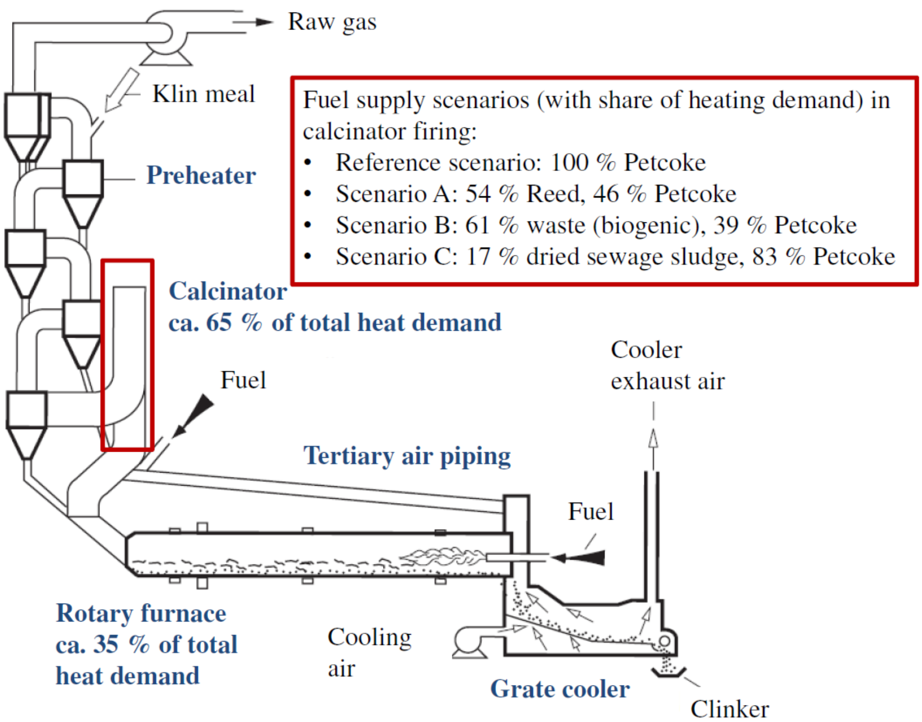


Figure 2. Overview of cement production process and calculated fuel scenarios
Source: own work.

To reflect changes in the market environment (like energy costs or costs in emission trading market) sensitivity analyses are conducted. This analyses helped to learn about the influence of individual factors. The price of emission allowances and the price of the reference fuel (petrol coke) are two factors which have a significant influence on the marginal abatement costs.

Based on the calculated marginal abatement costs and the various possible reduction potential of fossil CO_2 emissions, a marginal abatement cost curve can be shown in Figure 3.

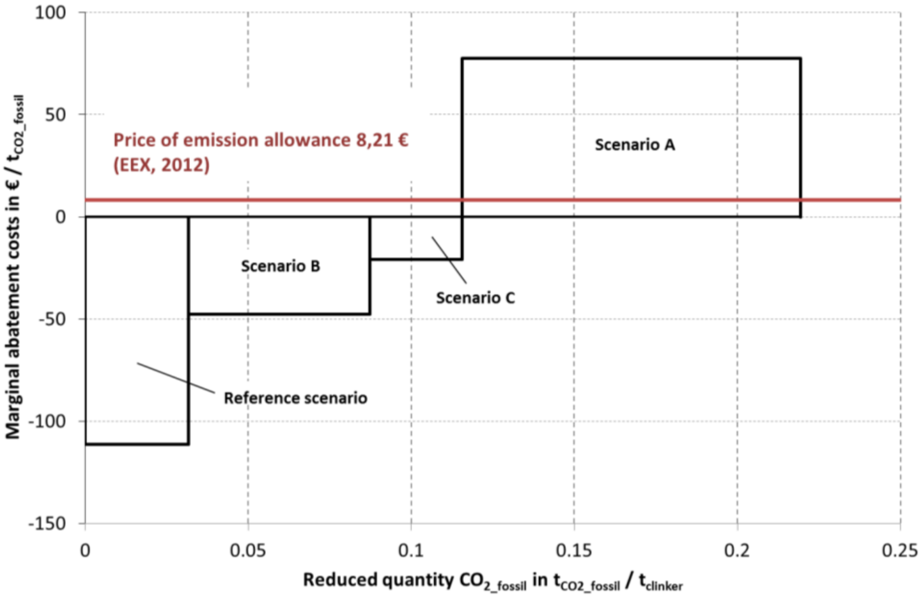


Figure 3. Marginal abatement costs – energetic utilisation of reed compared with different fuel mixes and CO_2 emission allowances
Source: Own work.

The scenario with the fuel mix with reed (scenario A) has the highest marginal abatement costs due to high production costs. Although the scenario which uses reed has the highest possible reduction potential of fossil CO_2. Compared to scenario A, scenario B, C and the reference scenario have negative marginal abatement costs but a lower fossil CO_2 reduction potential. Due to current market conditions the other alternative fuels are preferable.

4. Conclusions

From an economic point of view the production of chopped reed is significantly cheaper than the production of reed pellets. Harvesting of reed, as well as pelletizing, has a significant influence on the results of the economic performance. The economic findings could enhance considerably, when inventing a more efficient harvesting technology.

An investigation of market competitiveness with wood based biofuels is done. If the prices of chopped reed is compared to the market price for wood chips, this price cannot be reached. The production cost of chopped reed is between 14% and 26% above the market price of wood chips. On the other hand reed pellets are competitive to wood pellets. The production costs of reed pellets are between 8% and 25% below the market price of wood pellets.

The calculation of the marginal abatement costs of fossil CO_2 in the cement industry show that due to current market conditions, other alternative fuels are preferable to reed. Due to the high fuel production costs, the use of reed is too expensive compared with petroleum coke and other alternative fuels.

Acknowledgments

Research Partners in the project ENEREED are the University of Applied Sciences Fachhochschule Burgenland GmbH (project leader), Vienna University of Technology and the civil engineering consulting company TB Dr. Beckmann.

The project is realised in cooperation with (in alphabetical order): Esterházy Betriebe GmbH, Government of the Province of Burgenland, Güssinger Fernwärme GmbH, Herz Energietechnik GmbH, Lafarge Zementwerke GmbH and WWF – World Wide Fund for Nature. The project is funded by the Austrian "Klima- und Energiefonds" (carried out within the research promotion scheme "NEUE ENERGIEN 2020") and co funded by the Government of the Province of Burgenland, Lafarge Zementwerke GmbH and Herz Energietechnik GmbH.

Conflict of Interest

The authors declare no conflict of interest.

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Biomass transportation into power plants – calculation method of transportation distances

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Energy becomes indispensable nowadays. The economic standard of the countries is strongly affected by their energy supply. Fossil energy sources are rare so more and more renewable energy is needed to satisfy human needs. The most used renewable energy source is biomass in the word. It gives the 30–35 % of the energy supply in the developing countries and 3–4% in the developed countries (Demirbas 2004; Zeng et al. 2007). Biomass is a determinative renewable energy source in the Danube Region and also in Hungary. It can be arboreal or non-arboreal plant, main-product or by-product Láng (1984, 1985) and Bai et al. (2002).

Due to the regulation of the European Union all member states focus to the green energy so to the biomass also. Hungary favours the production of green power similarly to other countries in the European Union, based mostly on the directive 2001/77/EK. Hungary has excellent natural facility in plant growing. A large amount of biomass is produced in Hungary yearly. The biomass means the biggest energy potential for Hungary (Giber, 2006) that is why the country should focus to this.

By-products are also produced with the biomass, so the analysis of their usage is needed. There are different studies about the possible amount of the agricultural by-products used for energetics usage in Hungary: Bai (2011) has calculated 7–8 million t yearly and Gyulai (2007) has written maximum 10 million t of which 40–45% can be used.

Despite of wind, solar and water energy, transportation of biomass is necessary to get energy. This transportation process is an important and costly element of the energy production of biomass. The process has two sides: power plants need raw materials (demand) and biomass producers (farmers, forestries, etc.) want to sell their products (supply). In the crossing point of the demand and the supply the market price is given which will determine the maximum transportation distance.

The minimum needed transportation distance of the biomass user is compared with the calculated maximum economical distance of the biomass producer.

Table 1. The condition of the working of a biomass power plant

aspect of the power plant (demand)	condition	aspect of the farmer (supply)
minimum supply distance necessary for the safe working of the power plant [km]	≤	maximum economic transportation distance of the biomass producer (farmer, forestry ...) [km]

Source: Pintér (2012).

Based on the Table 1. an energetic plant can be safe supplied by biomass when the maximum economic transportation of the biomass producer is at least so big as the minimum supply distance necessary for the safe working of the power plant.

Consequently:

$$D \leq D'$$

where:

$$D = e \times \sqrt{\frac{\frac{\frac{\frac{E}{f}}{t}}{z}}{\pi}}$$

$$D' = \frac{I - fc}{vc}$$

after simplification:

$$e \times \sqrt{\frac{E}{h \times y \times z \times \pi}} \leq \frac{I - fc}{vc}$$

The markings are in the Table 2.

The method of calculation biomass transportation distances is summarized in the Table 2. where the 1–8 steps illustrate the side of the power plant (demand of the biomass) and the 9–11 lines illustrate the side of the farmer (supply of the biomass).

Sensitivity analysis are necessary to the values of the 'z' (which is dependent on the geographical place of the power plant), to the heating value and the specific output (yield) of the biomass and to the incomes and costs of the biomass producer in behalf of the better suit to the reality. The 4–6 steps and the 9–10 steps demonstrate this in the Table 2.

The variables of the context: the calorific value, the average yield, harvest area on the power station side, and the expenses and incomes on the smallholder's side. Analyses the change of all of them is necessary with sensitivity examination.

I took the revenues, i.e. the price of the paid biomass by the power station into consideration as income in the course of the burning of the biomass. The transportation, the bale/collect and bale loading expenses are incorporated in the expenses. It is obvious, that the transportation expense is directly proportional to the distance, while the expense of the baling and the loading is independent to the transportation distance so it is constant pro ton.

In the Table 2. there is an 'e' which value is not given, but here is calculated to Hungary. Using the below written method the value of 'e' can be calculated for different regions also.

I divide Hungary into three big geographical regions based on Alföldi et al. (2011):

- *Central Mountain Range*: contains the western Hungarian areas, the North and the Transdanubian Mountains. It gives one fourth of the territory of Hungary. I analysed the road infrastructure of Ajka and its surroundings.
- *Plain*: the Small Plain and the Great Plain are here and it gives half of the territory of Hungary. I demonstrate the road infrastructure of the plain areas through analysing the surroundings of Kisújszállás and Tiszapalkonya in Hungary.
- *Hills*: means the Transdanubian Hills which give one fourth of the territory of the country. I analysed the settlement of Söjtör.
- I analyse the air and road distances of the towns and villages which have more than 100 inhabitants and they are in 20 air km surrounding of the four chosen settlement. The "map24" program is helped by the calculation which can be used free of charge on the internet.
- The rate of the plain, hill and middle mountain areas of Hungary is defined by the average of the differences between the air and road distances. This rate is weighed by the rate of the big areas so the road-air distance rate of Hungary is calculated.
- I examine four settlements from three regions of Hungary to the accomplishment of the research.

Table 2. The logic of the research

Step	Mark	Defined value	Dimension	Condition
		SIDE OF THE ENRGETIC PLANT		
1.	P_{gross}	Gross energy product of the power plant	MW	$P_{gross} = P_{net} / \eta$
2.	P_{annual}	Annual energy production	MWh	run 8000 h/year
3.	E	Needed input energy	GJ	1 MWh = 3,6 GJ
4.	A	Needed total amount of biomass	t	The heat value is known ('h') [GJ/t]
5.	G	Needed production area where only the given biomass is produced	ha km^2	The yield of the biomass is known ("y") [t/ha]
6.	T	Needed supply area, which has 'z' % production area of the given biomass	ha km^2	The 'z' [%] is known
7.	r	The radius of the supply area (air distance)	km	$T = r^2 \times \pi \rightarrow r = \sqrt{T/\pi}$
8.	D	The needed minimum road transport to supply the power plant	km	The (road distance)/(air distance) is known ('e')
		SIDE OF THE FARMER		
9.	C	Costs	Ft/t Ft/tkm	Different cost types are known: dependent on the transportation distance (vc) [Ft/tkm] and independent on it (fc) [Ft/t]
10.	I	Incomes	Ft/t	Given price by the power plant is konwn [Ft/t]
11.	D'	Maximum economical transportation distance for a power plant	km	Costs and Incomes are known [Ft]
		THE COMPARISM AND ANALYSE OF THE 8. AND THE 11. LINES		

Source: Own work of the author.

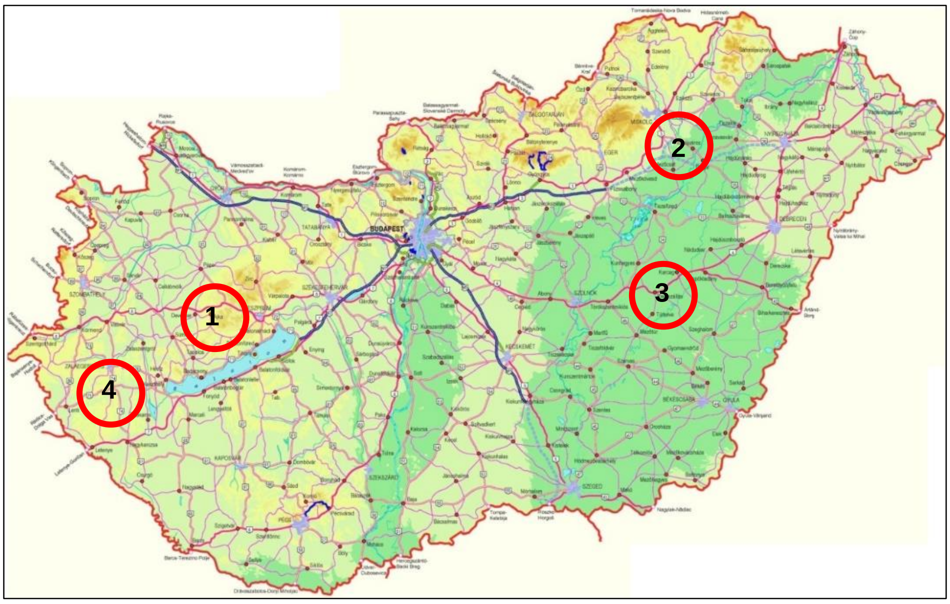


Figure 1. Study of air – road distances in Hungary
Legend: 1 – Ajka, 2 – Tiszapalkonya, 3 – Kisújszállás, 4 – Söjtör
Source: Own work of the author.

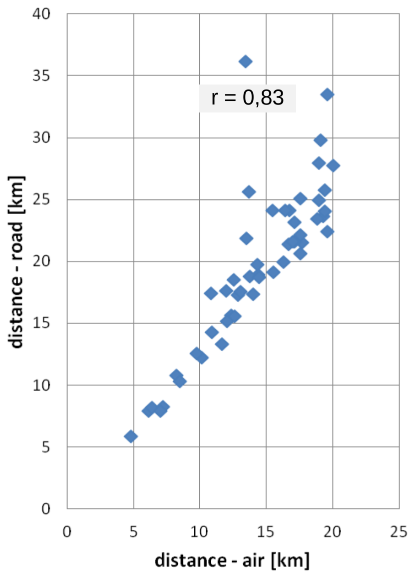


Figure 2. Road – air distances in Central Mountain Range (Ajka)
Source: Own work of the author.

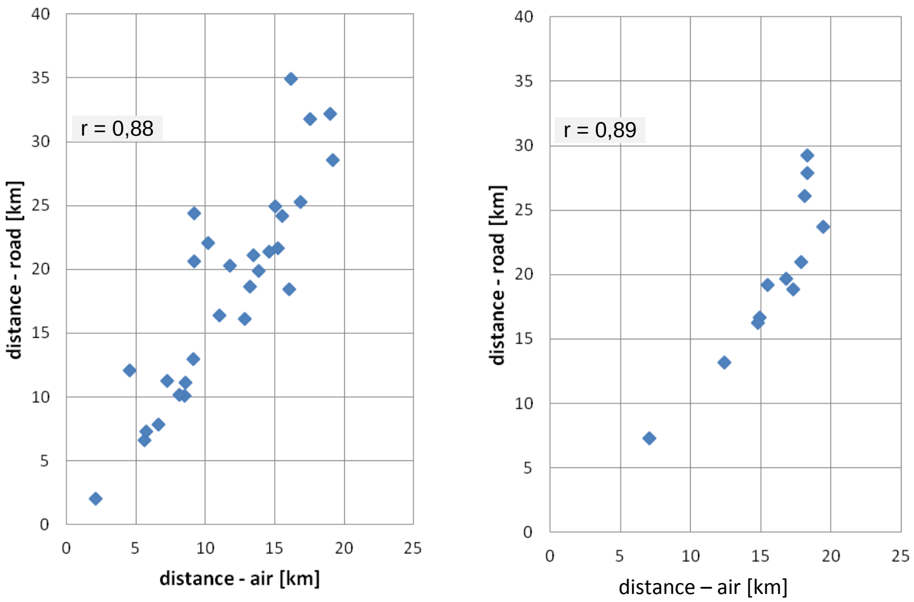
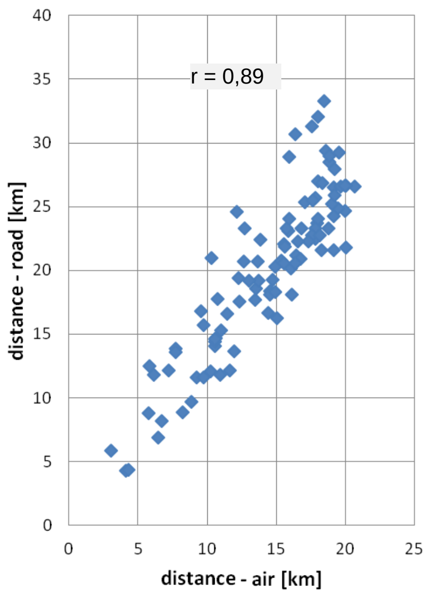


Figure 3. Road – air distances in Plain (left: Tiszapalkonya, right: Kisújszállás)
Source: own work of the author.



Graph 4. Road – air distances in Hills (Söjtör)
Source: Own work of the author.

1. Central mountains: where I examine road and air transportation distances between Ajka (Bakonyi Thermal Power Station) and the 51 settlements with a bigger number of inhabitants of 100 persons in a circle of 20 km around Ajka, correlation coefficient: 0.83.

2-3. Plain: The settlements of Kisújszállás and Tiszapalkonya represent it. The AES Borsodi Energetika Ltd. has worked in Tiszapalkonya until March 2011. I examine road and air transportation distances at 41 settlements around Kisújszállás and Tiszapalkonya with a bigger number of inhabitants than 100 persons in a circle of 20 km, correlation coefficients: 0.88 and 0.89.

4. Hills: Söjtör represents it in my research, where Zalai Hőerőmű Ltd. is planning the building of a straw power station. I examined 97 settlements, which are situated at least 20 km air distance from Söjtör with a bigger number of inhabitants than 100 persons, correlation coefficient: 0.89.

The value of the correlation coefficient fell between 0.7 and 0.9 in all the three examined regions, which report a tight, function-like positive direction contact between the air and the road transportation distances.

I established that the air distances are averagely 74.29 % of the road distances in the Central mountains, this value is 74.64 % on the plain areas, while 72.44 % on the hills, based on the examined characteristics.

The air transportation distance is 74.00% on average of the road transportation distance based on the results of examinations of 189 settlements in Hungary.

Based on the result of the calculation 1 km road transportation distance is equal to 0.74 km air distance onaverage in Hungary, i.e. 1.3514 km (1/0.74) road distance equals to 1 km air transportation distance. The received ratio was rounded up:

$$e = 1.3514 \approx 1.4$$

The upwards rounding is justified by the surplus distance of going into and out of the depot and in fields.

By the help of the ratio ‘e’ we have the missing parameter of the Table 2. and now we can calculate transportation distances at the side of demand and at the side of supply.

Transportation is necessary to the usage of biomass. This is an extra process which means extra cost at biomass compared with other renewables. The question is how we can calculate easily the necessary transportation distance. The author of this paper hopes, that the calculation and comparison of necessary transportation distances of different types of biomass can be easier by using these calculations methods.

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