Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Aquatic Sciences and Environmental Studies

Renewable energy potential and its exploitation on a regional scale

Based on the region CENTROPE

Karolina Nowak, BSc

Renewable energy potential and its exploitation on a regional scale, based on the region CENTROPE

Karolina Nowak, BSc

Supervisor: Martyn Futter,
Department of Aquatic Sciences and Environmental Studies SLU

Assistant Supervisor: Marina Bergen Jensen,
Department of Forest and Landscape LIFE-KU

Examiner: Ulf Grandin,
Department of Aquatic Sciences and Environmental Studies SLU

Credits: 30 hec
Level: E
Course title: Independent project/degree project in Environmental Science - Master's thesis
Course code: EX 0431
Programme/education: Master programme – Environmental Science in Europe, EnvEuro

Place of publication: Uppsala/ Copenhagen/ Vienna
Year of publication: 2011
Picture Cover:
Title of series: no:
ISSN:
ISBN:
Online publication: http://stud.epsilon.slu.se

Key Words: renewable energy, Centrope, regional, energy potential, centralized policies, feed-in tariffs

Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Aquatic Sciences and Environmental Studies

ABSTRACT

The renewable energy sector expands continuously due to ambitious energy goals for 2020 declared by the EU, however its expansion is hampered by several barriers in the field of costs, regulation and market performance. This study elaborates renewable energy potentials in the region Centrope and identifies in the next step possible factors affecting the successful development of renewable energy sector in the named region. The results showed that lack of information deriving from deviations in energy potentials on national and regional scale become incorporated in national energy policies and feed-in tariff laws leading to ineffective exploitation of renewable energy potentials on a regional scale. Additionally it was observed that centralized policies as found in the Czech Republic, Slovakia and Hungary enhance this process due to missing authorized regional autonomy, which could counteract and have an agenda regarding the exploitation of renewable energy potentials. Therefore it is recommended to enlarge regional autonomy in order to facilitate the development of renewable energy sector and provide more flexible feed-in tariffs taking into account deviations in renewable energy potentials on a regional scale.

PUBLIC SCIENCE SUMMARY

Regional potentials of renewable energy remain unused, although ambitious European and national commitments are made to increase the part of renewables in the energy sector.
The region Centrope has been analyzed by the study “Renewable energy potential and exploitation on a regional scale”, discovering the fact that current approaches and instruments used by national governments act inefficient in respect to the aimed expansion of renewable energy sector. Results of this study show that national potential analyzes provide not enough deeply investigations to support policy makers with basic information. Political decisions are then made incorporating lack of information about regional renewable energy potentials. As a result national legislation appears inappropriate, aiming for goals which cannot be fulfilled by regional areas, because their renewable energy potentials differ significantly from national estimations.
Furthermore Feed-in tariffs, which are known as “the main driver” for renewable energy expansion due to highly economical attractive and lucrative payments, are uncovered as likewise inefficient in their effect. Renewable energy sources with lower energetic value as biomass are far stranger supported by Feed-in tariffs than resources with high energetic value like geothermal energy. Especially the last-mentioned resources may require high initial investments but deliver remarkable energy output and contribute so much more to the achievement of the EU energy goals 20-20-20.

In the end, it is the common interest to fulfil the ambitious energy goals of each Member State of the EU. But inefficient support by renewable energy legislation and its instruments leads rather to a failure in the year 2020.

Therefore the author of the study “Renewable energy potential and exploitation on a regional scale” recommends a stepwise adaptation of national renewable energy legislation and Feed-in tariffs towards regional potentials of renewable energy. Such adaptation assists a competitive but sustainable development of the renewable energy sector.

The time is ripe to allow independent expansion of renewable energy by reducing interventions on the market and permit competitiveness of renewable energy sources. However governmental activeness should be maintained by a supportive function, which offers a stable and consequent financial framework creating a trustful but sustainable future.

TABLE OF CONTENT

1. Introduction 8
2. Methodology 9
3. The region Centrope 12
   3.1. Bioenergy 13
      3.1.1. Description 13
      3.1.2. Potential Areas 18
   3.2. Solar Energy 23
      3.2.1. Description 23
      3.2.2. Potential Areas 27
   3.3. Wind power 32
      3.3.1. Description 32
      3.3.2. Potential areas 36
   3.4. Geothermal energy 41
      3.4.1. Description 42
      3.4.2. Potential areas 46
   3.5. Legislation 50
   3.6. Financial support schemes in Centrope 53
4. Results of the survey – Renewable energy 58
5. Discussion 63
6. Conclusion 68
7. References 70
8. Appendices 76

LIST OF FIGURES

Figure 1: Agricultural area and forest in Centrope **14**

Figure 2: Bioenergy potential with environmental-compatible crop mix in Centrope **22**

Figure 3: Efficiency rates of single solar collector cells **24**

Figure 4: Elevation model of Centrope **27**

Figure 5: Yearly potential of electricity production by photovoltaic cells in Centrope **29**

Figure 6: Performance of photovoltaic modules (c-Si, CIS, CdTe) in respect to irradiation and temperature **30**

Figure 7: Yearly thermal potential of solar energy by solar collector cells in Centrope **31**

Figure 8: a) Energy output to the cube of average wind speed,
b) Rotor diameter and yearly generated power by wind turbines **33**

Figure 9: Wind energy potential in Centrope **37**

Figure 10: Nature protected areas in Centrope **39**

Figure 11: Urban areas in Centrope **41**

Figure 12: Geothermal fields of Europe **42**

Figure 13: Potential areas of geothermal energy in Centrope **46**

Figure 14: Feed-in tariffs in the Region Centrope from 2006-2008 .... **55**

Figure 15: Ranking of renewable energy sources for electricity generation **58**

Figure 16: Ranking of renewable energy sources for heating **59**

Figure 17: Expected expansion of renewable energy by sectors in 2020 .... **60**

LIST OF TABLES

Table 1: Utilization of biomass for bioenergy production **15**

Table 2: Advantages and disadvantages of bioenergy **17**

Table 3: Mobilization factors and energy yield of land use classes **19**

Table 4: Environmentally-compatible bioenergy potential by sector and Member State of CENTROPE in 2010 .... **20**

Table 5: Advantages and disadvantages of solar energy **25**

Table 6: Advantages and disadvantages of wind power **35**

Table 7: Roughness Classes and Roughness Length in respect to landscape types **38**

Table 8: Advantages and disadvantages of geothermal energy **44**

Table 9: National targets for renewable energy in the electricity sector 2010 and in total for 2020 **52**

Table 10: Important actions to facilitate considerable contribution of renewable energy sources .. **62**

1. INTRODUCTION

Renewable energy technologies are advancing forward and are on the way to penetrate the market. This trend derives mainly from the current issue of climate change and the need of global reduction of greenhouse gases.

The new energy goals of the EU designated in 2008 provide therefore an ambitious framework to guide renewable energy technologies towards a considerable contribution and successful penetration of the energy market. Although this framework is a good legal base, the relatively short term oriented goals impose immense pressure on the EU Member States thus they have less than 15 years left to cover 20% of total energy consumption in the EU by renewable energy.

Despite great efforts to facilitate the expansion of renewable energy, numerous barriers within the range of costs and pricing, regulatory and market performance exist. Such barriers cause slow transition to a ‘solar based society’. Furthermore they might impede even effective utilization of available renewable energy potentials. This study explores therefore the available energy potentials to utilize renewable energy sources and examines if existent barriers affect effective exploitation of these potentials. However the study area is limited to the region Centrope, located in Central Europe and comprises several sub regions of the neighbouring countries Austria, the Czech Republic, Slovakia and Hungary. Additionally the focus is set on the regional scale. Regional renewable energy potentials may remain unexploited due to several factors affecting national policies. Beyond that only four renewable energy sources have been taken into consideration. Bioenergy, solar and wind power and geothermal energy were identified as sources of the new generation, thus they experienced a significant rise in the last couple of years. On one hand financial support schemes promoted mainly the technology of these four renewable sources while on the other hand their technological performance became improved by intensified research.

The Centrope region has been selected for this study thus it bears considerable differences within national energy policies and renewable energy potentials, and permit therefore a better insight into the political and economic environment of renewable energy expansion.

This study has been conducted in collaboration with the University of Copenhagen, Faculty of Life Sciences, and the environmental consulting firm mecca, located in Vienna. This co-operation allowed therefore an elaboration of this work combining three different perspectives including theoretical, practical and environmental aspects and provides thus a higher level of objectiveness.

The following chapters explain and describe firstly the methodology of this study and pass into reviewing of existent data for the elaboration of renewable energy potentials in the selected study area. Later on results of a conducted survey will be presented following up by a discussion of the obtained information by this study. The closing forms a conclusion chapter giving a small outlook.

2. METHODOLOGY

This chapter examines the approach used in this study to identify factors causing barriers for successful progress of renewable energy production in the case of the Centrope region. This approach requires the exploration of current legal and economic environment for expansion of the renewable energy sector in Centrope. Therefore two main methods have been used in order to obtain needed background data, including existing policies and financial support schemes in context of renewable energy as well as available renewable energy potentials in Centrope.

Hence a regional analysis of renewable energy potentials does not exist so far for Centrope, the first step of this study required a literature review to collect information about each potential of renewable energy sources considered in this study and provide comprehensive overview energy potentials in Centrope. Implicated renewable energy resources are bioenergy, wind power, solar energy and geothermal energy. Additionally data of current energy policies and feed-in tariffs of each member state of Centrope have been obtained by contacting responsible renewable energy agencies and published reports.

Acquisition and analysis of background data led later on to a classification of centralized and decentralized countries in Centrope. This aspect enabled therefore the formulation of the following hypotheses:

> *Centralized energy policies impede effective utilization of renewable energy potentials on a regional scale.*

In order to test this hypothesis a second method of quantitative approach seemed appropriate. Consequently a survey has been conducted, which should also enable the identification of factors causing barriers for renewable energy production in this region, especially in the context of centralized energy policies. Assumptions made regarding these factors induce a list of research questions.

- Does lack of information exist on national level about regional renewable energy potentials? If yes, does it result in inefficient utilization of regional renewable energy potentials?
- Why does lack of information lead to inefficient utilization of renewable energy potentials on regional scale? Does it become incorporated into national legislation?
- Do centralized countries experience inefficient utilization of renewable energy potentials on regional scale due to their centralized policy structure?

- Are feed-in tariffs also affected by lack of information on national scale and lead therefore likewise to inefficient utilization of renewable energy potentials on regional scale?

The provided research questions served for adequate setting and grouping of questions for the survey. A semi-structured questionnaire design has been used for this survey to obtain explicit responses but provide also space for individual contribution of participants to the outcome of the survey. The sample of the survey consists of key actors in the sector of renewable energy like environmental consulting firms, renewable energy agencies or similar organization and electricity grid providers. While consulting firms were required to be located within the Centrope region to ensure knowledge about the study case area, other participants didn't necessarily need to fulfil the requirement. In addition the sample has been divided into four subsets of 8-10 participants according to member states of Centrope.

Thus the questionnaire was addressed to experts, specific issues in context with renewable energy where incorporated into five question groups, whereas one additional group served for obtaining demographic items and was placed at the end.

The first group served for a ranking of renewable energy sources according to their promising character to achieve EU-Energy Goals for 2020 in respect to national renewable energy potentials. The ranking has been asked for the sector electricity as well as heating. The second question group focused on the expansion of renewable energy and which sector would experience the strongest. Question group number 3 allowed participants to give individual response regarding barriers for the enhancement of renewable energy production. The forth question group examines weather centralized or decentralized energy policies are more appropriate or effective to achieve the set EU-Goals for 2020. The last content question group explored the importance of provided actions to facilitate penetration of renewable energy. The detailed questionnaire can be found in the appendix A.

The elaborated questionnaire has been transferred into an online survey application, which allows participants an interactive and quick handling of the questions via internet access. After pretesting of this survey, the duration of the questionnaire was estimated between 10-15 minutes, while the survey itself was activated for a time range of one and a half months. Selected participants received a letter via email inviting them to participate in the survey and providing access to the survey application by a web link. Furthermore anonymity and confidential treating of data has been ensured. After two weeks a first reminder was sent out to motivate participants who haven't responded yet to the questionnaire. The second reminder followed two weeks later.

At the date of expiration about 50% of contacted participants have answered the questionnaire. The obtained answer sets have been then analysed and processed with computer calculation programs. The report of the survey results is provided in chapter 4 'Results of the survey –

Renewable energy', while separated visualization of the results can be also found in the appendix B.

Finally it is necessary to point out that the survey output remained limited due to restricted time range for the study as well as probably undervalued sampling size considering a response rate of 50%. However the option to provide the questionnaire as a web application allowed obtaining answers from four countries at low costs within a short time period. Although this questionnaire was provided in English, language barriers could have influenced the response rate negatively. Participants may feel more motivated to answer a questionnaire which is provided in their native language. On the contrary personal interviews could bring participants into unpleasant situations due to language difficulties, while a web application enables participation in familiar surroundings.

3. THE REGION CENTROPE

Centrope as a quadrangle of four countries, Austria, the Czech Republic, Slovakia and Hungary became officially declared in 2003 as a region of intensive co-operation and networking to strengthen the potential of economic and social beneficiaries in the Central European Region (Centrope Consortium, 2006).

Such co-operation requires cross-border communication especially between the following federal states and regions: Vienna, Lower Austria, Burgenland – Austria; Trnava district, Bratislava district – Slovakia; Györ-Moson-Sopron, Vas – Hungary and South Moravia from the Czech Republic (Centrope Consortium, 2006). Although South Bohemia didn't officially enter the Region Centrope it has been often taken into account for cross-border co-operations, thus it represents an important partner region for economy and trade relations of the western part of Lower Austria (Plha, 2010, pers.comm). Therefore all analysis regarding the Centrope region will include South Bohemia as an actual part of Centrope.

In 2004 the East European countries as Slovakia, the Czech Republic and Hungary entered the EU. This accession enabled new possibilities for co-operation as well as let opportunities arising to strengthen the existent network (Centrope Consortium, 2006). Although Centrope is now part of the EU and has a common legislative base many difficulties can arise due to different economical development back in the history caused by the Iron curtain as well culture differences resulting in four different languages and opinions of shared future.

Nevertheless the establishment of Centrope should provide an appropriate framework to facilitate dynamic development resulting in 'growing together' of Centrope's parts. Therefore a common vision for 2015 was built in the year 2006 and commits participating regions to intensify their co-operation by pilot projects in the following sectors (Centrope Consortium, 2006):

- The economy should experience a boost by innovations. Renewable resources offer many opportunities for innovative technologies, which can serve as economic impulses. The pilot project focuses on 'Bio Substances' enabling production of organic plastic or other mixed composites using various biological matter (Centrope Consortium, 2006).
- Stronger co-operation regarding the Labour market allows more flexibility and increases job opportunities for more than 6,5 million inhabitants in Centrope. About 2,8 million people work and live in cities greater than 50,000 inhabitants. This fact illustrates that urban areas bear more attractiveness and should experience closer co-operation as

it is shown in the project 'Twin cities – Vienna and Bratislava' (Centrope Consortium, 2006; ARGE Centrope Agency, 2010).

- Furthermore the vision recommends more support for the education and research sector, thus knowledge based economies rely strongly on successful and progressive research. Therefore a pilot project of co-operative programs for higher education was established, which allows student cross-border education (Centrope Consortium, 2006).
- Apart of the mentioned sectors an additional focus is set on culture and tourism to overcome cultural differences and alleviate communication despite language differences. In result many cross-border events as concerts or movie festivals should provide more cultural exchange between people living in Centrope (ARGE Centrope Agency, 2010).
- The last focus is dedicated to transport and environmental issues, which are needed to be improved in order to facilitate regional development. Therefore a pilot project was recommended to elaborate a Map showing various characteristics of Centrope like infrastructure, environmental features and demographic data (Centrope Consortium, 2006).

Although many aspects have been considered in the elaborated Vision in 2006, the renewable energy sector remained rather untouched. The following potential analyses of renewable energy sources should therefore provide also a base for future shared development in this sector and encourage Centrope to stronger co-operation and networking in order to exploit its energy potential most efficient.

3.1. BIOENERGY

This chapter examines the potential of generating energy from biogenic matter. Firstly a short description will be given, following up by potential estimations of bioenergy.

3.1.1. DESCRIPTION

Bioenergy can be obtained by converted and processed biomass. This resource originates either from forestry or agriculture. Common conversion processes are combustion, fermentation for biogas production and extraction of oil and ethanol. Depending on type of technology bioenergy can be gained in form of heat, electricity or even transport fuel (EEA, 2006). However liquid biofuels won't be further considered in the upcoming remarks. Hence they are strongly related to the traffic sector, an adequate evaluation of the potential from liquid biofuels would exceed the scope of this work.

Because bioenergy resources vary as much as the vegetation provides different types, a general overview of two main land use classes, forest and agricultural area, presented in Figure 1 can be useful. Centrope's forestal areas are dominated in the western and southern part by coniferous trees and mixed forests, whereas the eastern part is characterized by broad-leaved trees. In general it is to note that rather mountainous regions in the west as also partially in the south of Lower Austria bear a considerable share of forest to the total area. Agricultural areas are more typical in plain territories as the Vienna Basin and the Little Hungarian Plain, hence lower altitudes and slope gradients offer more favourable conditions for demanding crops, like fresh vegetables and permanent crops as fruits and wine. Less favourable agricultural areas are usually planted with cereals and root crops or provide sufficient nutrients for pasture, meadows and woodlands (PGO, 2005a; PGO, 2005b; PGO, 2010).

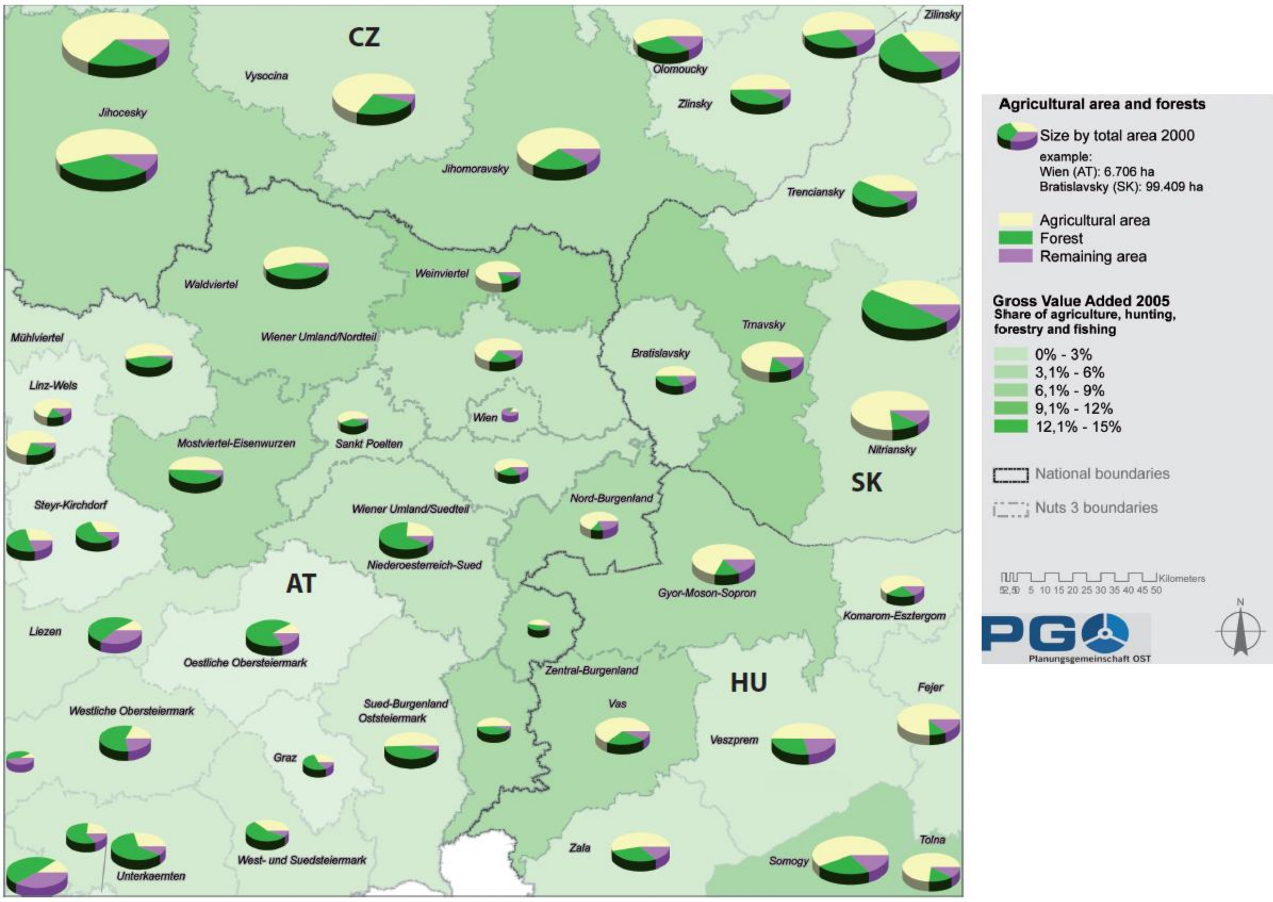


Figure 1: Agricultural area and forest in Centrope
Source: PGO, 2005a; modified

TECHNOLOGY

Bioenergy can be produced by several conversion processes of biomass. These are distinguished in thermo-chemical and bio-chemical processes. Furthermore extraction of oil is also possible but won't be considered in the upcoming explanations. As mentioned before it is strongly related to the transport sector (Faaij, 2006).

The following remarks will focus on two main biomass conversion processes: direct combustion in the range of thermo-chemical conversion and digestion as a bio-chemical conversion. Both processes enable the use of bioenergy for heat and electricity generation, partially even for fuel (Faaij, 2006). While direct combustion is usually utilized for forestal biomass, digestion processes are used for conversion of agricultural biomass. However soft wood, which is considered as agricultural biomass hence it is grown on arable land, serves for combustion instead due to its woody characteristics.

The following Table 1 presents therefore the utilization of biomass for bioenergy production according to the used technology type. Woody biomass as hard and soft wood suits best for combustion, although it requires dry matter with very low water content at about 20% (Jirjis, 2009). These conditions can be obtained by prior processing of wood resulting in products like wood chips and pellets. On the other side agricultural biomass is mainly used for digestion processes. Biogas extraction of bioenergy crops appears to be efficient, thus anaerobic digestion does not require highly dry matter. A water content of 40-50% assists gas formation optimally (Tetzlaff, 2010).

However lower water content can be determinant for combustion processes and resulting energy output. The more green biomass is incinerated the lower the obtained energy per biomass unit (Jirjis, 2009; Lechner, 2004).

Table 1: Utilization of biomass for bioenergy production

Forestal biomass	Agricultural biomass	
Forest areas (hard wood)	Woodlands (soft wood)	Bioenergy crops
harvest residues, complementary fellings	perennial crops, short rotation forestry	annual food or fodder crop (optimized)
stem wood, stem top and stump, branches, foliage, roots, etc.	poplar, willow, miscanthus, etc.	sugar cane, maize, perennial grasses, cereals, etc.
dry matter (wood chips, pellets, etc.)	dry matter (wood chips, pellets, etc.)	moist matter (silage, press cake, etc.)
direct combustion		digestion - biogas
heat and power		

All over it is to note that storage of biomass demands at least reduced water content to about 15% to ensure enduring conservation. Otherwise destruction processes like fermentation occur and disable further utilization of biomass. Therefore especially woody biomass has to undergo conversion processes in order to maintain continuing supply of resources. Whereas bioenergy crops can be either utilized directly for biogas production permitting destruction processes or be stored under controlled measures called silage. This measure allows an enduring storage of green biomass by hermetically sealed packages. However after silage the water content needs to be adapted to obtain still efficient gas formation. This can be achieved by pressing of biomass resulting in a press cake of about 50% water content (Tetzlaff, 2010; Buchgraber, 2006).

As mentioned before direct combustion is applied to dry woody biomass. The actual combustion process, where wood is transformed into a gas mixture and ash, is called pyrolysis. This process requires very high temperatures to ensure complete degradation of woody biomass. The high temperature requirement derives from the typical composition of wood. The structural components, cellulose, hemicelluloses and lignin reach their complete degradation at different temperature ranges. While hemicelluloses requires the lowest temperature of 200-260°C, cellulose is degraded at about 240-350°C. Lignin at the contrary needs a temperature from 280-500°C to degrade completely (Quaak, et al., 1999; Jirjis, 2009). Although the whole combustion process needs to happen in an inert atmosphere, a continuously supply of oxygen is obligatory to maintain the progressive degradation of biomass (Jirjis, 2009).

The combustion of biomass takes place in a furnace, where pyrolysis degrades wood to ash and gas. The developed heat is then transported by flue gas to a boiler including heat exchanger, which in turn forwards the heat to the connected heating system (Quaak, et al., 1999). Apart from heat generation also electricity can be gained by an additional step. The resulting gas mixture can be transported to electricity generation plants, where gas turbines transform heat into electricity.

The second named technology was conversion of agricultural biomass by digestion process. In contrary to combustion, digestion has to take place in absence of oxygen, which means under anaerobic conditions. Therefore the digester tank needs to be hermetically built as well as stand high pressures during the degradation process. Moist biomass can thus be degraded by microbial activity. To ensure sufficient amount of active bacteria a temperature of at least 20°C has to be provided. However the successive decomposition of biomass originates in different temperature sensitivity of active bacteria. Psychrophile bacteria need a temperature of approximately 25°C, while mesophile bacteria function best at 32-38°C. Thermophile bacteria just start to degrade substrate at about 42-55°C (Rutz and Janssen, 2007).

Besides temperature also different functions of bacteria determine the digestion process. At the beginning hydrolytic bacteria transform complex organic matter into basic molecules like amino acids and sugars. Afterwards fermentation starts, where bacteria transform these molecules to organic acids. Finally acidogenic microbes break remaining molecules down to methane and carbon dioxide. Thus the end product of anaerobic digestion is biogas and consists mainly of methane and carbon dioxide with a ratio of 6:4 (Nayono, 2010; Rutz and Janssen, 2007; Lechner, 2004). For the actual utilization of bioenergy a purification process of the gained biogas is needed.

The obtained gas with a content of 95% methane can be then used for any gas applications providing heat or electricity (Rutz and Janssen, 2007).

Anaerobic degradation during dry digestion takes between several weeks and a few months for wet digestion due to differences in biomass type and digestion temperature (Nayono, 2010).

Advantages and Disadvantages

The following explanations point out advantages and disadvantages of bioenergy production. Table 2 displays therefore the main aspects.

Table 2: Advantages and disadvantages of bioenergy

Advantages	Disadvantages
High availability	Low energy output
Economical feasibility	Competition with food/fodder production
Stable base load of energy supply (heat)	Strong limitation by protected areas
Spatial structures	
Balanced emissons during energy production	

Bioenergy is highly available due to great diversity of vegetation. Nevertheless its potential is significantly limited by competiton with food or fodder production as well as protected areas. However bioenergy production remains to be economical feasible, hence investment costs are considerable lower than for wind or even solar energy exploitation.

On the other side energy from biomass provides in comparison to conventional energy resources low energy output in respect to mass. This in turn might lead to increasing consumption of land for bioenergy. Although bioenergy production appears to be less efficient it permits due to continuous resource supply a stable base-load for smaller or middle-sized plants. Very large-scaled plants need greater catchment areas and risk therefore insufficient base-load supply. Most common decentralized middle-scaled plants adapt optimally to regional spatial structures. Bioenergy can be also produced and utilized by a household which makes the energetical potential also available to smaller demands.

Finally it is to note that production of bioenergy causes just as much emissions as can be captured by the grown biomass. Therefore bioenergy exploitation might not be free of emissions but incorporates them back into biomass due to its cycle continuity.

Criteria for potential areas

Bioenergy resources function complimentary, so that their potential appears high. However certain factors set limitation upon bioenergy potential. These factors have been identified and will be described in the upcoming list.

- Protected areas cover large parts of forest areas, so that a mobilization of wood for bioenergetical utilization is restricted due to designated zones permitting only certain tending strategies (mecca, 2008; EEA, 2006).
- Thus bioenergy crops are also cultivated on arable land; a conflict of interest emerges between food/fodder production and bioenergy cropping. This competition can be avoided by replanting fallow land, which hasn't been used due to over production of food products in the last decades. However some regions need to ensure firstly basic food supply and can thus not enable many areas for bioenergy mobilization (mecca, 2008; Tetzlaff, 2010; EEA, 2006).
- Site characteristics like soil fertility and water capacity determine growing conditions for a region. Low soil fertility and water availability restrict opportunities to may grow high yielding bioenergy crop due to its relatively high nutrients demand. Furthermore bad growing conditions limit the possible crop diversity, so that only few crop types can deal with the given soil characterisitics.
- Bioenergy crops are optimised to fulfil their requirements of high energy content. Crops with less environmental impacts should be therefore selected in order to ensure sustainability in the cropping system. The recommendation of environmentally-compatible crop mix is provided by the EEA and will be thus included in assessment of bioenergy potential (2006).

3.1.2. Potential Areas

Centrope bears a great diversity of resources for bioenergy production. As presented in Figure 1 agriculture is dominating Centrope's landscape and contributes therefore the most to a mobilization of land for bioenergy. 10% of arable and grass land can be mobilized, although the competition between food or fodder production and energetical utilization of biomass still exists. Fallow land can be used up to 50% of existing areas (mecca, 2008). The provided mobilization factors are presented in Table 3 and derive from interactions of explained criteria for identification of potential areas, as protecting areas, conflict of interest and growing conditions.

Table 3: Mobilization factors and energy yield of land use classes

Biomass	Energy yield (theoretical) MWh/ha/a	Mobilization factors	Energy yield (practical) MWh/ha/a	Ranking
Forest area	16	0.4	6.4	3
Arable land	40	0.1	4	4
Grass land	35	0.1	3.5	5
Fallow land	30	0.5	15	1
Reed	26	0.5	13	2

Source: mecca, 2008; modified

Furthermore fallow land gives the opportunity for dedicated bioenergy crop cultivation in respect to the selected crop mix and cropping systems. As already mentioned before the selected crop mix needs to be environmentally-compatible but still yields a large crop. In example perennial crops like willow or poplar reduce soil erosion and compaction, whereas maize as an annual crop shows environmental impacts in these categories. In addition its high vulnerability towards diseases and high nutrients demand makes it less favourable for sustainable energy crop cultivation. With in annual crops cereals should be prioritized due to their high environmental compatibility. Usually if several crops have similar environmental performance, the preference should be given to less frequently grown crops in order to increase biodiversity at the field (EEA, 2006).

The enabled forest areas for bioenergy are mainly restricted by protecting areas to reduce human interventions in the ecosystems. However the designation of zones with differing protection degrees allows certain tending strategies in the uttermost zone of a protecting area. Thus the mobilization factor is estimated at about 40% for bioenergy production.

Also additional forestal biomass can be mobilized by utilization of so far not extracted parts of trees as stumps, roots and branches. Nevertheless the aspect of environmentally- compatible measures has to be respected, hence an over extraction of the mentioned tree parts can disturb the ecological balance of a forest due to missing nutrient input (EEA, 2006; Andrae, 2006).

The following Table 4 demonstrates now bioenergy potential available in the Member States of Centrope. This potential estimation considers previously described criteria as also dedicated bioenergy crop mix on agricultural areas. The numbers are provided in unit of oil equivalents, mass, volume and energy to visualize bioenergy potential in practical and theoretical manners.

Table 4: Environmentally-compatible bioenergy potential by sector and Member State of Centrope in 2010

Country	Bioenergy potential (without waste streams) in 2010						
	Agriculture		Forestry		total	Energy yield (total)	
	MtOE	1 000 t	MtOE	m³	MtOE	GJ	PJ
Austria	0.6	8,778.8	3.3	18,738,260.3	3.9	163,285,200	163.3
Czech Republic	0.8	3,601.5	0.8	7,687,491.4	1.6	66,988,800	67.0
Hungary	1.2	3,151.4	0.2	6,726,555.0	1.4	58,615,200	58.6
Slovakia	0.2	2,701.2	1.0	5,765,618.5	1.2	50,241,600	50.2

Source: EEA, 2006; modified

Austria has considerably more forestal than agricultural potential. However the possible mobilization leads to the highest total potential in comparison to other countries of Centrope. Although Czech Republic provides the highest potential within east European countries of Centrope, Austria's potential for bioenergy utilization is more than two times higher than Czech Republic's bioenergy potential. This difference may be founded in the ratio of forest areas to total area, thus forestal biomass has a higher energy output than agricultural biomass (PGO, 2010; mecca, 2008).

Hungary's bioenergy potential should be assumed to be the highest in this comparison due to its country size. But the Hungarian landscape is dominated by agricultural activities and bears only a small share of forest areas, which in turn leads to significantly lower bioenergy potential (PGO, 2010). In addition intensive agricultural practice as greenhouse growing hampers strongly the mobilization of areas for bioenergy production (Gergerly, 2009, pers.comm.). Slovakia on the other side experiences main limitation to area mobilization by protected areas covering large parts of forest. Furthermore agricultural land is restricted to remaining areas but needs to serve for basic food supply. This situation enables therefore only few areas for bioenergy production (PGO, 2005b).

Scaling down the just provided national bioenergy potential to a regional scale, Centrope's resources for bioenergy production seem to be more divers within the agricultural sector but remain to origin mainly from the same land use type. Figure 2 illustrates therefore the allocation of forest and agricultural resources as well as potential environmentally-compatible crop mix in Centrope.

According to the allocation of forest areas in Centrope, woody biomass is predominantly available in the western parts showing continuity from South Bohemia over southern parts of Lower Austria towards southern Burgenland and Vas. High bioenergy potential from forestry can be found in the south-western part of Lower Austria. Other forestal areas bear less potential due to their comparatively small share to total area.

The remaining parts of Centrope are characterized by agricultural activities, especially the eastern parts with Trnava district in Slovakia and Györ-Moson-Sopron in Hungary. While the centre of Centrope as surroundings of cities like Brno, Vienna and Bratislava serves for basic food supply, the peripheral areas offer more opportunities for crop diversification within dedicated bioenergy crops.

The environmentally-compatible crop mix has been adapted to each subregion of Centrope and is also illustrated in the Figure 2. Regions designated for basic food supply experience a strong competition between bioenergy crops and food production. Therefore only few areas can be mobilized for bioenergy. These areas are mainly fallow land and offer the opportunity to plant crops with high energy yield as perennial crops and short rotation forestry, whereas perennial crops have been prioritized in areas with low share of wood land in order to reduce interruptions of the structural landscape (EEA, 2006). In addition double cropping systems can provide high yields at low environmental impacts on soil and water resources. The yearly rotation of C3 and C4 plants lead to a high environmental performance due to optimal exploitation of nutrients in the soil. However an adequate selection of crops requires more detailed on-site investigations for this system (Tetzlaff, 2010; EEA, 2006).

As mentioned before peripheral areas suit better for more diversity within bioenergy cropping. South Bohemia offers due to current land use good conditions for short rotation forestry and perennial crops as well as cereals and grass land. Double cropping systems have been excluded for these regions due to rather poor soil fertility. North-western part of Lower Austria provides a similar crop mix but bears better soil conditions for double cropping systems.

On the other side middle parts of Lower Austria enable a high diversification of bioenergy crops. However the priority should be given to more energy efficient crop types as short rotation forestry and perennials. Comparable crop mix was also identified in the south of Centrope. Although the share for food production is increasing towards East, several areas for short rotation forestry, perennials as well as cereals can be enabled.

The district Györ-Moson-Sopron is characterized by intensive cropping and provides therefore no suitability for grass land. However double cropping systems and growing of cereals remain to be adequate for the given soil conditions. In addition short rotation forestry and perennial crops can be also planted to increase biodiversity on the fields.

The district Trnava has a high share of agriculture, although its soil fertility is rather low and suits therefore only for cereals and perennial crops. Short rotation forestry proved to be less appropriate due to open landscape structures in this subregion.

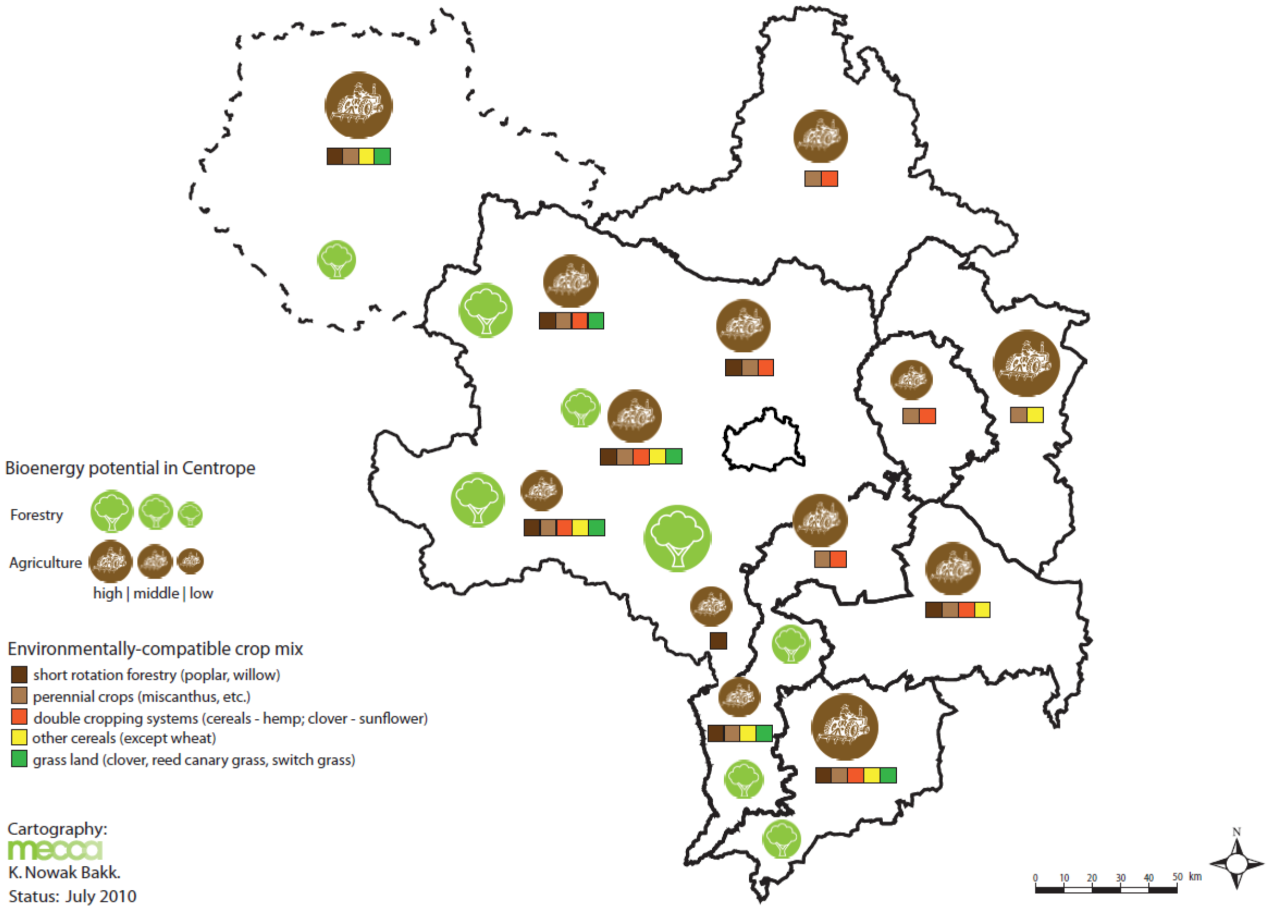


Figure 2: Bioenergy potential with environmental-compatible crop mix in Centrope
Source: PGO, 2005ab; EEA, 2006

At the end it is to note, that forestal biomass appears to be a bioenergy resource with less flexibility due to its slow growth. Also the energy output varies hardly within different types of wood. Agricultural biomass on the contrary offers broad diversification in respect to energy output and crop type, which leads to the environmental benefit of increasing biodiversity. Although bioenergy crops are less weather dependent than conventional food crops, they remain to be more sensitive to weather extremes than forest. Therefore a complementary utilization of forestal and agricultural resources should be aimed for bioenergy production.

3.2. SOLAR ENERGY

This chapter examines the potential of generating energy from the sun. Firstly a short description will be given, following up by potential estimations of solar energy.

3.2.1. DESCRIPTION

Solar energy is the main driving force on earth. It initiates many natural activities like rain, wind and photosynthesis. However not all energy which comes from the sun can be utilized. About 30% of the actual irradiation beam is reduced while entering the atmosphere. Processes as reflection, scattering and absorption decrease total global insolation from 219 000 MWh to about 1000 W/m² at the surface during clear sky conditions (Austrian Energy Agency, 1999-2010).

Sun irradiation can be separated in direct and diffuse irradiation. Over the year shares of direct and diffuse light are balanced, but the monthly average of diffuse irradiation can vary. Middle Europe receives about 40% diffuse irradiation in May and 80% in December (Austrian Energy Agency, 1999-2010; Šúri et al., 2007).

While diffuse irradiation is less favourable for exploitation of solar energy, direct insolation plays an important role. Nevertheless direct insolation is also affected by seasonal variability. Less variability between summer and winter time can be measured in the south due to latitudinal location. In areas situated at high latitudes observed deviations can vary up to 100% from a yearly average (Šúri et al., 2007).

TECHNOLOGY

Solar energy can be exploited by two main technologies. While photovoltaic cells transform solar energy into electricity, solar collectors utilize it for heat production.

The former technology provides various photovoltaic modules. The current market situation offers three common modules which are based either on crystalline silicon (c-Si), Copper-Indium-Gallium-Selen (CGIS) or Cadmium-Telluride (CdTe) material. The last two modules are known as thin-film based technologies, while c-Si provides the most common mono- and polycrystalline module on the market (Huld et al., 2009).

Thin-film based modules show higher efficiency rates because of less sensitivity to diffuse light, but crystalline modules produce more energy per m². On the other side c-Si and CGIS modules are relatively sensitive to high temperatures, but CdTe occurs to be rather sensitive to spectral changes of light (Huld et al., 2009; My Energy GIE, 2009a).

Photovoltaic panels consist of a semi conductor material like Silicium. Its main characteristic is that it becomes electronically conductive when it gets in contact with light or heat. This attribute is utilized to generate electricity by tapping electric charge (German Society for Solar Energy, s.a.). Technology of photovoltaic permits by direct use a contribution to energy supplying systems.

Furthermore photovoltaic modules are mounted in three different ways: horizontal, vertical and optimal inclined. While horizontal panels are seldom due to their low energy output, vertical installations can be found very often included in architecture and mounted on facades. Optimal inclined modules follow the most advanced technology. Some installations are fixed on the roof at an optimal angle to the sun, whereas other photovoltaic panels follow the rise and set of the sun with one or two-axis tracking systems (Súri et al., 2009; PVGIS – European Communities 1995-2010).

The second technology can be divided in two common modules of solar collectors: flat-plate collectors and evacuated-tube collectors.

Solar energy is captured by an absorber in a flat-plate collector. The received heat is transferred to a medium which stores the energy. A selective surface coat and an appropriate insulation at the back of the collector maximize the energy output of this technology. Evacuated-tube collectors transform solar energy into heat in a similar way, although the evacuation of glass tubes substitutes the conventional insulation (My Energy GIE, 2009b; German Society for Solar Energy, s.a.).

The following Figure 3 illustrates the efficiency rates of single solar collector cells. The optical loss describes the share of sunlight which could not penetrate the collector glass and remained to be reflected. On the other side, thermal loss varies in respect to the ambient temperature of the collector. High temperature differences lead to increasing heat exchange and limit thus the energy output of solar collectors (German Society for Solar Energy, s.a.; Austrian Energy Agency, 1999-2010).

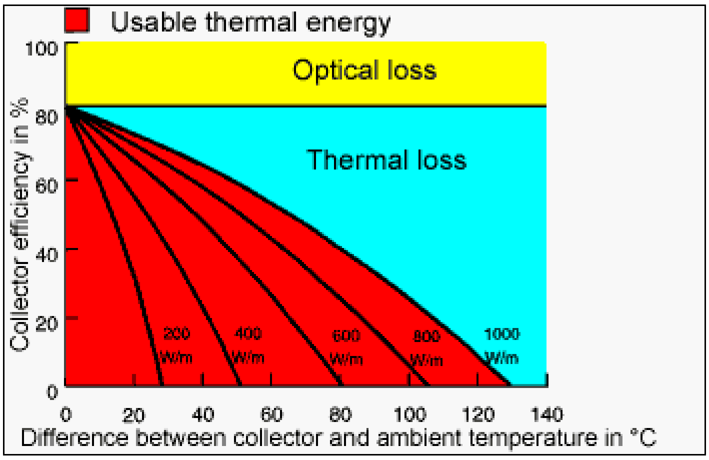


Figure 3: Efficiency rates of single solar collector cells, Source: German Society for Solar Energy, s.a.

Solar collectors serve in general for heating up sanitary water or buildings. Also additional heating of swimming pools is quite common in Central Europe (Austrian Energy Agency, 1999-2010).

Advantages and Disadvantages

The following explanations will describe advantages and disadvantages of solar energy. Table 5 presents for this purpose the main aspects.

Table 5: Advantages and disadvantages of solar energy

Advantages	Disadvantages
High availability	Unstable energy supply
Independent of spatial structures	Many feed-in possibilites for electricity required
Economical feasibility	Technology efficiency
Energy production free of emissions	

Although solar energy is provided all over the earth, not everywhere it is reasonable to exploit this energy. Geographical features may limit the irradiation income at the surface. Nevertheless utilization of solar energy can take place and rather independently of spatial structures. However solar panels can be combined with architecture of buildings forming new facades and provide thus energy. Installations of solar panels can be made in urban areas as well as on the country side. However this independency may be restricted in respect to feed-in possibilities, especially for photovoltaic systems. Many feed-in possibilities can overload the electricity grid with peaks of high supply.

Furthermore energy supply provided by the sun is very unstable; hence the energy output is influenced by many factors in particular by weather conditions and seasonal variability of the sun. Therefore is solar energy suitable to provide neither a base-load of energy nor to cover consumption peaks. Only occasional situations when favourable weather conditions occur at the same time as energy demand are beneficial for energy contribution by solar resources.

On the other side economical feasibility of solar technology improved in the last years by subventions and feed-in tariffs, so that a significant increase of installations is noticed. This beneficial development alleviates stand-alone energy supply of households, which in turn boost the market penetration of renewable energy technologies. Although technological efficiency of solar panels, especially solar collectors, bears potential for improvement, energy production from solar resources remains to be free of emissions and is therefore beneficial for the climate.

CRITERIA FOR POTENTIAL AREAS

Solar energy as mentioned before is a resource which can be utilized wherever sufficient irradiation is measured. However some factors may have a stronger effect on the incoming irradiation. This part will therefore explain the main influencing factors of solar energy potential.

- The key factor latitude determines the angle of incident sunlight to the earth surface. Thus tropical areas near the equator receive the most irradiation, which is decreasing with higher latitudes towards north. Middle Europe is located at latitudes from 45-55°. Additionally optical thickness of the atmosphere affects the insolation beam by absorption and scattering, so that a reduced amount of irradiation reaches the surface (Šúri et al., 2007; Hofierka and Cebecauer, 2008).
- Elevation and terrain are important geographical features, which influence the irradiation at the surface. While elevation determines also the optical thickness of the atmosphere and so the gradient of direct and diffuse light, terrain features as mountains or hills can restrain the irradiation at the surface by shadowing neighbouring areas. Low altitudes of the sun in particular during the winter time can lead then in mountainous areas to a radical limitation of sunlight. On the other side mountains provide also good potential areas for solar energy use (Hofierka and Cebecauer, 2008).
- Atmospheric conditions like weather processes affect strongly irradiation. Cloud formations and precipitation decreases the share of direct sunlight and increases diffusion of light. Diffuse light bears less energy due to undergone several scattering and reflection processes. Furthermore the chemical composition of the atmosphere can also play an important role. High pollution rates lead to absorption and more scattering processes, which in turn reduce the incoming energy by the sunlight and modify its spectrum. (Šúri et al., 2007; Hofierka and Cebecauer, 2008).
- Time dynamics of the sunlight appear during daytime as well as over the year through seasonal variability. The reason for these dynamics is the angle of incidence. In the morning and evening the sunlight is weaker than at midday and provides therefore less energy to use. Likewise the seasonal variability between summer and winter can present up to 100% variation from a yearly average of irradiation (Šúri et al., 2007; Hofierka and Cebecauer, 2008).
- Additionally exposition to the sun as well as the orientation of solar panels on buildings can improve the outcome of energy significantly.

3.2.2. POTENTIAL AREAS

As already described in the previous explanations, geographical features play a significant role for the potential of solar energy use. According to Figure 4 which shows an elevation model of Centrope the main potential areas can be identified in the south-eastern part of Centrope, where low lands of the Pannonian Plain are situated. Mountainous terrain of Granite and Gneiss highlands to the west and respectively the Alps to the south-west of Centrope reduce incoming irradiation by shadowing neighbouring areas. Especially during the winter time, when sun altitudes become low, irradiation at the surface decreases to a minimum. Areas surrounded of mountainous terrain are therefore less suitable for solar energy use.

On the other hand hills and mountains can also provide very good potential areas due to decreased optical thickness of the atmosphere and elimination of shadows (Hofierka and Cebecauer, 2008).

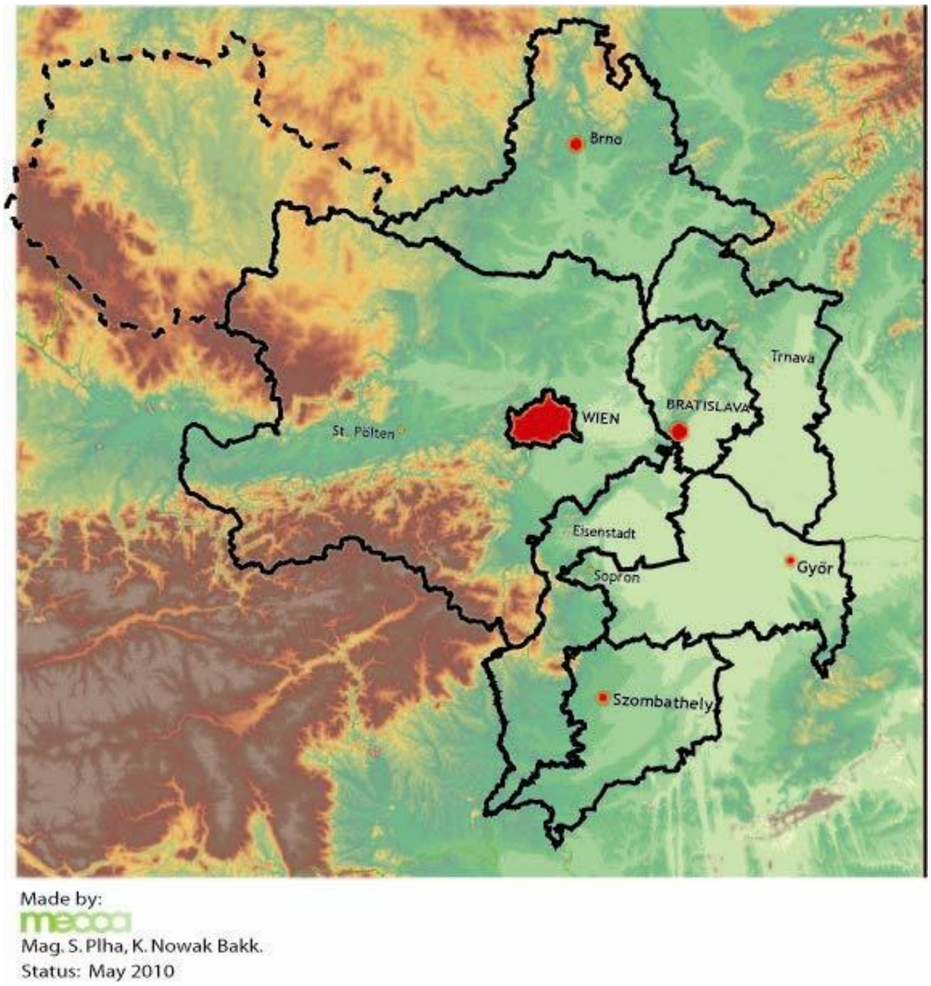


Figure 4: Elevation model of Centrope
Source: Centrope map, 2010

However a more detailed analysis of potential areas for solar energy use requires knowledge about local climatic and atmospheric conditions. Centrope, which lies almost completely in Central Europe is characterized by continental summers and rather dry winters and receives at the surface about 1100-1400 kWh/m² of irradiation. Hence it is situated in the range of latitudes 45°-55° the atmosphere above Centrope is relatively thick. This leads to a high diffusion of light and rather low direct insolation (Šúri et al., 2007; PV GIS - European Communities, 1995-2010). Furthermore high pollution rates in the atmosphere can enhance the effect of scattering and influence the spectrum of light, which in turn can affect the energy output of solar panels (Hofierka and Cebecauer, 2008; Huld et al., 2009).

But to maximize the energy output of the incoming irradiation it is necessary to bring solar panel modules into the optimal position to the sun. The optimal inclination angle for photovoltaic panels in Centrope is 34°- 36° depending on local conditions (Šúri et al., 2007; Huld et al., 2009). Solar thermal panels require about 40° of inclination to optimize their energy output (My Energy GIE, 2009c).

The open source software PVGIS provided by European Communities (1995-2010) allows a relatively accurate estimation of potential electricity production by photovoltaic panels. The calculations are based on collected temperature and irradiation data over several years. The following Figure 5 derives from these calculations and demonstrates exemplarily the yearly potential electricity production for Centrope at standard test conditions. These conditions imply a temperature of 25°C, an optimal inclination angle of 35° as well as the orientation of the system towards south (0°). A photovoltaic panel provides in general 1 kWh/m² peak power and has an efficiency rate of 75%. Additionally total system losses have been estimated by the software at about 24% (Šúri et al., 2007; PV GIS - European Communities, 1995-2010; Huld et al., 2009). The photovoltaic technology of crystalline silicon has been selected for the estimation of potential electricity production, thus it is the most common installed photovoltaic module (Huld et al., 2009).

Furthermore eleven localities presented in Figure 5 act as benchmarks for various levels of solar energy potential in Centrope. Česke Budejovice, Brno and Breclav illustrate the part of Czech Republic, while Krems, St. Pölten and Vienna represent the Austrian part of Centrope. Slovakia is displayed by Bratislava and Trnava and Hungary is expressed by Sopron, Szombathely and Györ.

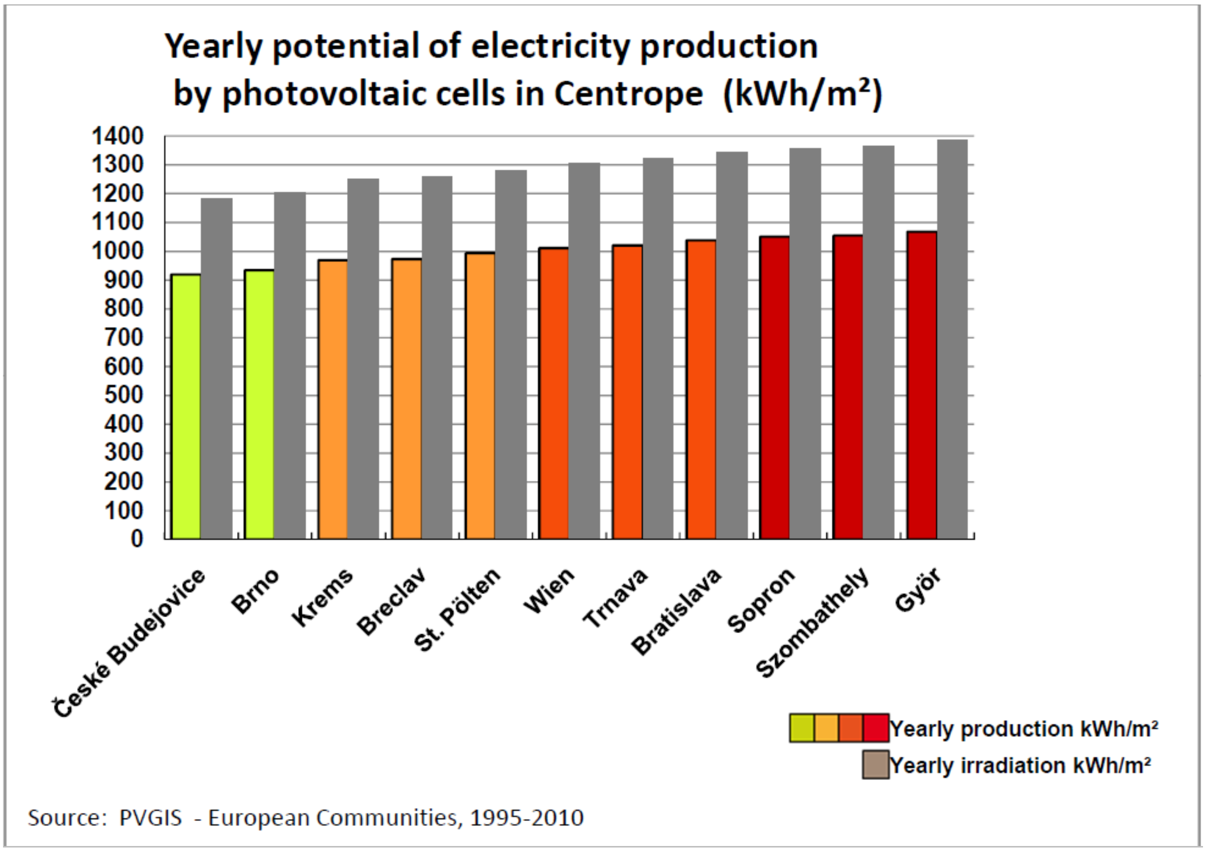


Figure 5: Yearly potential of electricity production by photovoltaic cells in Centrope
Source: PV GIS - European Communities, 1995-2010

The Czech Republic has a rather low potential for solar energy use compared to the Hungarian part of Centrope, while Austrian and Slovakian parts represent the middle field. Areas around Česke Budejovice and Brno can provide 900-950 kWh/m². In contrast Hungary can achieve 1050-1100 kWh/m². Slovakia follows shortly after Hungary with 1000-1050 kWh/m². Eastern part of Austria shows similar values as Slovakia, although the western part holds less solar energy potential, which is 970-1000 kWh/m².

The locality Breclav represents a special case. Its area lies in a very close vicinity to the West Carpathians and benefits therefore also from the good conditions of Slovakian solar energy potential.

Overlapping these results with the elevation model from Figure 4, assumptions made previously regarding potential areas in Centrope are confirmed. The Danube depression starts near Vienna and continues further east into the Pannonian Plain, following the same path the potential for solar energy use is continuously increasing towards south east of Centrope.

Beyond that an optimal exploitation of the potential of solar energy can be reached by a reasonable selection of photovoltaic technology. Comparing the performance of different technologies available presently at the market can bring significant beneficiaries for the energy output (Huld et al., 2009). At the present offered technologies are the common crystalline silicone (c-Si) module and two thin-film based modules with CIGS and CdTe. A comparison of these technologies in respect to temperature and spectral sensitivity as well as irradiation efficiency can entail up to 12% more energy output (Huld et al., 2009).

The following Figure 6 shows graphs of relative efficiency regarding irradiation and temperature of the named technologies.

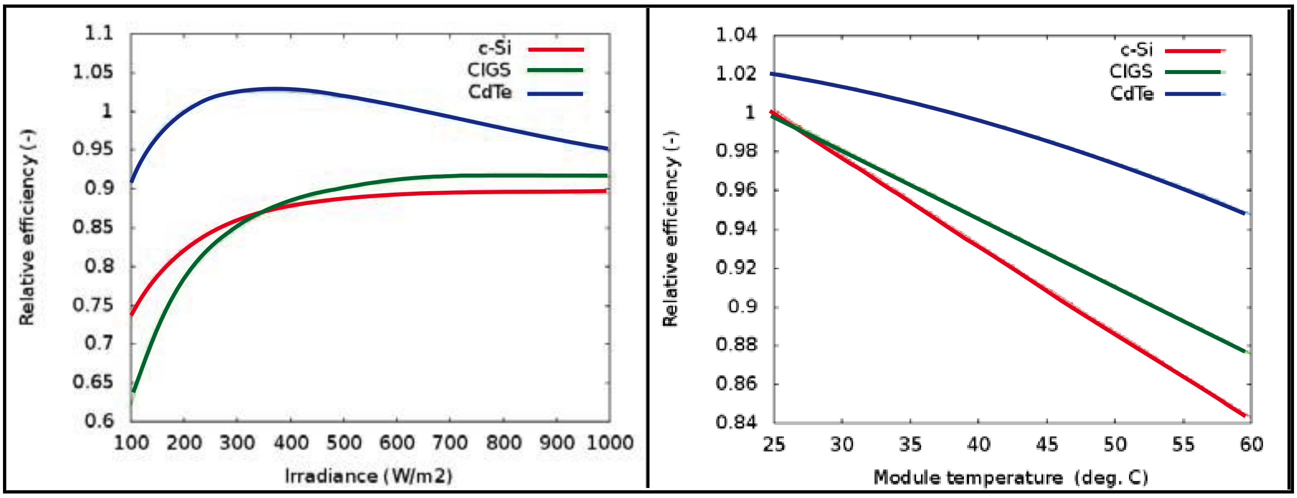


Figure 6: Performance of photovoltaic modules (c-Si, CIS, CdTe) in respect to irradiation and temperature
Source: Huld et al., 2009

Photovoltaic modules of c-Si and CIGS behave relatively similar with increasing irradiation, although c-Si modules show a better efficiency ratio at low irradiation levels. From 700 W/m² of irradiation the efficiency remains in stagnation of both technologies. In contrast to that, thin-film based technology with CdTe has its peak at about 400 W/m². After the peak its efficiency is decreasing with increasing irradiation, although CdTe modules remain to show higher overall efficiency (Huld et al., 2009).

Regarding temperature sensitivity, the performance of crystalline silicone modules is influenced the most by increasing temperatures. CIGS modules are a bit less sensitive. CdTe modules show a minimal influence by higher temperatures and perform therefore significantly better than CIGS and c-Si modules (Huld et al., 2009).

On the other hand CdTe modules appear to be quite sensitive to changes in the light spectrum. These changes occur especially when the atmosphere contains high amount of pollutants. Every pollutant absorbs and reflects different wavelengths of the sun light and cause thus effects of scattering and diffuse light (Huld et al., 2009; Súri et al. 2007). C-Si and CIGS are less susceptible to spectrum changes (Huld et al., 2009).

Hence solar energy can be used not only for electricity production but also for thermal purposes; the following Figure 7 demonstrates efficiency rates of solar collector systems in Centrope.

Compared to photovoltaic panels solar thermal energy exploitation occurs less efficient. Experts estimated efficiencies of 30% at unfavourable conditions and up to 55% at best conditions (Kniffler, 2004). Figure 7 displays therefore an efficiency rate of 45%.

These low values are mainly influenced by conversion and system losses where heat becomes released through distribution pipes and insufficient insulation (Austrian Energy Agency, 1999-2010; Kniffler, 2004).

Furthermore it is to note, that efficiency rates of solar collector cells decrease significantly with increasing temperature differences between collectors and surrounding air (Austrian Energy Agency, 1999-2010; Kniffler, 2004).

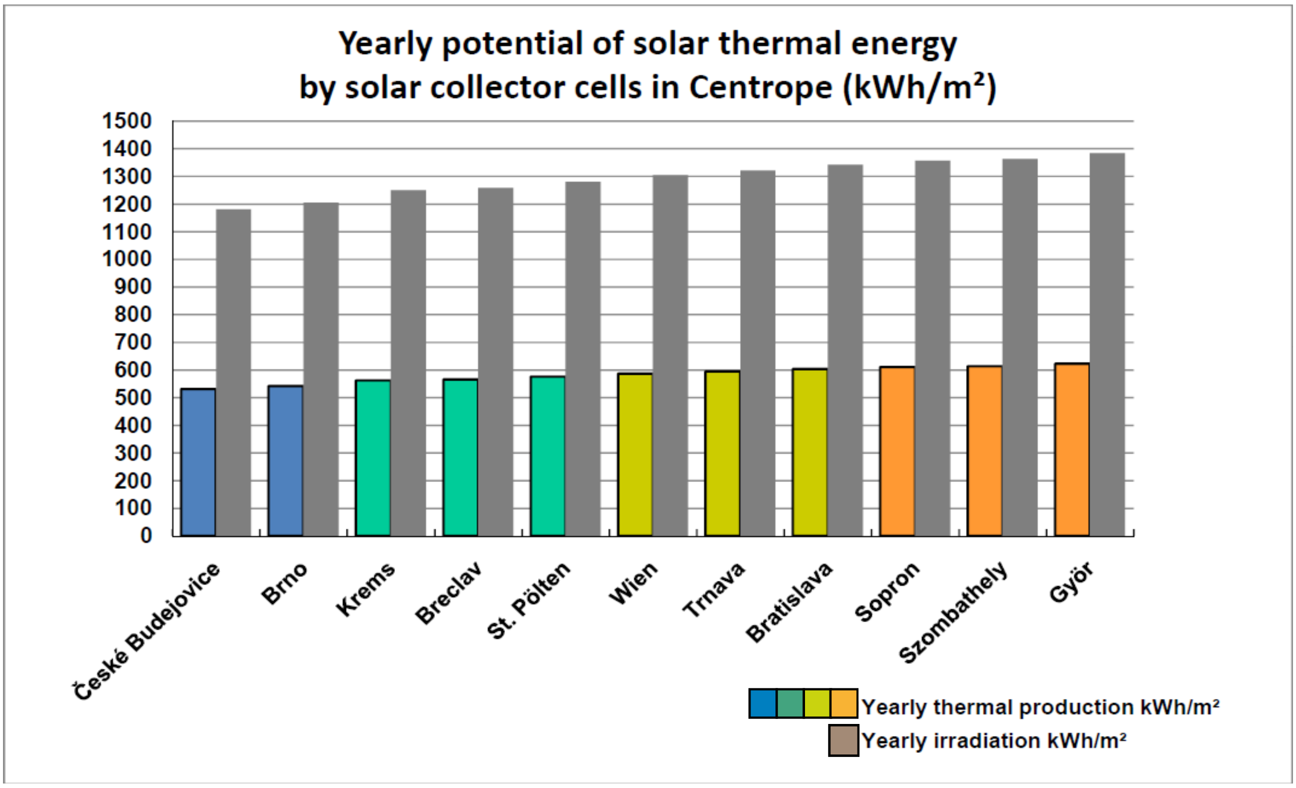


Figure 7: Yearly thermal potential of solar energy by solar collector cells in Centrope, Source: PV GIS - European Communities, 1995-2010; Kniffler, 2004

The thermal energy difference between areas with low solar energy potential like Czech Republic and areas with high solar energy potential as Hungary is about 100 kWh/m². However all presented localities show an energy potential of less than 650 kWh/m² per year. The yearly energy consumption of a single family house for warm water heating can be covered 60-70% with adequate installation (My Energy GIE, 2009c). The solar thermal energy technology bears therefore less potential for exploitation but offers still a considerable option for energy supply for certain purposes as heating up of swimming pools (Austrian Energy Agency, 1999-2010).

At the end it is to mention that exploitation of solar energy can be achieved everywhere where significant irradiation is measured, although the actual potential relies strongly on technical efficiency and may not offset costly technologies (Dunlop et al., 2005).

3.3. WIND POWER

This chapter examines the potential of generating energy from the wind. Firstly a short description will be given, following up by potential estimations of wind energy.

3.3.1. DESCRIPTION

As many other renewable energies wind power derives from the sun, but only 1-2% of incoming solar energy on earth is converted to wind. Nevertheless wind consists of 50 to 100 times more converted energy than total biomass production on earth (DWIA, 2003a).

The conversion process relies strongly on the natural characteristics of air. It becomes heated up by the sun and expands with decreasing density. This causes a rise of the air parcel and thus air movement. Likewise cooling air parcels sink to the ground due to contraction and increasing air density. These air circulations can be observed on the global as well as on a local level. While global wind pattern rather influence the climate, locally appearing winds have more effect on the daily weather (Øgendal, 2008; Oke, 2003 [1987]).

However for utilization of wind energy only surface winds play an important role. These winds are strongly influenced by the surface and go up to altitudes of about 100m. Hence the ground's surface is not plain; the roughness of obstacles like greater cities and forest areas can determine the wind flow considerably. Furthermore geographical features as the terrain influences strongly wind direction and wind speed. Two different effects are at this crucial. The first effect, called tunnel effect, occurs by air compression through a narrow mountain pass or valley. The wind speed increases rapidly. Although it is necessary to note that this natural "tunnel" should be softly embedded in the landscape otherwise rocky and edged hillsides might cause a lot of turbulence which in turn could overrule the effect of increasing wind speed. The second effect, known as hill effect, emerges similar. Air becomes compressed along the way up the windy hillside and will be released on the other side of the hill. Therefore ridges of hills provide higher wind speed. But also here smooth hillsides can be advantageous for the increase of wind speed. However it is to note that these two effects have to be distinguished to mountain and valley wind pattern, which may cause confusion in this context (Øgendal, 2008; DWIA, 2003bcd; Burton et al., 2001).

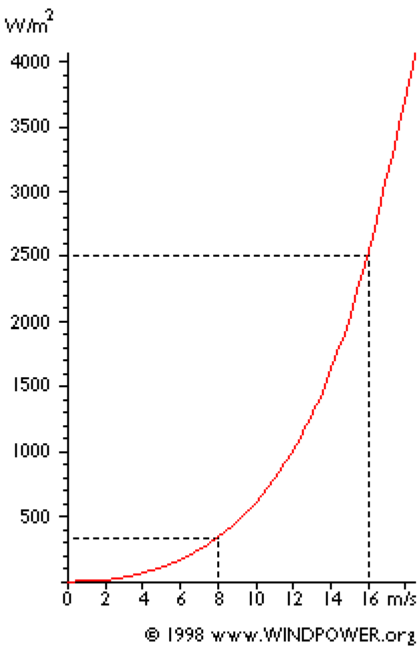
TECHNOLOGY

Wind energy is usually exploited by the technology of wind mills. In the initial stages they served simply for driving mechanical movement, nowadays they provide immense electrical power. Power generation by wind depends on the following three basic factors: density of air, wind speed and rotor area.

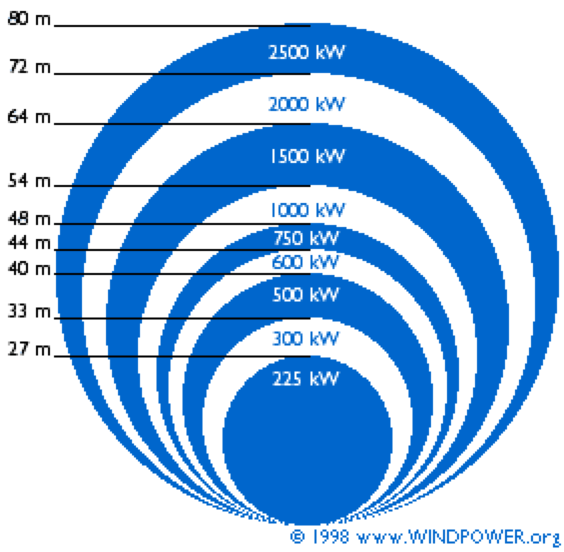
The density of air is about 1,225 kg/m³ at normal atmospheric standards with 15°C. Hence the atmospheric conditions vary the air density changes also appropriately. So it is decreasing slowly with increasing humidity, but shows significantly higher values at a low temperature than during hot temperatures. Moreover with higher altitudes the air pressure decreases and so also the density of air. To summarize wind mills receive more energy from the wind with increasing air density (Øgendal, 2008; Oke, 2003).

Wind speed as a main factor for wind energy generation occurs to be essential, while the other factors remain to be complementary. In general a minimum wind speed of 5-6 m/s or an energy density of approximately 220 W/m² is required to make this technology economically feasible. The content of energy of a wind behaves to the third power of the average wind speed. So as e.g. 6 m/s of wind speed is measured and results in an energy output of 216 W/m² (DWIA, 2003f; mecca, 2008). As Figure 8 a) shows, the higher the wind speed the greater the steps for energy output.

Another important factor is the rotor area, which increases with the square of the rotor diameter. The bigger the rotor area the more energy can be harvested in a year by a wind mill. So a small turbine with a diameter of 27 m may just produce 225 kW per year, but a turbine twice as large provides about 1 MW of yearly power (DWIA, 2003e). Figure 8 b) illustrates the rising capacity of turbines depending on their rotor diameter.



a)



b)

Figure 8: a) Energy output to the cube of average wind speed,
b) Rotor diameter and yearly generated power by wind turbines,
Source: a) DWIA, [1998] 2003f; b) DWIA, [1998] 2003g

In the historical development of wind energy technology, the horizontal type of turbines became usually established as it used to be more efficient than a vertical form. Also different turbine designs with two and three blades are used in the most cases. Whereas two blades designs require the possibility to tilt the rotor in order to avoid destructive shocks by wind to the system, three blade systems stay stable and become therefore more utilized (DWIA, 2003hi).

Besides turbine design also the choice of generators is decisive. While smaller generators can run many hours a year and harvest energy even at lower wind speeds due to less weight, greater generators need high wind speeds and provide then also high energy supply but may be used less hours per year. Therefore wind turbines become appropriately adapted to selected wind sites (DWIA, 2003j).

Also the tower height needs to be well calculated. It depends not only on the size of the turbine and generator but also on the local terrain roughness. Obstacles like buildings and forest areas cause friction, so that wind streams experience wind shear or get even turbulent around and behind the obstacles. Strong wind shear effects and turbulence result in uneven forces acting on the rotor blade and can lead to unfavourable conditions for wind energy utilization (Øgendal, 2008; DWIA, 2003k; Burton et al., 2001).

So far the most common installed capacities of wind turbines in Centrope are between 800 kW and 2 MW. Additionally Figure 8 b) provides a small overview about the size and electricity generation capacity of common wind turbines in Europe. The biggest wind mill was installed in 2007 in Northern Germany with about 7,5 MW capacity at a hub height of 135 m and a rotor diameter of 127 m (Upphoff and Brand, 2008).

Usually wind turbines get installed in a park formation to exploit the wind potential of a site. They become situated perpendicular to the main wind direction in a distance of 3-5 times of the rotor diameter size, while in the wind direction a distance of 5 to 9 rotor diameter appears. The formation is determined by a trade off between costs of connection to electricity grid and the energy loss originating from wind turbines shading one another. An optimal formation reduces these energy losses to 5% (DWIA, 2003l).

Advantages and Disadvantages

The upcoming explanations describe briefly advantages and disadvantages of wind power. Table 6 will therefore present the main aspects.

Table 6: Advantages and disadvantages of wind power

Advantages	Disadvantages
Middle availability	Strong regional differences
High energy output	Unstable energy supply
Economical feasibility	Limited by spatial structures
Few feed-in possibilities	
Energy production free of emissions	

Although wind energy potential is relatively well distributed through Europe, it is strongly regional restricted. Geographical features and obstacles increase the roughness of the surface and thus cause great variations in wind speed between sites. Wind power technology on the other side provides high efficiencies, so that the energy output is maximised. However wind remains to be uncontrolled due to natural atmospheric processes and is therefore not suitable to provide base-load energy supply, but can be used complementary to other energy sources.

Wind power's economical feasibility is supported by the economies of scale originating from a cost reduction with increasing electricity generation. Also the expanding market of wind turbine production panders investment costs for electricity producers. Nevertheless several restrictions are set by spatial structures, because certain buffer zones towards settlements as well as natural protected areas have to be considered for turbine installations.

Besides the mentioned aspects wind power generation requires only few feed-in possibilities, but can still lead to enormous peaks, which may overload electricity grids, especially during strong wind periods. Anyway wind power is produced free of emissions and is therefore advertised as a clean technology.

Criteria for potential areas

As already mentioned before, wind power generation depends strongly on available wind flow with a minimum speed. But also additional criteria determine the actual utilization of wind energy potentials. The following remarks will therefore provide a short description of these determinants.

- A minimum value of average wind speed need to be measured and should range between 5-6 m/s. Also an energy density value of about 220 W/m² matches the minimum requirement for a feasible operation of wind turbines. Hence wind energy potential varies strongly between regions and localities, also geographical features have to be considered, which might increase average wind speed by physical effects (mecca, 2008; Øgendal, 2008).

- Strictly managed nature protected areas prohibit any installations in the designated areas. Natura 2000, National parks, UNESCO World Heritage as well as Ramsar- protected areas and Nature parks are designated by european and national law and need to be respected. A high density of such designated areas may limit the utilization of wind energy significantly (mecca, 2008; Hanslian and Pop, 2008).
- Furthermore settlement structures reduce potential areas not only by their shear effect on the wind flow causing turbulence but also by the necessity of security measures and landscape protection. Buffer zones are established between 500m in the Czech Republic and 1200m in Burgenland, Austria. Also military areas and airports have to be considered (mecca, 2008; Hanslian and Pop, 2008).

- Additionally already installed inventory of wind turbines can limit further expansion of wind power generation sites. This may happen in the case of high density of installed turbines. New installations placed very close to eachother can experience wind shade and be therefore less efficient, whereas more suitable sites are prohibited due to settlement structures and protection areas (mecca, 2008; DWIA, 2003lm).

3.3.2. POTENTIAL AREAS

As previous chapters explained wind energy potential is strongly influenced by geographical features which in turn determine the actual wind speed. Centrope's potential for wind power utilization shows significant variations due to regional terrain differences displayed in Figure 4 in the chapter Solar Energy. As the following Figure 9 illustrates the biggest wind energy potential is located in the south east of Centrope, where a smooth transition of Austrian downs continues to the Pannonian Basin into the Hungarian Plain. Wind speed can locally occur up to 8m/s (Centrope map, 2010; Balogh, 2006).

On the other side of Centrope, Alps and the mountainous terrain of Granite and Gneiss highlands intercept the wind flow coming prevailing from the West and slow down the wind speed to about 4-6 m/s. However the formation of these mountainous areas shapes a natural channel which navigates the westwind to open space and accelerates the wind speed by the tunnel effect. Reaching then the Vienna Basin and spreading out into the Danube and Pannonian Basin the wind speed can increase up to 7 m/s (Balogh, 2006; Zamg, 2010)

Although mountainous areas can act beneficially for higher wind speed, disadvantageous location can also bring adverse effects as in the case of Slovakia. The Western Carpathians function like wind shelters and decelerates the wind coming from the West to about 3 m/s shortly before Centrope's border on the east side of the Trnava district.

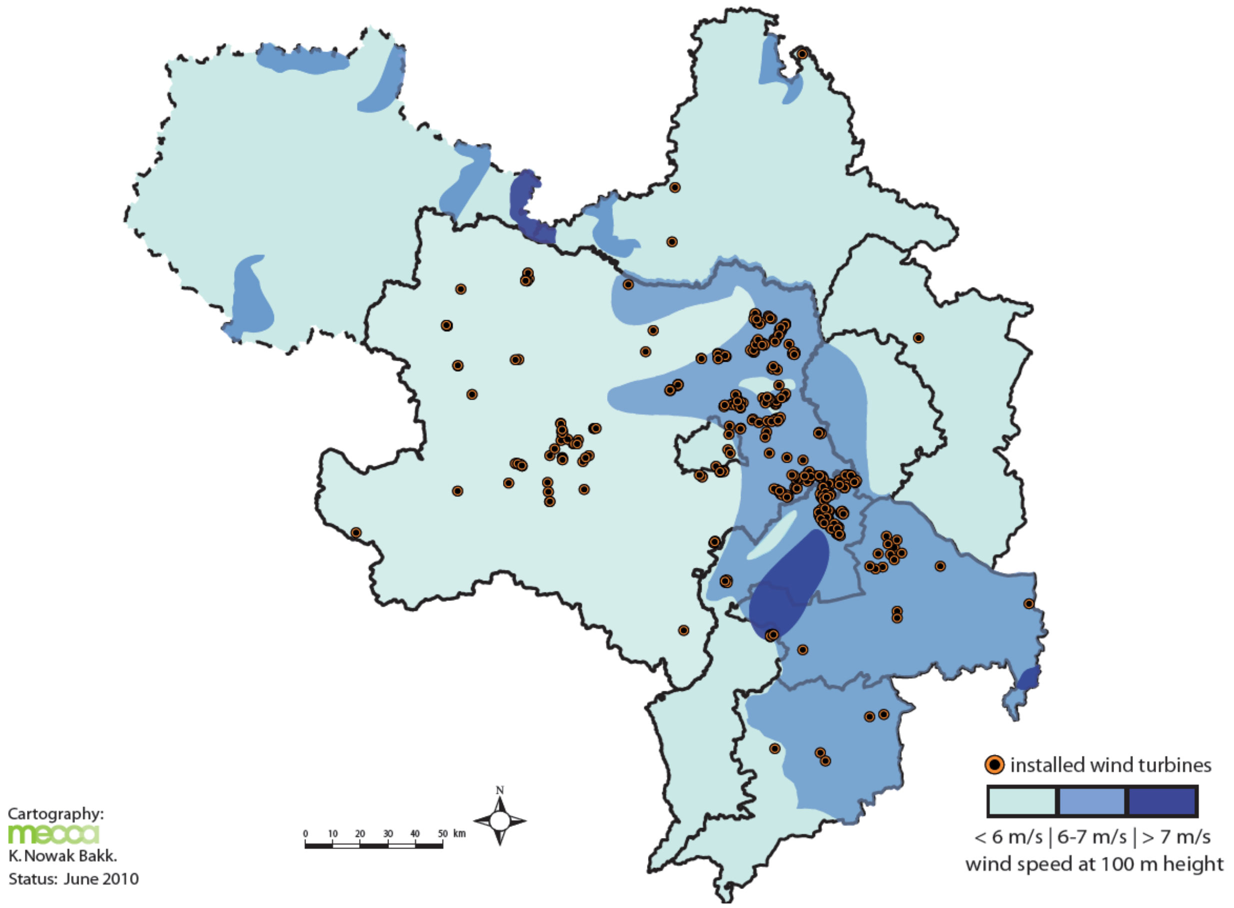


Figure 9: Wind energy potential in Centrope
Source: Zamg, 2010; mecca, 2009; Federal state Lower Austria, Federal State Burgenland; Township Vienna; Hanslian and Pop, 2008; EWEA, 2009; Slovakian wind potential, 2008

Besides geographic terrain also landscape features determine appearing wind flows in Centrope. While big obstacles like urban areas with tall buildings and dense forest areas influence the wind speed negatively, flat agricultural land and water surfaces can increase the energy output significantly (Oke, [1987] 2003). As shown in Figure 9 the area of Neusiedler See (Lake) and the following agricultural land in the Hungarian Plain obtain high wind speed for enormous wind power generation. Table 7 provides therefore a grouping of roughness classes and resulting energy output according to the available landscape types.

Table 7: Roughness Classes and Roughness Length in respect to landscape types

Roughness Class	Roughness Length m	Energy Index (per cent)	Landscape Type
0	0,0002	100	Water surface
0,5	0,0024	73	Completely open terrain with a smooth surface, e.g.concrete runways in airports, mowed grass, etc.
1	0,03	52	Open agricultural area without fences and hedgerows and very scattered buildings. Only softly rounded hills
1,5	0,055	45	Agricultural land with some houses and 8 metre tall sheltering hedgerows with a distance of approx. 1250 metres
2	0,1	39	Agricultural land with some houses and 8 metre tall sheltering hedgerows with a distance of approx. 500 metres
2,5	0,2	31	Agricultural land with many houses, shrubs and plants, or 8 metre tall sheltering hedgerows with a distance of approx. 250 metres
3	0,4	24	Villages, small towns, agricultural land with many or tall sheltering hedgerows, forests and very rough and uneven terrain
3,5	0,8	18	Larger cities with tall buildings
4	1,6	13	Very large cities with tall buildings and skycrapers

Source: Troen and Lundtang Petersen, 1991 after Danish Wind Industry Association, 2003

On the contrary the Czech Republic bears quite rough and uneven landscape in South Moravia causing turbulent wind flows with large and small-scaled eddies. These eddies show a high variation of wind speed and would result in unequal forces acting on a wind turbine. Therefore South Moravia bears less wind energy potential as other countries in Centrope.

Nevertheless some spots of higher potential for wind power generation can be still identified in the Czech Republic. Most of them are located in South Bohemia, where locally greater valleys or plain uplands permit an acceleration of wind up to 7 m/s and provide therefore favourable sites for wind energy utilization.

In spite of existing wind energy potentials in Centrope, the utilization of wind power is limited by legally manifested factors. At first strictly managed nature protected areas like National Parks or Natura 2000 limit the space for turbine installations. As it is displayed by Figure 10, a large area in the Austrian part of Centrope is covered by designated zones. Partially also Hungary and Slovakia show area-wide coverage of protected nature. Only the Czech Republic has less natural habitats designated. Due to the allocation of protected areas fewer sites remain to be beneficial for wind power generation. While Czech Republic has the possibility to utilize all of its spots of wind energy potential due to hardly any intersection of protected nature and potential areas, the Slovakian part of Centrope is greatly covered by strictly managed protection areas. Especially the Bratislava district, which would bear high wind energy potential, has strongly reduced space for feasible installations. On the contrary the Hungarian district Györ-Moson-Sopron and Austrian part of Centrope experience less reduction of space; hence their potential areas don't intersect in a large scale protected nature habitats. Therefore North-east and South-east parts of Austria and main parts of the Hungarian Plain remain for potential utilization and feasible wind power generation.

Vienna as a big city causes too much turbulence in the ambient atmosphere and wind speed reduction by tall buildings. Just North-eastern suburbs with high share of agricultural land offer some sites for wind power generation.

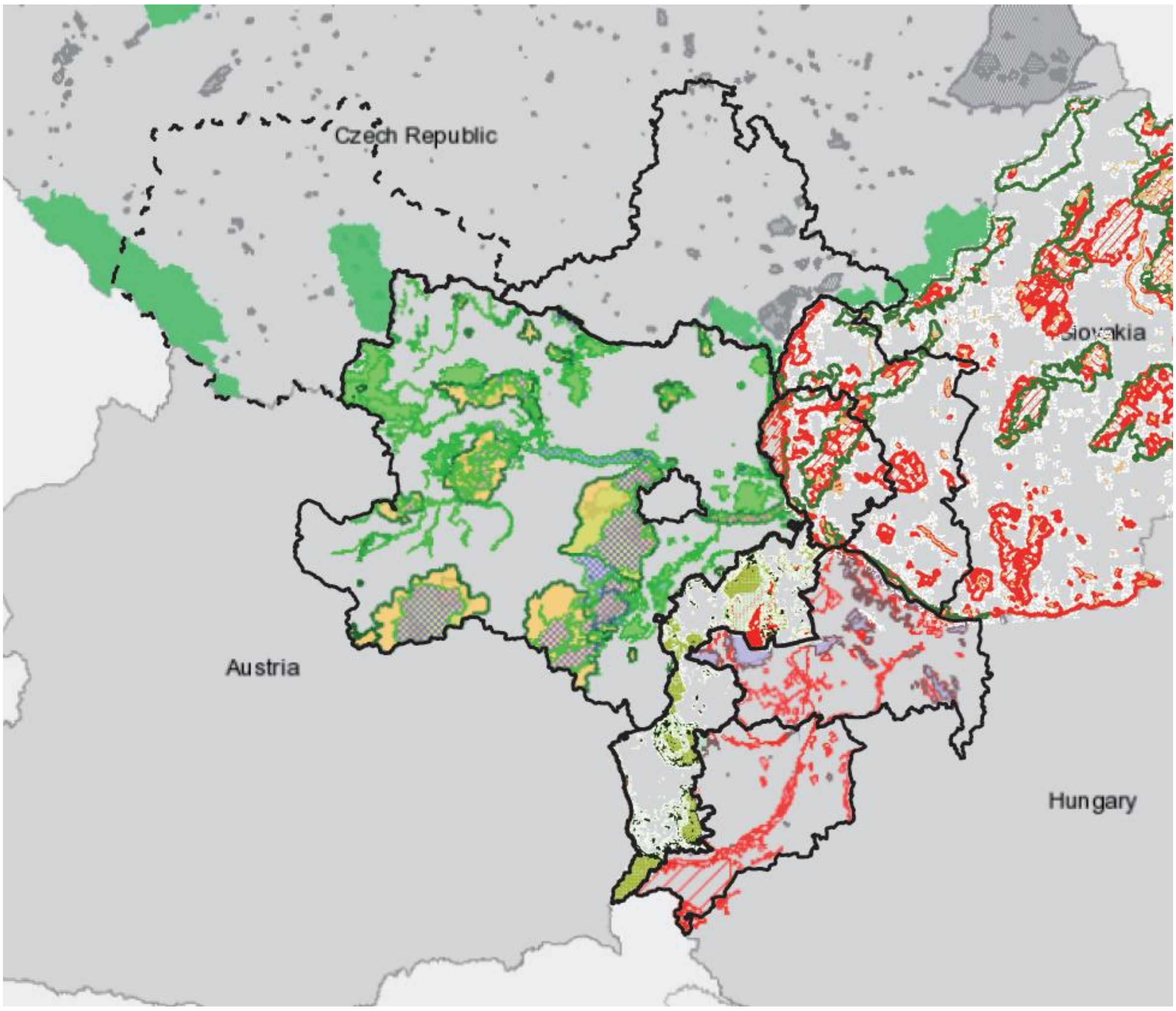


Figure 10: Nature protected areas in Centrope *)
Source: Centropemap, 2010; Sloveńska agentúra životného prostredia, 2010; Federal State Burgenland, 2009
***)** Protected areas are displayed in various colours according to the countries preference and do not indicate any special features.

In addition to nature protecting areas also settlement structures occur to be limiting for the utilization of wind energy potentials. Urban areas like great cities and towns require for turbine installations security distances of at least 500m up to 1200m to any settlement. Strong urban sprawl can therefore significantly reduce number of potential sites for wind power generation.

Figure 11 illustrates roughly areas with high population density and thus high agglomeration of buildings and settlements. South Bohemia in the Czech Republic is sparsely populated and has only few and rather smaller urban agglomerations. These urban areas are not placed or just not situated at the edge of wind potential zones. On the contrary South Moravia has almost a two time larger populated area including the second biggest city of the Czech Republic. However these urban agglomerations still don’t interact in a significant way to utilize South Moravia’s wind potential.

The Slovakian part of Centrope has in total a similar number of inhabitants like South Moravia, although their distribution is different. The main urban agglomeration is Bratislava and is placed closely to the Austrian border. Other greater settlements are spread onto the south- eastern direction of the districts Bratislava and Trnava. Despite the fact that in the Slovakian part of Centrope urban areas alone would not represent such obstacles to the utilization of available wind potential, the additional occupation of space by urban areas and nature protection areas result in a rigorous reduction of potential sites for wind power generation. So the actual utilization of available wind energy requires rational selection of sites and optimal siting of wind turbines in order to gain as much wind power as possible.

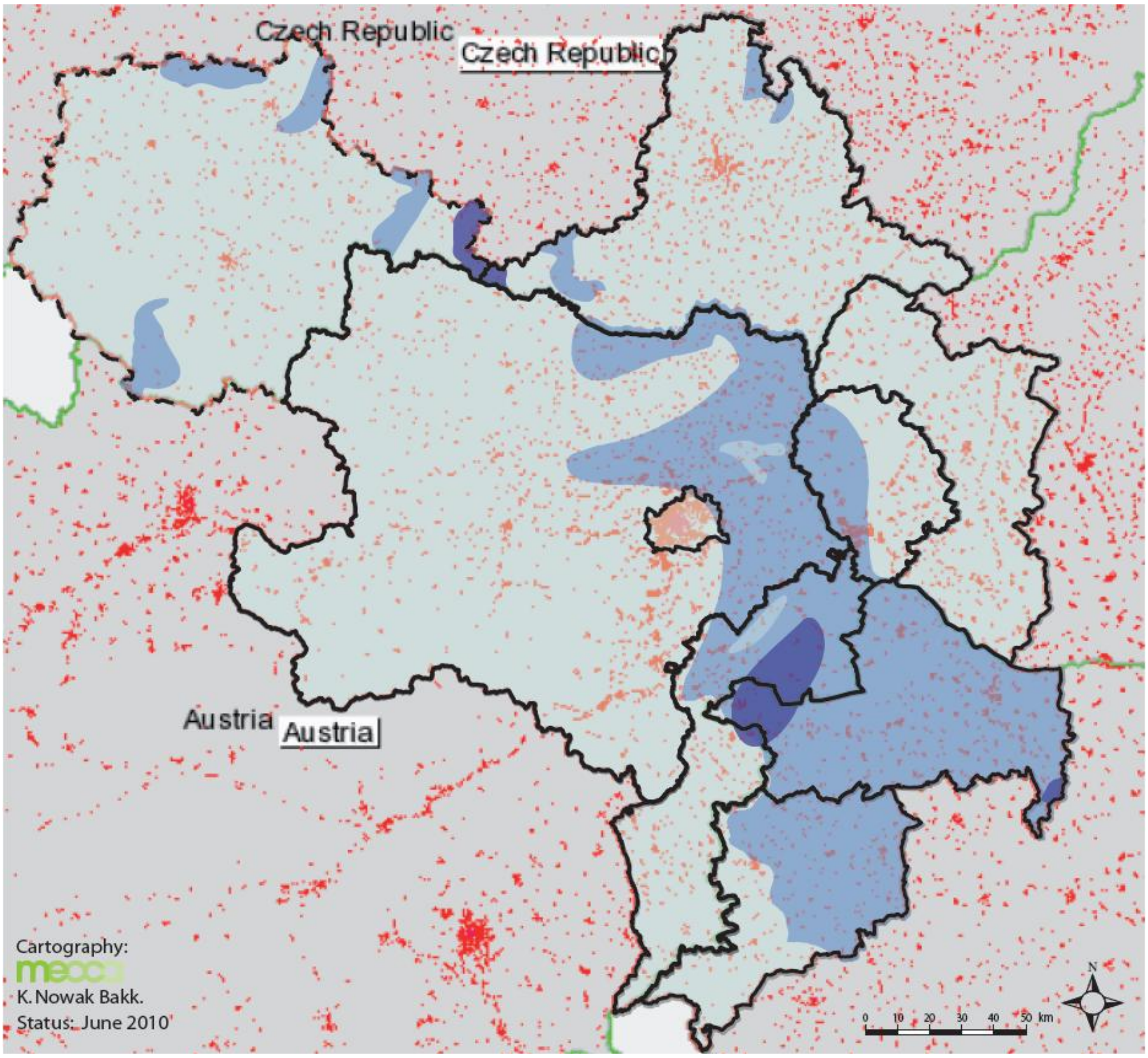


Figure 11: Urban areas in Centrope,
Source: Centrope map, 2010; mecca, 2010

Finally the inventory should be taken into the consideration of potential areas for wind energy utilization. Hence the installed capacity in Czech and Slovakian part of Centrope is marginal, further deployment of power generation can be aimed due to available areas of wind energy potential. Although as mentioned before Slovakia needs a very careful and accurate analysis for the selection of sites. Moreover Austria, where nature protection areas reduce also the potential areas for wind energy utilization, its settlements are quite densely placed and the relatively strong urban sprawl originating from the capital city Vienna is effecting potential areas of wind power generation significantly. Nevertheless these remaining potential areas are well exploited as figure CV at the beginning of the chapter shows. In fact Austria's wind energy utilization can barely expand in space but rather by increasing the producing capacity using repowering and upgrading installed technologies. Hungary on the other side has still some potential areas remaining for wind power generation; hence the density of settlements is rather low. Only bigger towns like Sopron, Györ or Szombathely are located on the edge of higher potential areas. Furthermore repowering can also be an option for Hungary, where older turbines with less capacity can be replaced.

3.4. GEOTHERMAL ENERGY

This chapter examines the potential of generating energy from the heat capacity of the earth. Firstly a short description will be given, following up by potential estimations of geothermal energy.

3.4.1. DESCRIPTION

Geothermal resources are defined as storage of energy underneath the surface of the ground. This energy appears in the form of heat and can be captured by aquifers of thermal waters and dry rocks (Antics and Sanner, 2007).

The geothermal gradient describes the energy potential of a geological region. On average 25-30°C/km can be measured with increasing depth (Dickson and Fanelli, 2004; Fridleifsson, et al., 2008). Regions with higher geothermal potential can be distinguished according to this gradient. Geological regions, which provide higher temperatures than 180°C are considered as high enthalpy fields, and measured temperatures under 180°C define regions as low or middle enthalpy fields. Very high temperature fields are rarely located in Europe due to low relation to volcanic activity. Only some hot spots like Iceland, Italy and Turkey provide a high geothermal gradient (Fridleifsson, et al., 2008). On the other side many regions with low or middle enthalpy are presented in Europe as also Figure 12 shows.

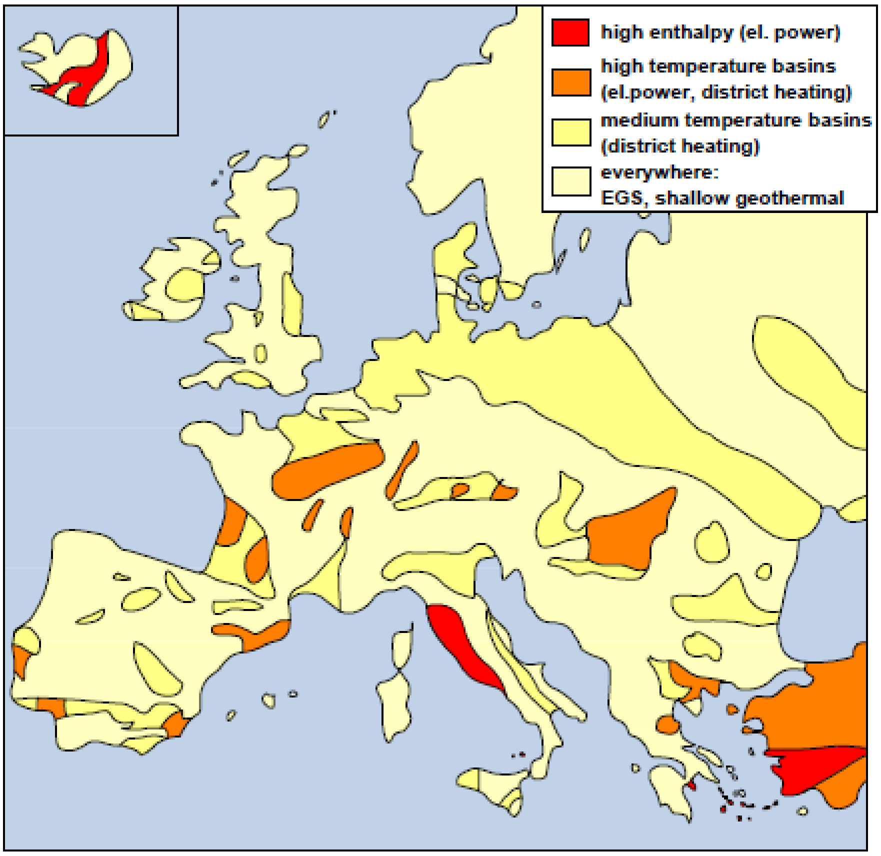


Figure 12: Geothermal fields of Europe
Source: EGEC, s.a.

TECHNOLOGY

Geothermal energy can be used for electricity generation and for heating. While conventional technology permits electricity generation only for geothermal waters with temperatures higher than 180°C, heating for buildings can be provided at about 80°C of geothermal water temperature (Fridleifsson, et al., 2008).

Hence Centrope doesn't bear high enthalpy fields the use of geothermal energy for electricity generation is very low. But many binary plants using new technology of organic rankine cycles have been established in the last couple of years. An additional organic working fluid with a low boiling point enables a more efficient electricity generation. In the same time geothermal water can be used directly for heating. Furthermore geothermal plants can consist of either open or closed systems. Already installed systems are in general open, which means that geothermal water is used directly and after usage the water becomes disposed at the surface. However direct use is limited to the chemical attributes of thermal water (Fridleifsson, et al., 2008). So as high contents of minerals can cause scaling and corrosion in system and distribution pipes and require therefore some chemical treatment before entering the distribution system (Jakubec and Kocskovics, 2005).

However an open system leads to an over-exploitation of aquifers and a drying-up of the geothermal resource in a long term. This can be avoided by a closed system. After usage extracted water will be reinjected into the aquifer through additional wells. This method can maintain a geothermal utilization for a long duration, although the installation costs might be higher than for an open system. Supplementary heat exchangers have to be integrated in order to transport heat from geothermal water to a second closed system, which is then distributing and circulating the hot liquid through a pipe system to settlements (Fridleifsson, et al., 2008; Ákoshegyi and Árpási, 2005). The method of closed systems offers also opportunities for multipurpose utilization, like combinations of hot sanitary water, space heating and balneology (Ákoshegyi and Árpási, 2005).

Besides the already mentioned technologies two other approaches are common. The first technology functions in rather shallow depths of 50-300 m and is therefore locally independent. This method is known as heat pumps and can be established in a vertical as well as in a horizontal way. Hence this method provides only lower temperatures up to 30°C and suits rather low energy consumption like single houses, this technology will be less considered into the regional potential of renewable energy source in Centrope (Fridleifsson, et al., 2008; mecca, 2008).

The second approach to use geothermal energy is to establish petrothermal systems. A working fluid is circulating similar to a closed system, though it is pumped to a hot dry rock at a depth of 2500-5000 m where it can absorb geothermal heat. Back at the surface it becomes distributed by the pipe system and can provide energy for heating and electricity production. Although this technology bears a high potential for geothermal energy use, the installation of such a plant can lead to high investment costs due to necessary detailed investigations as well as expensive technology equipment. However these enhanced geothermal systems can ensure sustainable long term energy supply (mecca, 2008; Ziller, s.a.).

ADVANTAGES AND DISADVANTAGES

The following remarks summarize advantages and disadvantages of geothermal energy. Table 8 provides therefore a demonstration of the main aspects.

Table 8: Advantages and disadvantages of geothermal energy

Advantages	Disadvantages
High availability	Spatial structure
High energy potential	Economical feasibility
stable base-load of energy supply	Non-covering of irregular peaks of energy demand
Need for only 1 feed-in possibility for electricity	
Energy production free of emissions	

Source: mecca, 2008

Even though many potential areas have been explored by experts, not all of them are suitable for usage. Geothermal resources require an adequate spatial structure where sufficient demand for energy production exists. Furthermore distribution systems in form of district heating play an important role. Are all these factors given, geothermal energy potential seems to end almost in perpetuity according to the technological state of art. The only limitation which can hamper utilization remains to be economical feasibility. High investment costs, detailed investigations and well drilling can exceed the profitability of geothermal energy use (mecca, 2008).

However an installed geothermal plant provides a guaranteed base-load of energy due to its continuity. Nevertheless its energy supply appears to be insufficient to overcome irregular peaks of energy consumption. Regarding electricity generation and distribution geothermal energy utilization shows an important advantage hence it requires only one feed-in possibility (Jakubec and Kocskovics, 2005; mecca, 2008).

Besides the already presented aspects, geothermal energy permits energy production completely free of emissions. CO2 emission rates for geothermal plants are decreased to 1% in comparison to conventional coal-firing plants (Fridleifsson, et al., 2008). Furthermore no other pollutants or noise is emitted by the plant during geothermal energy production (mecca, 2008).

Moreover geothermal energy allows cascading multi-purpose utilization due to technological progress. Combinations of Electricity generation, heating, balneology, aqua culture and green house agriculture are possible (mecca, 2008).

CRITERIA FOR POTENTIAL AREAS

As already mentioned above the current potential of geothermal energy source depends on various factors and can change over time. In the case of geothermal energy it is necessary to note that it is an on-site energy source. Only optimal geological conditions can guarantee the usage of this energy.

Therefore the following explanations will describe the requirements for a geological region which can offer a long-term exploitation of geothermal waters.

- State of knowledge about attributes of geological regions has to be well advanced. Temperatures, porosity and permeability of aquifers as well as chemical characteristics of geothermal waters have to be known in order to establish a geothermal plant. Already existent wells or drills for fossil resources can provide here complementary data (mecca, 2008).
- Geothermal aquifers should have about 60°C at a depth of 2000 m in order to be identified as low or middle enthalpy fields. This means that a temperature gradient of more than 28-30°C/km is required. Additionally sufficient pressure in an aquifer can alleviate extraction. Therefore a flow rate of more than 10l/s will be needed (Dickson and Fanelli, 2004; mecca, 2008).
- Spatial structures play an important role for the identification of geothermal potential areas. Sufficient population densities as well as distribution systems like district heating systems are necessary to make a geothermal utilization reasonable and feasible. Furthermore distances between settlements and geothermal plants should not exceed the average of 25-30 km. Although the temperature drop in pipes of 27 km with large diameter and high flow rate maintain to be negligible, distribution of geothermal water in small diameter pipes with less flow rates can cause a temperature drop of 3,5°C over 10 km (Baldursson, pers.comm. after Fridleifsson, et al., 2008; mecca, 2008).
- Moreover geothermal energy utilization for electricity and heating should not compete with the already established economical branch of balneology (mecca, 2008).

3.4.2. Potential areas

Centrope's long tradition of balneology leads to the assumption of many potential areas for geothermal usage. However these areas should not stay in competition to the economical contribution of balneology, but may be located in the vicinity or used as a multi-purpose energy source (Ákoshegyi and Árpási, 2005). Figure 13 demonstrates potential areas with opportunities for geothermal utilization.

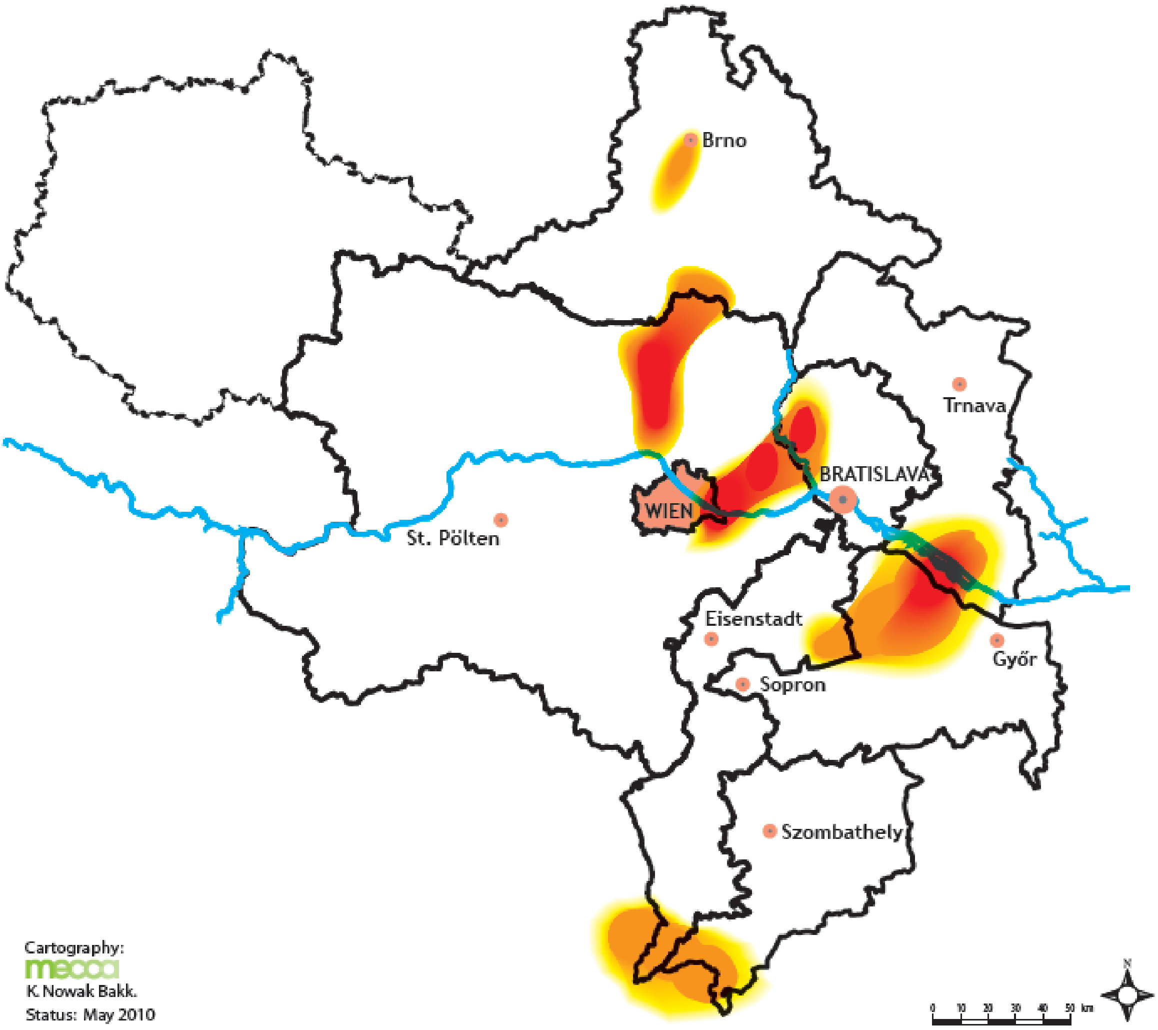


Figure 13: Potential areas of geothermal energy in Centrope
Source: mecca, 2008

The following geological zones have been analysed in respect to the requirements for potential areas and will be outlined due to their fulfilment.

The Czech Republic has one main geological region bearing geothermal potential which overlaps with the territory of Centrope. It is located in the east of the country and continues to the West Carpathian Foredeep in Slovakia. Hence it structure is characterized by nappes, the geothermal areas show a similar pattern of hot spots. A significant hot spot in this case is one in the south of Brno. Although it is relatively small for a geothermal field it could match partially the energy demand of Brno due to its vicinity. Knowledge of the geological structure and physical parameters was provided by old exploration wells for fossil resources. The West Carpathian Foredeep can provide geothermal hot spots with temperature gradients up to 100°C/km, while the geothermal field next to Brno offers about 40-60°C at a depth up to 2000 m. According to experts the geothermal potential could be sufficient for 2 geothermal plants (Myslil et al., 2005; Myslil and Stibitz, 2000; Batocletti et al., 2001).

Another hot spot occurred at the Dyje River next to the Austrian border. This geothermal field is rather unexplored, only shallow boreholes indicate geothermal potential. Furthermore experts assume that due to geological zones in the ground the actual geothermal potential could continue behind the Austrian border, where it emerges in an aquifer at a depth of 3000-4000 m (Myslil et al., 2005; mecca, 2008). This potential area called Laa-Stockerau is partially already used for balneology purposes. However this geothermal field suits for multi-purposes usage, hence almost 65% of the local settlements are connected with a district heating system. Additional data for geological characteristics was provided by investigation for fossil resources (mecca, 2008).

Hence geological zones of sediments exceed national borders; many of the potential areas for geothermal energy use are located in cross-border territories. An example therefore is the area Zwerndorf-Schwechat-Wien starting in Austria and continues further north of Bratislava to the Western Carpathians behind the Slovakian border (mecca, 2008; Fendek and Fendekova, 2005). The potential on the Austrian side is relatively high, thus the temperature measured in 2700m depth was about 100°C. Additionally the knowledge of existent drills, wells and aquifers is sufficient. Furthermore settlements are beneficially structured for distribution purposes due to a high population density caused by urban attractiveness (mecca, 2008).

According to estimations by PGO up to 60 000 households can be supplied in this region by geothermal energy, including suburbs of Vienna and smaller cities in its vicinity (2009). Geothermal waters from this potential area can be used for district heating as well as sanitary purposes like hot tap water (Jakubec and Kocskovics, 2005).

While the conditions are very favourable on the Austrian side, the Slovaks have a different starting position. Old natural gas reservoirs in the Slovakian part of the Vienna Basin provided energy to the region for several decades. Hence its exploitability is at the final stage new technologies and approaches emerge to expand the potential of these reservoirs. One possible solution is the depressurization of aquifers. This method is usually applied on active aquifers, which are characterized by a water inflow caused by low pressurized conditions in the reservoir through the extraction of gas. This water inflow disables recovery processes of the aquifer by blocking the permeability for gas flow. In order to counteract this natural process, intensive water withdrawal offers a successful opportunity (Drozd et al., 2005).

Several investigations have been made for the structure Závod, which is located in the above described area north of Bratislava. Experts recommend this method but point out that usage possibilities for the extracted geothermal waters are obligatory to ensure an economically feasible implementation. Therefore this potential area underwent further surveys which have shown water temperatures between 130°C and 170°C at a depth interval of 3 300 to 5 400m. The geothermal energy potential was estimated for about 40 MW_t (Drozd et al., 2005).

The second potential area in Slovakia is located in the Galanta area south-east of Bratislava. This geological region displays the Central depression of the Danube Basin and represents the northern ridge of the Pannonian Basin (Fendek and Fendekova, 2005; Jakubec and Kocskovics, 2005). Measurements showed a temperature of 88.5°C at a depth of 2 000 m, which is favourable for geothermal energy use. The geothermal potential is estimated for about 40 MW_t (Fendek and Fendekova, 2005). Therefore a geothermal heat plant was established in 1996, which supplies already about 1243 flats, regional hospital, a school and shopping centres with sanitary hot water and heat (Galantaterm, s.a.). The heating plant's base load is provided by geothermal energy and will be supplemented by natural gas. This happens when the outside temperature sinks to -2°C and the geothermal energy appears to be insufficient (Galantaterm, 2008; Jakubec and Kocskovics, 2005).

Although geothermal waters from Galanta have a high content of minerals, which inhibits the direct use, the exploitability of geothermal energy is possible. Galanta's geothermal heat plant consists of several heat exchangers, which heat up fresh water for sanitary and heating purposes (Jakubec and Kocskovics, 2005).

Compared to other potential areas; Galanta's geothermal potential lies rather in technology improvement. Reinjection wells could close the system of geothermal energy supply and prolong the usability term of the reservoir (Jakubec and Kocskovics, 2005).

As already mentioned the Galanta area is part of the Pannonian Basin, which continues into the Hungarian Plain. The western section represents the Little Hungarian Plain and one of the geological regions with the highest geothermal potential in Centrope. Hungary itself consists of a high temperature basin, which is suitable for electricity production as well as district heating (Antics and Sanner, 2007). This geological region provides geothermal water with temperature between 30 and 100°C at a depth of 1000 – 3000 m. Some local points have even water temperatures which exceed 100°C at the surface (Ákoshegyi and Árpási, 2005).

However the West Hungarian geothermal energy potential is mainly used for balneology purposes. Experts claim that a change in the thermal water management could triple Hungarians geothermal energy use. This could be achieved by a multipurpose approach combining balneology with direct use for heating and electricity generation. A multipurpose utilization requires though a modification of the extraction system for geothermal waters. Closed systems have to be established, where reinjection wells ensures the recovery process of water aquifers and prolong therefore also the usability term of geothermal reservoirs (Ákoshegyi and Árpási, 2005).

The Pannonian Basin brings up a little offshoot behind the Austrian border and allows in a relatively small region called "Seewinkel" also geothermal energy use. Although after first investigations this geological region doesn't seem to provide high temperature of thermal water, its existent heat potential could match energy demands for heating of smaller towns like Sopron (Hungary), which is situated in the vicinity of this geothermal field. Therefore Seewinkel is considered as a potential area for geothermal energy use (mecca, 2008).

Another offshoot of the Pannonian Basin arises in the southeast of Hungary where it continues to the geological region "South Burgenland Swell" behind the Austrian border (mecca, 2008). This area is characterized by very young volcanism which emerges as relatively high geothermal energy potential. Temperatures of more than 100°C have been measured at a depth of 2000 m. Nevertheless this geothermal potential has been used like in other presented areas mainly for balneology. According to experts electricity generation and district heating could be involved into the utilization through the establishment of cascade systems (Goldbrunner, 2005).

3.5. LEGISLATION

The region Centrope consists of four different countries, which are also Member States of the European Union. The EU set a common legislative base for energy goals for 2020 which are implemented and accomplished by national law of each Member State. However this national implementation can be done in many variations which in turn imply divert energy policies within the region Centrope.

The following explanations will briefly describe the main objectives of each national energy policy in the context of renewable energy. Finally common parts based on EU goals will be provided.

At first it is to note that Czech Republic, Slovakia and Hungary entered the EU in 2004 and are still in the process of integrative and harmonizative adaptation, both economically as well as legally. These countries have a common history been developed behind the iron curtain. Although this curtain fell about two decades ago, the development remains slow towards west European standards.

While Austria has decentralized policy permitting federal states some autonomy, the east European countries as Czech Republic, Slovakia and Hungary are still dominated by centralized policies where most decisions have to be made on a national level and regions are not allowed to take any actions outstanding national agreement.

Slovakia as an east European country has therefore a relatively centralized energy policy. The main objectives are to provide and ensure reliable as well as sufficient supply of electricity and heat. Furthermore the national energy demand should be reduced to reach less energy intensiveness (Ministry of Economy – Slovakia, 2001). To meet the set goals by the last updated energy act in 2004 several priorities have been proposed. The following list provides those which are strongely related with the development of renewable energy. Measures to obtain energy efficiency and savings on the consumption side need to be implemented. As proposed in the Slovakian energy policy combined production of electricity and heat can increase energy efficiency significantly. Improvements of plants and network can reduce losses during transmission and transportation of energy and ensure therefore reliable supply of electricity and heat.

Also diversification of energy sources should be enhanced in order to reduce dependency on energy originating from risky regions, where reliable supply cannot be maintained (Ministry of Economy – Slovakia, 2001). Especially, due to the fact of more than 90% imported primary energy. Slovakia's conventional resources as brown coal, natural gas and oil are marginal. An exploitation of renewable energy as biomass can acquire additional sources. However bioenergy is mainly supported by the government in mountainous and rural areas, where natural gas transport is limited (Ministry of Economy – Slovakia, 2001; Coenraads, et al., 2008).

Although many measures support renewable energy, an important priority is given to utilization of nuclear power to provide sufficient electricity for the country. This option was identified by the

Slovakian government not only as economically efficient, but also environmentally acceptable as long operation is ensured to be safe (Ministry of Economy – Slovakia, 2001). This priotization may lead to more attractiveness for nuclear power thus it bears significantly more energy than renewable energy sources.

Financial support is mainly given for electricity production from renewable energy sources. This support is regulated by tax reliefs and feed-in tariffs, which are detailed described in the next chapter. Beside tariffs also subsidies for investment costs are offered for heat plants using renewable energy sources, like geothermal energy, biomass and solar power.

On the contrary to Slovakia Czech Republic has one of the lowest energy import rate in the EU due to its great supply of coal. Although it has similar objectives to Slovakia, its support of renewable energy seems to be stronger. Especially due to feed-in tariffs which show great flexibility and promote therefore more attractiveness for renewable energy production. More details can be found in the next chapter. Also additional bonuses are paid for combined heat and power plants. Several programmes of financial support aim also on improvements of transmission and reduction of losses (Coenraads, et al., 2008; EREC, 2009a).

Although Czech Republic doesn’t prioritize nuclear power as such, the enormous capacity of already installed nuclear power plants, as e.g. in Temelin, hampers significantly progress of renewable energy exploitation (Coenraads, et al., 2008).

The main distinction between the Hungarian energy policy appears in contrast to the Czech and Slovakian policies. Hungary has an Energy Savings Strategy and Action Plan providing more concrete objectives to increase consumption of renewable energy. While electricity from renewable energy is appropriate promoted and supported, the heating sector remains less subsidized. Only investment support has been mobilized in the last couple of years. Partially it can be also financed by feed-in tariffs for co-generation plants. However the main focus is set on bioenergy and biofuels in Hungary. Geothermal energy and wind power are also supported by policies although experience continuously restrictions in order to ensure grid stability. These restrictions are furthermore a measure to prepare the sector for the change of supporting systems. A new system will be established based on tradeable green certificates (Coenraads, et al., 2008; EREC, 2009b). Although nuclear power may be an option to provide sufficient energy supply, it is not prioritized in the context of energy policies as Slovakia does.

Austria on the contrary combines energy with climate policies, thus a reduction of emitted greenhouse gases can be mainly achieved by energy savings and emission free energy production likewise by renewable energy resources. The most significant characteristic of Austrian’s policy is the division between national and regional duties. Although energy goals regarding renewable energy are national wide promoted, federal states or even regions get encouraged to develop their own agenda how to contribute to the achievement of national goals. Therefore additional budget has been mobilized to support renewable energy projects on regional scale (Coenraads, et al., 2008; Schuster, 2010).

Apart from this financial support feed-in tariffs exist and follow the principle of ‘first come, first serve’, which implies certain insecurity for renewable energy producers (Coenraads, et al., 2008). Furthermore it is to note that Austria does not see nuclear power as an environmentally friendly option like its Centrope partner countries Czech Republic, Slovakia and Hungary might do. Nuclear power is considered as jeopardizing human lives as well as environment; therefore no nuclear power plant has been so far activated on Austrian territory.

Finally a closer overview of the EU-directive 2001/77/EC for renewable energy will be given. The core objective is to increase electricity production from renewable energy sources to the share of 21% of total electricity consumption in the year 2010. This objective should enable the achievement of set EU targets with 20% of renewable energy production for 2020. The following Table 9 provides for the region Centrope national targets for electricity generation by renewable energy for 2010 as well as targets for 2020. Although no country reached their targets in 2010, Bulgaria, Germany, Denmark, Hungary and a few more came very close due to successful expansion of renewable energy. Additionally it is to note that according to the EU-Directive 2001/77/EC the following renewable energy sources are taken into account: wind and solar power, geothermal and bioenergy including combustion and biogas generation, as well as hydro power on larger and smaller scale including wave and tidal power (Klein, et al., 2008; EU-Directive 2001/77/EC).

Table 9: National targets for renewable energy in the electricity sector 2010 and in total for 2020

Country	RES-E 2010	RES 2020
Austria	78.1%	34.0%
Czech Republic	8.0%	13.0%
Slovakia	31.0%	14.0%
Hungary	3.6%	13.0%

Source: Klein, et al., 2008; modified

Motivation to reach national and EU targets derives mainly from three issues. At first climate change requires reduction of greenhouse gases, whereas renewable energy sources are more or less emission free and are therefore a considerable option. Also risks by nuclear power plants make renewable energy more attractive. The Second issue deals with the dependence on energy imports and insecurity of energy supply. Renewable energy technologies can raise the grade of self-sufficiency by exploiting renewable resources and maintain energy supply. Furthermore the existent scarcity of fossil fuel leads to new coping strategies may use renewable energy. The third motivation factor is the enhancement of economical competitiveness resulting in more jobs and new technology sector (Klein, et al., 2008). Such additional beneficiaries appear essential especially in times of economical crisis.

3.6. FINANCIAL SUPPORT SCHEMES IN CENTROPE

As already mentioned in previous chapters, first steps towards the achievement of the set EU goals for 2020 have been new established national policies including regulations for subventions and feed-in tariffs (FIT). In the case of Centrope four FITs have been implemented varying in date of establishment as well as in level of tariffs and duration of support. The following descriptive explanations will examine Centrope's support schemes. Hence Hungary is planning to switch to a green certificate system in the nearest future; a brief overview of this system will be given at the end of the chapter.

Several studies conducted in the last couple of years have assessed the effectiveness of different support schemes applied in the EU and pointed out that FITs are the most successful method to accelerate the deployment of renewable energy technologies. Good implementation can bring besides economical and environmental benefits also advantages in the social and security sector. Furthermore their great flexibility deriving from various design options allows appropriate adjustment to technological progress and renewable energy potentials. Additionally FITs provide investment attractiveness to small as well as middle and big scaled electricity producers, so that all actors obtain the possibility to contribute to the share of renewable energy (Mendonça, 2007; Barclay, 2009).

Despite the mentioned positive aspects, FITs require regularly revision of levels, duration and design. Many factors like state of art and capacity changes are needed to be considered while designing tariffs in order to maintain investment security. In the case of Centrope all four FITs are annually revised whereas Slovakia and Hungary account only inflation into adjustment of tariff levels (EREC, 2009b; Coenraads et al., 2008; Klein et al., 2008).

In general FITs can be distinguished between two main types. While **fixed tariffs** provide a certain price for fed-in electricity and ensure purchase conditions, **premium designated tariffs** permit more flexibility. In the region Centrope only Czech Republic offers the choice between fixed and premium tariffs. The last named option intends regular pricing at the electricity market but provides additionally a so called green bonus on top on the received price. Premium tariffs hold therefore a higher profit margin than fixed tariffs but bear the risk of not legally ensured purchasing (EREC, 2009a; Klein et al., 2008).

Although all other countries in Centrope merely offer fixed tariffs, Slovakia makes an exception regarding purchase obligations. Electricity grid operators are not obliged to purchase energy from renewable sources in the conventional meaning. The amount of renewable energy they have to take up equals simply their distribution and transformation losses (Klein et al., 2008).

The following design option gives to a FIT the biggest possibility for variation and flexibility, the so called **stepped tariff**. Diversifications are usual in respect to technologies, plant size or capacity scope and fuel. All member states of Centrope have stepped tariffs available but show different level of structuring. Austria, Czech Republic and Slovakia provide diverse level of tariff according to supported technology. Furthermore the size of plants is incorporated in the remuneration of electricity generation (Klein et al., 2008).

For instance Austria classifies payments for electricity generation from biomass in respect to the plant size, so that the tariff level decreases with increasing capacity of the plant. In addition a fuel distinction between pure forestry biomass and supplementation of biogenic waste is considered for the tariff level, which in turn can experience a decrease up to 40% with waste supplementation (Energie-Control, 2010). Fuel distinction does not necessary apply to the other countries in Centrope.

However Hungary presents a rather unusual structure of tariff levels. It distinguishes between weather dependent renewable energy sources and such being rather independent of weather but easier to control. Weather dependent sources are solar and wind power, whereas energy from biomass and geothermal energy is considered as controllable. Electricity generation from solar and wind power receives a constant remuneration which becomes annually adjusted to the inflation. Energy from biomass and geothermal energy on the other hand experience graded tariff levels in respect to energy demand. At high peaks of demand remunerations appear to be relatively high but decrease stepwise with decreasing demand and remain at a very low level during the time deep off peak (Klein et al., 2008; EREC, 2009b).

The following Figure 14 serves now for illustration of the descriptive explanations of FITs in Centrope provided above. It shows the development of tariff levels from 2006 to 2008, sort by country and renewable energy technology. Furthermore it allows a comparison of the **tariff level** variation in Centrope.

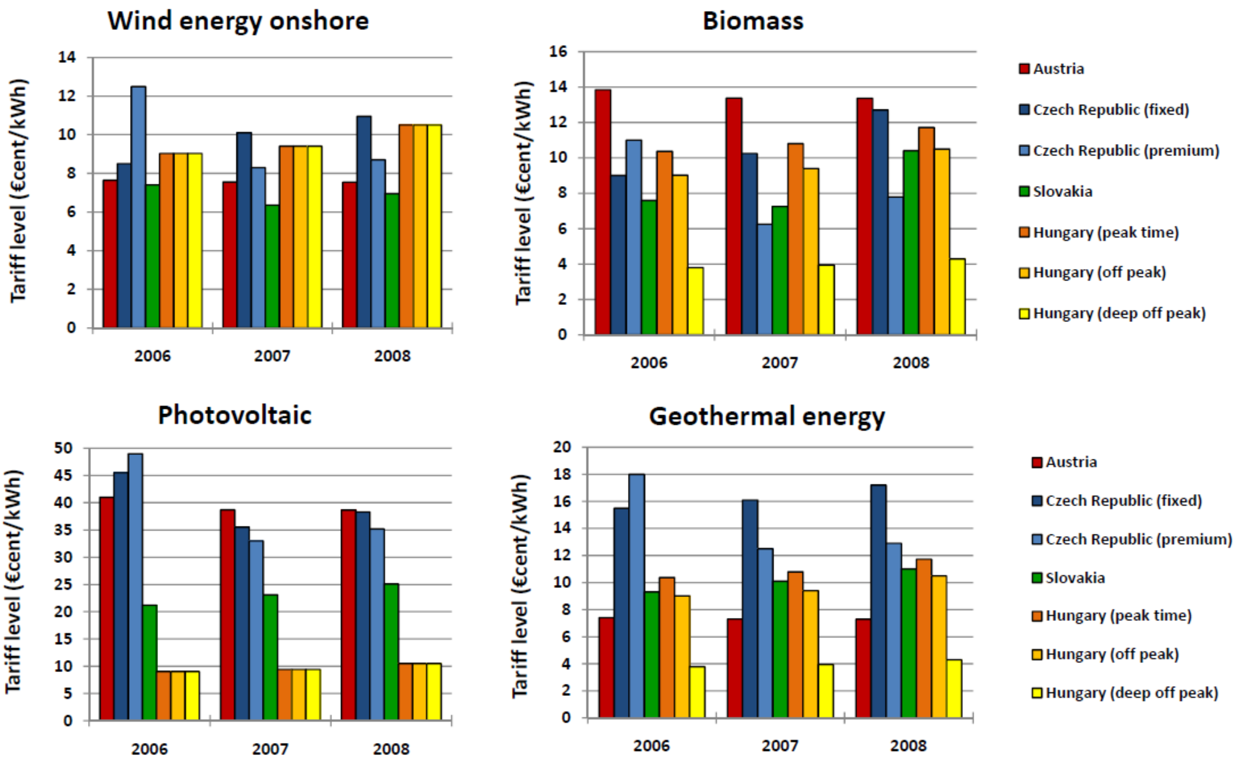


Figure 14: Feed-in tariffs in the Region Centrope from 2006-2008,
Source: Klein et al., 2006; Klein et al., 2008; Energie-control, 2009

In the last couple of years, Wind energy experienced financial boost by the Czech Republic, while Slovakia remains to provide less attractive tariffs. Hungary keeps as already mentioned their tariffs at a constant level and adjust them to inflation annually. Austria on the contrary offered more or less stagnating tariffs for electricity generation by wind power.

Energy from biomass is strongly and continuously supported by Austria, although Czech Republic is closely following up despite the great variation between fixed and premium tariffs. Also Slovakia increased significantly its tariffs for biomass technologies in 2008. Hungary provides high tariffs for energy generated during peak time demand, but remunerations for electricity deep of peak fall far short.

Electricity generation by photovoltaic technology experienced the strongest financial support, where Austria and Czech Republic forge ahead. However drastic cut-offs happened to tariff level between 2006 and 2007 in the Czech Republic. Slovakia started with a low level of payments in 2006 but is slowly catching up Czech Republic. Hungary offers only very low prices for electricity from solar power compared to the other countries of Centrope.

Geothermal energy received strong support from Czech Republic where Austria's tariff remains at a low level. Slovakia and Hungary represent the middle field, although again Hungary's deep of peak payments undercut even Austria's low tariffs for electricity from geothermal energy.

Besides the level of tariffs the set **duration for support** emerged to be essential for successful development of renewable energy, thus it is guaranteeing investment security. Long enduring financial support attracts investors far more than short periods of support. Centrope ensures financial support in the average between 13 and 15 years depending on the country, whereas Slovakia has started their FIT in 2005 with a limited time period of one year. Anyway the subsequent acts on Slovakia's FIT led to an extension of the period to 15 years (Coenraads et al., 2008; Klein et al., 2008). On the contrary Hungary didn't restrict the duration for financial support, so that tariffs will be paid for unlimited time. However Hungary is planning to establish a green certificate system, which should take over the effect of driving deployment of renewable energy (EREC, 2009b.).
Nevertheless the designated budget for financial support of renewable energy remains to be restricted for a certain time period and becomes renewed for the upcoming support duration. This restricted budget prohibits then either new registrations of renewable energy plants already at the administrative level or results in financial support with a rapid decline of tariffs over time (Schaffer, 2010, pers.comm.). To forestall drastic declines of financial supports and maintain investment security Czech Republic set a limitation to annual degression of FITs resulting in a maximal reduction 5% per year (Coenraads et al., 2008).

Finally it is to note that all countries in Centrope incorporated the costs of FITs equally among consumer types, whereas just Austria provides an additional advantage for electricity-intensive industries to reduce the effect on their competitiveness by higher electricity prices. This is regulated by a grid level system classified by different voltage ranges. Households with the lowest voltage level are charged more while electricity-intensive industries with the highest voltage range contribute less to coverage of FITs costs. Austria's **burden sharing** results in 78% of the average contribution by consumers covered by electricity-intensive industries and a contribution of 111% by households (Klein et al., 2008).

At the closing of this chapter the **green certificate system** remains to be explained, thus Hungary is considering to change its financial support scheme. As a type of quota systems governments determine the share of electricity generation from renewable energy sources. Addressed producers, distributors as well as consumers are then obliged to comply with the set standards by renewable energy credits, also called green certificates. To obtain these certificates three options are available: own generation of renewable energy; purchasing electricity from other renewable energy producers or buy certificates from other credit holders on the tradable green certificate market (Mendonça, 2007).

Although the system seems to provide rapid growth of renewable energy in the beginning, it bears also some risks. Over time the development may becomes driven by large companies and areas with high potential of renewable energy, whereas other beneficial aspects could remain under-utilized like creation of jobs and economical development of rural areas. Therefore adequate monitoring needs to be involved in the implementation of a green certificate system (Mendonça, 2007).

4. Results of the survey – Renewable energy

The following chapter presents results of the conducted survey „Renewable Energy – Barriers and Potentials". The upcoming descriptive explanations will follow the order of the questionnaire provided in the appendix A.

The results are divided into two groups. The first part is related to renewable energy sources while the second part serves for better understanding of the current situation in respect to policy and economy.

At the beginning of the questionnaire, experts have been asked to provide a ranking of the most promising renewable energy sources for electricity generation as well as for heating. Figure 15 demonstrates therefore the aggregated results for electricity generation. The Aggregation became categorized into centralized and decentralized countries in order to visualize existing differences within Centrope. Czech Republic, Slovakia and Hungary represent group of centralized countries while Austria remains a decentralized country.

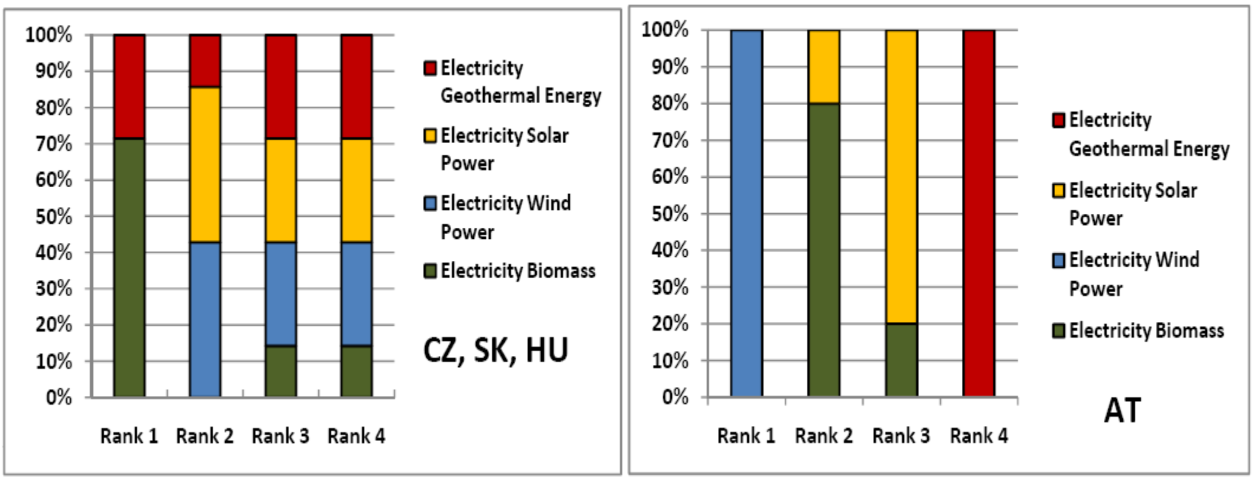


Figure 15: Ranking of renewable energy sources for electricity generation

As it is shown in Figure 15, rank 1 is dominated by biomass and wind power, while solar power and geothermal energy remains to be less promising for electricity generation. A closer look on national level demonstrates clear variations between countries. While Austria claims wind power to be the most promising energy source, the other countries like Czech Republic and Slovakia still obtain biomass as very effective. Hungary on the other side expects the biggest potential in geothermal energy following up by wind power, presented by the red bar in the left figure. Solar power though seems to be less promising for Hungary.

These variations indicate already significant differences in renewable energy potentials between countries and are mainly determined by typical geographical features as explained in previous chapters.

The obtained results for the heating sector show a different ranking regardless the exclusion of wind power. However grouping of countries became here fore differently set to provide better visualization of differences in ranking of promising energy sources, as seen in Figure 16. Hungary has been pointed out to demonstrate its significantly higher potential of geothermal energy compared to other countries in Centrope.

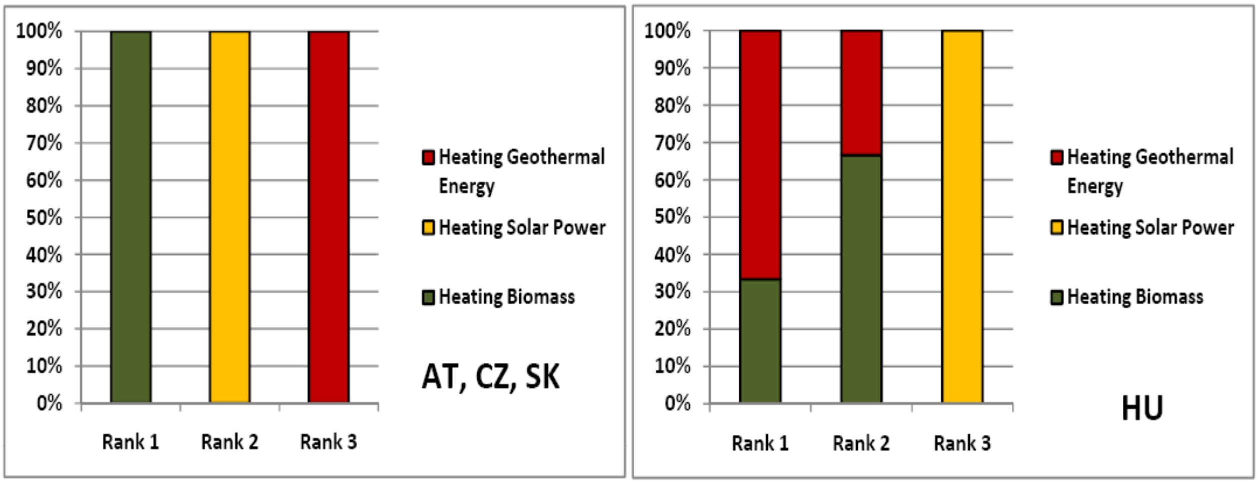


Figure 16: Ranking of renewable energy sources for heating

Rank 1 in the heating sector is strongly determined by biomass, while solar power and geothermal energy play a subordinate role. Splitting these results by countries, Austria, Czech Republic and Slovakia provide the same estimations as the left diagram of Figure 16 shows. Only Hungary considers geothermal energy more effective than bio energy. However solar power got ranked by Hungary as the least promising renewable energy source for heating.

The next survey question served for an estimation which sector will experience the strongest expansion of renewable energy by the year 2020. Results have separated between electricity and heating. As Figure 17 presents the strongest expansion is expected to occur in the housing sector. Although industries and offices will experience less expansion of renewable energy, public buildings represent the sector with the least expansion of renewable energy.

Variations between countries are only marginal. While the Czech Republic counts on the electricity sector, Hungary expects the strongest expansion of renewable energy for heating. Slovakia and Austria remain with rather balanced expectations for both sectors.

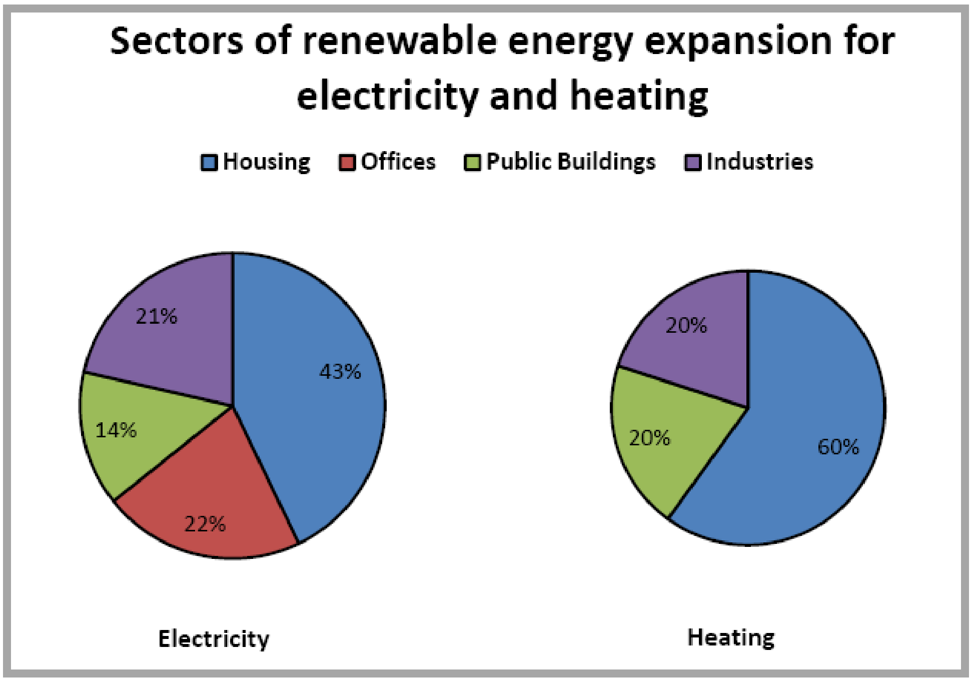


Figure 17: Expected expansion of renewable energy by sectors in 2020

The second part of the survey focused on legislative and economical framework. Firstly experts were asked to identify more appropriate energy policies to achieve the set EU-Goals for 2020.

About 79% of polled experts find decentralized energy policies as necessary to achieve the EU-goals 2020 most effectively, while 21% favorite rather centralized policies to fulfill the goals.

Further results indicate also that the following actions are important to facilitate a considerable contribution of renewable energy.

Table 10 illustrates a more detailed view.

Table 10: Important actions to facilitate considerable contribution of renewable energy sources

Level of importance		
very important	**important**	**less important**
Expansion and improvement of the electricity grid	Implementation of profitable feed-in tariffs to enhance investments	Harmonization of regulations (quotas, certificates, feed-in tariffs)
Promotion of renewable energy technologies as economic impulses	Increase of EU-funded projects to enforce renewable energy development	Consideration of spatial planning in renewable energy decisions
Enforcement of energy saving to alleviate penetration of renewable energy	Expansion of regional autonomy to facilitate renewable energy production	Strenghtening of cross-border co-operation in research, policy and economy
Rise of collective consiousness in society for more understanding and support	Opposing lobbyism against renewable energy supply by electricity grid operators	Establishment of energy regions

According to the polled experts key actions are selected to be enforcement of energy saving as well as an expansion and improvement of electricity grids. Furthermore promotion of renewable energy technologies as economic impulses is of high priority. Nevertheless the importance of collective consciousness in the society is not negligible, but rather high.

Besides that also economical actions like profitable feed-in tariffs and EU-fund of renewable energy projects are expected to obtain more attention. According to interviewed experts regional autonomy for renewable energy production is less needed, while lobbyism against renewable energy supply should be opposed.

On the other side harmonization of regulations and network oriented cross-border co-operation remain to be less important according to the survey results. The least importance shows consideration of spatial planning for renewable energy decisions and establishment of energy regions.

5. Discussion

Previous chapters provide needed information, which can be now interpreted and brought into relation with the set hypothesis that centralized energy policies impede effective utilization of renewable energy potentials on a regional level.

Firstly centralized countries in the Region Centrope are those which experience a long path of development behind the iron curtain. These countries are Czech Republic, Slovakia and Hungary. Austria is identified as a west or middle European country due to its acceptation of the offered Marshall plan back in history. However in respect to renewable energy policies the term centralized will be as followed understood and limited. Centralized policies bear decisions made on a national level and are determined by legislation. Furthermore regions or federal states have any autonomy to differentiate designated policies to their needs and capacities.

Especially in the context of renewable energy, where optimally adapted framework is essential to facilitate and drive penetration of renewable energy technologies, such centralized policies may hold back further development.

The following explanations will now lead to the assumption that several factors are affected by over centralized energy policies and impede therefore effective utilization of renewable energy potential.

The first influencing factor is lack of information. Most analysis of renewable energy potentials are made on national scale. Potential analysis can be barely found on regional or even local scale, which may has its reason in rising costs due to more detailed acquisition of data.

However significant differences occur between national and regional scaled potentials. These differences origin from divert landscape and vegetation types as well as their share to total area within a country. A country with almost 70% of mountainous area bears maybe on a national average only small potential for solar energy utilization, but can still provide bright spots of high insulation rates measured on flat areas, as e.g. Austria does. Only if renewable energy potentials show marginal variation within countries, national established policies can act adequately.

The following comparison of obtained results regarding the ranking of most promising renewable energy sources of each country with the conducted potential analyses for the region Centrope illustrates significant differences and underlines the fact of lacking information.

As shown in Figure 15 wind power is assumed by Czech Republic, Slovakia and Hungary to be less promising for electricity production than bioenergy, although Hungarian and Czech parts of Centrope provide several potential areas for wind energy utilization. While the Little Hungarian plain provides beneficial conditions, spots of locally optimal siting enables wind energy production in the Czech Republic. Bioenergy on the other side is the most promising energy source for electricity production in the Slovakian part of Centrope, thus its wind energy potential is low. Also solar energy appears to be more promising in Bratislava and Trnavsky district than the national assumption provides. Hungarian parts of Centrope bear also high solar energy potentials hence the insolation rate is the highest in Centrope. Furthermore geothermal energy can contribute in the Slovakian and Hungarian parts of Centrope much more to electricity production than the national ranking shows. The Czech Republic assumes a national wide high availability of geothermal energy, but Czech parts in Centrope offer only limited potential so that geothermal energy remains to be less promising for these parts of Centrope.

Rather cost intensive technologies for electricity production from geothermal energy lead to less attractiveness for utilization. This could lead to more intense exploitation of less energy efficient renewable energy sources than geothermal energy, as it also the fact in Austrian parts of Centrope. Although several potential areas are identified, high investment costs for utilization of geothermal energy give preference to less costly renewable energy technologies. According to national ranking of Austria wind energy is the most promising energy source, which matches also with the available potential in Austrian parts of Centrope. Bio and solar energy are less promising national wide but show in Centrope high potential permitting more intense exploitation. Geothermal energy as mentioned before remains unattractive, despite high potential availability.

A similar picture is observed in the heating sector, even though wind energy is excluded. Austria, Czech Republic and Slovakia consider bioenergy and solar energy as most promising, while geothermal energy still obtains the last rank. In the case of Slovakia, Centrope has geothermal potential areas which could be exploited and provide therefore significant energy supply for heating. On the other side solar energy potential is rather marginal in Czech parts of Centrope and provides so less energy for heating. As mentioned before the available geothermal potential in Austria located in the Centrope region is estimated much higher than national wide, so that a considerable contribution of energy supply could be provided in Centrope compared to national assumptions.

Hungary on the contrary trusts in geothermal and bioenergy, while solar energy is less promising. But Centrope’s parts of Hungary have strong intensified agriculture, which serves with big shares for basic food supply. In this case bioenergy might be less exploitable than national wide. Furthermore solar energy utilization can be intensified due to high solar insulation rate and decompensate the reduction in bioenergy use. Regarding geothermal energy Hungarian parts of Centrope provide areas with high potential, therefore the national estimation matches also for Centrope’s region.

If such differences in renewable energy potentials, as presented so far, are not known due to missing analysis on regional scale, misleading assumptions become incorporated to national energy policies. In the special case of centralized policies, lack of information is strongly notable because regional available potentials of renewable energy remain to be unexploited due to lacking autonomy and the obligation to follow given focus and emphasis of national oriented energy policies. Although about 79% of interviewed experts hold decentralized policies for more effective or appropriate to achieve the set EU-Goals 2020 for renewable energy, the action to expand regional autonomy in order to facilitate renewable energy production was classified as less important. At the same time according to interviewed experts the strongest expansion of renewable energy is expected in the sector housing. However to fulfill this expectation, more individuality is required due to significant differences in energy potentials on various scales. This autonomy can be rather obtained by authorizing regions to act more efficiently in renewable energy production than by standardized national policies. Furthermore an expansion of regional autonomy can awake more interest and rise collective consciousness in society about renewable energy technologies and consequently open up new energy potentials. These potentials occur then mainly on the scale of households likewise in the case of photovoltaic cells, which can be mounted on each roof.

Although legislation is a main influencing factor for renewable energy, economical incentives seem to drive anyway the penetration of renewable energy technologies.

National energy policies are usually based on potential analysis of similar scale, so that resulting feed-in laws follow the same path and make some promising energy sources more cost attractive. This fact enhances inefficient exploitation of renewable energy in two ways. While too low tariffs increase economical attractiveness of renewable energy technologies only marginal, significantly high tariffs lead on the contrary to intense utilization of such technologies. However inadequate levels of feed-in tariffs induce inefficient exploitations of renewable energy sources especially in the described cases above where differences between regional and national potential analysis occur.

As in the case of Slovakia, national legislation focus less on renewable energy than it considers nuclear power as an efficient option for warranting energy supply. These aims become reflected in the set level for feed-in tariffs. Slovakia offers despite continuous increase the lowest support for renewable energy technologies in comparison to other countries in Centrope. Especially the feed-in tariff for photovoltaic-cells appears to be almost 10 €cent lower than Austrian and Czech support. In Slovakian parts of Centrope adequate tariffs in the solar energy sector would be beneficial for utilization of this energy source, particulary in the absence of high wind energy potential.

Albeit national assumptions about renewable energy potentials determine the level of feed-in tariffs, investment costs remain to be insufficiently considered for renewable energy support. Hungary offers for solar energy dramatically low tariffs, which need to increase at least by the factor 5 to cover generation costs of photovoltaic cells. Such deficient financial support of solar energy induces more attractiveness for less costly energy sources and let the high available potential of solar energy unexploited in Hungary.

On the contrary of deficient support lies over promotion of less costly energy sources like biomass. In the case of Austria technologies for bioenergy utilization are strongly subsidized exceeding generation costs by the factor of 2 and result therefore as highly economical attractive compared to other cost intensive energy sources as geothermal energy.

The Czech Republic on the other side provides over all a high level of feed-in tariffs, especially for solar and geothermal energy. However Centrope's parts in the Czech Republic offer only low potential for these sources, but economic incentives given by high feed-in tariffs lead to more intense exploitation of lower energy potentials.

In summary centralized energy policies restrict regional actionability to utilize efficiently local renewable energy potentials. Furthermore energy policies act in general on a national level and are therefore based on national energy potential analyses. But as presented above regional and national renewable energy potentials can vary significantly and may conflict so with the set focus and emphasis of national energy policies. Centralized countries as the Czech Republic, Slovakia and Hungary experience then in particular inefficient exploitation of regional energy potentials. In the case of Austria, authorization of regional autonomy could compensate differences between national and regional energy potentials and showed therefore more efficient exploitation of renewable energy.

However whole Centrope is affected by inefficient feed-in tariffs which are again based on national analysis and national energy policies. Also lobbyism by conventional energy producers or even by actors within the renewable energy sector may influence additionally the effectiveness of feed-in tariffs. As a result rather cost intensive technologies which bear usually high energy potential remain to be insufficiently supported while less costly energy sources become over subsidized despite their lower energy output. Furthermore feed-in tariffs are known as the most flexible financial support scheme for renewable energy, but regional differences in energy potentials continue to be disregarded. Thus penetration of renewable energy technologies is mainly driven by economical incentives; such economical framework leads to even more inefficient exploitation of renewable energy source on regional scale, resulting in intense exploitation of less energy efficient sources and rather moderate utilization of highly energy efficient technologies.

Penetration of renewable energy technologies is strongly forced by legislation and economical instruments by the government. Such governmental interventions cause market distortions and may lead in the long run to a suboptimal market situation due to their inefficiency and inconsequence.

In order to avoid inefficient exploitation of renewable energy potentials and to maintain sustainability several improvements of legislative and economical framework are advisable.

Centralized countries need to expand regional autonomy to facilitate efficient exploitation of renewable energy. At the same time electricity grids require technical upgrade to ensure transition of electrical power. Furthermore reallocation of financial support for renewable energy production can be obtained through more specific feed-in tariffs in respect to regional available potentials as well as investment costs for technologies. Moreover cooperation between regions as well as cross-border enhances networking and allows optimal utilization of the wide variety of renewable energy potentials by connected grids.

Continuous and flexible respond through stepwise adaptation of legislation and economical incentives remain necessary to reduce inefficient exploitation of energy potentials and to permit so sustainability within the renewable energy sector. Although to ensure penetration of renewable energy, measures for enforced energy savings are obligatory.

6. CONCLUSION

The renewable energy sector expands continuously due to ambitious goals for 2020 declared by the EU, however its expansion appears slower than expected by experts. Previous analyses identified several barriers existing for successful transition towards renewable energy based society. Such analyses examined barriers on a larger scale and didn't conduct the circumstances on a smaller scale. This work on the contrary points out that renewable energy potentials differ between national and regional scale. Thus usually policies regarding renewable energy are set national wide, differences in regional energy potentials are not taken into account. Furthermore this lack of information becomes also incorporated in feed-in tariff laws. Especially in the regional Centrope where centralized policies as can be found in Czech-Republic, Slovakia and Hungary lead to a misguided exploitation of renewable energy potentials on a regional scale. Observations made during this study showed that rather cost intensive technologies which bear usually high energy potential remain insufficiently supported while less costly energy sources become over subsidized despite their lower energy output.

Moreover regional energy potentials remain unexploited if they deviate strongly from national energy potentials hence only national wide promising sources experience adequately financial support by feed-in tariffs. On the contrary renewable energy sources with low energy potential on a regional scale become highly economical attractive by lucrative feed-in tariffs, although their exploitation should be rather of moderate dimensions due to their limited potential. At the same time renewable energy sources of high potential remain unattractive and unexploited.

Authorization of more regional autonomy regarding the renewable energy sector could enable effective utilization of energy potentials in the named countries and facilitate the achievement of the set EU goals for 2020. Additionally adaptation of feed-in tariffs to regional differences could induce effective exploitations of energy potentials on a regional scale and provide so a better mix of energy sources to maintain energy supply.

However at the current state Centrope experiences a short-term oriented promotion of renewable energy technologies which leads to rather uncoordinated development of this sector driven strongly by economical incentives and national energy policies. Looking from a long term perspective such ineffective exploitation of energy potentials can steer into a blind alley and reverse the advancing development of renewable energy into stagnation. Therefore it is recommended to enhance the development of solar energy especially in the south-east of Centrope, where high insolation rates are measured. Likewise wind power generation can be forced in plain areas and deliberate siting of wind mills in the Czech parts of Centrope can rise the share of renewable energy constribution significantly. Geothermal energy should particularly be intensified where bigger settlements or even cities serve for adequate purchase structure. Bioenergy on the contrary offers immense potential for peripheral areas where the resources are locally available and ensure so stable base load of energy.

7. REFERENCES

Ákoshegyi, G & Árpási, M 2005, 'Multipurpose Utilisation of Thermal Water in Hungary Prospect and Future'. *Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005,* ed International Geothermal Association. Available from: http://pangea.stanford.edu/ERE/pdf/IGAstandard/pdf/WGC/2005/1415.pdf [31 May 2010].

Andrae, F, 2006, *Grundlagen der Waldbewirtschaftung,* University of Natural Resources and Life Sciences, Vienna.

Antics, M & Sanner, B 2007, 'Status of Geothermal Energy Use and Resources in Europe'. *Proceedings European Geothermal Congress 2007. Unterhaching, Germany, 30 May - 1June 2007,* ed International Geothermal Association. Available from: http://pangea.stanford.edu/ERE/pdf/IGAstandard/EGC/2007/082.pdf [31 May 2010].

ARGE Centrope Agency, 2010. *Centrope.* Available from: http://www.centrope.com [24 July 2010]

Austrian Energy Agency 1999-2010, *Komponenten einer thermischen Solaranlage*. Available from: http://energytech.at/solar/portrait_kapitel-4.html [01 June 2010].

Barclay, R 2009, *Feed-in Tariffs*. *Are they right for Michigan?* Available from: http://www.countrylines.com/wp-content/uploads/files/Feed-in%20Tariffs%20Paper_June22.pdf [23 June 2010].

Battocletti, L & Lawrence, B 2001, *Geothermal Resources in Eastern Europe*. Available from: http://www.bl-a.com/ECB/PDFFiles/GeoResEE.pdf [31 May 2010].

Buchgraber, K, 2006, *Grünlandbewirtschaftung,* University of Natural Resources and Life Sciences, Vienna.

Centrope Consortium, 2006. *Centrope – Vision 2015*. Project Principals of Centrope 2003-2006. Vienna.

Centrope map, 2010. The Centrope map. Available from: http://www.centropemap.org/mb242_pgo/frames/index.php?PHPSESSID=ju3ld17s8l7kbrj6vin9qe k1t0&gui_id=centrope_pgo_sld [22 July 2010]

Coenraads, R, Reece, G, Kleßmann, C, Ragwitz, M, Held, A, Resch, G, Panzer, C, Konstantinaviciute, I & Chadim, T 2008, *Renewable Energy Country Profiles*. Available from: http://isi.fraunhofer.de/isi/publ/download/isi08b33/progress-renewable-energy-countryprofiles.pdf?pathAlias=/publ/downloads/isi08b33/progress-renewable-energy-countryprofiles.pdf [18 March 2010].

Dickson, MH & Fanelli, M 2004, *What is Geothermal Energy?*, Istituto di Geoscienze e Georisorse, CNR , Pisa, Italy. Available from: http://www.geothermal-energy.org/files-31.html [29 April 2010].

Drozd, V, Vana, O & Pereszlenyi, M 2005, 'Possibilities of Production Enhancement of Natural Gas and Geothermal Energy Potential. Utilization from Carbonate Reservoir Rocks in the Zavod Structure in the Slovak Part of the

Vienna Basin'. *Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005,* ed International Geothermal Association. Available from: http://pangea.stanford.edu/ERE/pdf/IGAstandard/pdf/WGC/2005/1512.pdf [29 April 2010].

Dunlop, E, Huld, T, Šúri, M & Ossenbrink, H 2005, 'Is solar electricity in Europe expensive?'. *Proceedings from 20th European PhotovoltaicSolar Energy Conference and Exhibition. Barcelona, Spain, 6-10 June 2005,* ed European Commission - Joint Research Center. Available from: http://re.jrc.ec.europa.eu/pvgis/doc/paper/2005-Barcelona_7CO.8.4_Dunlop_etal.pdf.

DWIA 2003e, *Guided Tour in wind energy. The Energy in the Wind: Air Density and Rotor Area*. Available from: http://guidedtour.windpower.org/en/tour/wres/enerwind.htm [01 July 2010].

DWIA 2003h, *Guided Tour on wind energy. Wind Turbines: Horizontal or Vertical Axis Machines?* Available from: http://guidedtour.windpower.org/en/tour/design/horver.htm [02 July 2010].

DWIA 2003g, *Guided Tour on wind energy. Size of Wind Turbines*. Available from: http://guidedtour.windpower.org/en/tour/wtrb/size.htm [02 July 2010].

DWIA 2003l, *Guided Tour on wind energy. Park Effect*. Available from: http://guidedtour.windpower.org/en/tour/wres/park.htm [01 July 2010].

DWIA 2003k, *Guided Tour on wind energy. Roughness and Wind Shear*. Available from: http://guidedtour.windpower.org/en/tour/wres/shear.htm [02 July 2010].

DWIA 2003j, *Guided Tour on wind energy. Optimising Wind Turbines*. Available from: http://guidedtour.windpower.org/en/tour/design/optim.htm [02 July 2010].

DWIA 2003i, *Guided Tour on wind energy. Wind Turbines: How many blades?* Available from: http://guidedtour.windpower.org/en/tour/design/concepts.htm [02 July 2010].

DWIA, *Guided Tour on wind energy. Wind Shade*. Available from: http://guidedtour.windpower.org/en/tour/wres/shade.htm [01 July 2010].

DWIA, *Guided Tour on wind energy. The Power of the Wind: Cube of Wind Speed*. Available from: http://guidedtour.windpower.org/en/tour/wres/enrspeed.htm [02 July 2010].

DWIA 2003c, *Guided Tour on wind energy. Speed Up Effects: Tunnel Effect*. Available from: http://guidedtour.windpower.org/en/tour/wres/speedup.htm [01 July 2010].

DWIA 2003a, *Guided Tour on wind energy. Whence wind?* Available from: http://guidedtour.windpower.org/en/tour/wres/index.htm [01 July 2010].

DWIA 2003d, *Guided Tour on wind energy. Speed Up Effects: Hill Effect*. Available from: http://guidedtour.windpower.org/en/tour/wres/hill.htm.

DWIA 2003b, *Guided Tour on wind energy. Geostrophic winds*. Available from: http://guidedtour.windpower.org/en/tour/wres/geostro.htm [01 July 2010].

EEA 2006, *How much bioenergy can Europe produce without harming the environment?,* Copenhagen. Available from: http://www.eea.europa.eu/publications/eea_report_2006_7 [18 July 2010].

Energie-Control 2010, *Einspeisetariffe für neue Ökostromanlagen 2010*. Available from: http://e-control.at/portal/pls/portal/portal.kb_folderitems_xml.redirectToItem?pMasterthingId=911210 [21 June 2010].

EGEC, s.a., *The voice of geothermal industry in Europe*. Available from: http://www.egec.org/ [15 June 2010]

EREC 2009a, *Renewable Energy Policy Review. The Czech Republic*. Available from: http://www.erec.org/fileadmin/erec_docs/Projcet_Documents/RES2020/CZECH_REPUBLIC_RES_Policy_Review_09_Final.pdf [22 June 2010].

EREC 2009b, *Renewable Energy Policy Review. Hungary*. Available from: http://www.erec.org/fileadmin/erec_docs/Projcet_Documents/RES2020/HUNGARY_RES_Policy_Review__09_Final.pdf [22 June 2010].

EU- Directive 2001/77/EC. Renewable energy. Bruxells.

European Commission - Joint Research Center (ed.) 2005, *Proceedings from 20th European PhotovoltaicSolar Energy Conference and Exhibition. Barcelona, Spain, 6-10 June 2005*.

European Communities 1995-2010, *PV GIS*. Available from: http://re.jrc.ec.europa.eu/pvgis/apps/pvest.php# [01 June 2010].

EWEC (ed.) 2008, *Europe's premier wind energy event. Proceedings*.

Faaij, A 2006, 'Modern Biomass Conversion Technologies' in *Mitigation and Adaptation Strategies for Global Change,* ed Springer, pp. 343–375. Available from: http://kfrserver.natur.cuni.cz/global/pdf/FAAIJ_biomass2006.pdf [22 July 2010].

Fendek, M & Fendekova, M 2005, 'Country Update of the Slovak Republic'. *Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005,* ed International Geothermal Association. Available from: http://pangea.stanford.edu/ERE/pdf/IGAstandard/pdf/WGC/2005/0173.pdf [29 April 2010].

Fridleifsson, IB, Bertani, R, Lund, JW & Rybach, L 2008, 'The possible role and contribution of geothermal energy to the mitigation of climate change'. *IPCC Scoping Meeting on Renewable Energy Sources, Proceedings. Luebeck, Germany, 20-25 January 2008,* eds O Hohmeyer & T and Trittin, pp. 59–80. Available from: http://www.geothermal-energy.org/files-5.html [29 April 2010].

Galantaterm s.a., *Zoznam odberatel'ov*, Galantaterm s.r.o. Available from: http://galantaterm.sk/prod02.htm [29 April 2010].

Galantaterm 2008, *Environmental Report 2008*. Available from: http://galantaterm.sk/Environmental_Report_2008_EN.pdf [29 April 2010].

Gergerly, M 2009, *Agriculture in Hungary*. pers. comm., Uppsala.

German Society for Solar Energy s.a., *Solar Collectors: Different Types and Fields of Application*. Available from: http://www.solarserver.de/wissen/sonnenkollektoren-e.html#fla [01 June 2010].

Goldbrunner, J 2005, 'State, Possible Future Developments in and Barriers to the Exploration and Exploitation of Geothermal Energy in Austria - Country Update'. *Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005,* ed International Geothermal Association. Available from: http://pangea.stanford.edu/ERE/pdf/IGAstandard/pdf/WGC/2005/0147.pdf [01 June 2010].

Halás, O, 'New Projects of Geothermal Energy Utilization in District Heating System in Slovakia'. *Geothermal District Heating Projects: Technical and Economic Feasibilty for Organization in Central European Conditions.* Session 2, ed International Geothermal Days Slovakia 2009 [29 April 2010].

Hanslian, D & Pop, L 2008, 'New wind map and wind energy potential of the Czech Republic'. *Europe's premier wind energy event. Proceedings,* ed EWEC. Available from: http://www.ewec2008proceedings.info/ewec2008/allfiles2/263_EWEC2008fullpaper.pdf [02 July 2010].

Hofierka, J & Cebecauer, T 2008, 'Spatially distributed assessment of solar resources for energy applications in Slovakia', *Folia Geographica*, no. 12, pp. 97–114. Available from: http://www.fhpv.unipo.sk/kagerr/pracovnici/hofierka/projekty/Hofierka_Cebecauer_Folia12.pdf [01 June 2010].

Hohmeyer, O & and Trittin, T (eds.) 2008, *IPCC Scoping Meeting on Renewable Energy Sources, Proceedings*. *Luebeck, Germany, 20-25 January 2008*.

Huld, T, Gottschalg, R, Beyer, H & Topič, M 2009, 'Mapping the performance of PV modules of different types', *Progress in Photovoltaics, Research and Applications*. Available from: http://re.jrc.ec.europa.eu/pvgis/doc/paper/2009_PiP_1axis_strategies.pdf [01 June 2010].

International Geothermal Association (ed.), *Proceedings World Geothermal Congress 2000. Kyushu - Tohoku, Japan, 28 May - 10 June, 2000*.

International Geothermal Association (ed.) 2005, *Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005*.

International Geothermal Association (ed.) 2007, *Proceedings European Geothermal Congress 2007. Unterhaching, Germany, 30 May - 1June 2007*.

International Geothermal Days Slovakia 2009 (ed.), *Geothermal District Heating Projects: Technical and Economic Feasibilty for Organization in Central European Conditions*. Session 2.

Jakubec, H & Kocskovics, M 2005, 'Utilization of Geothermal Resources in Galanta - Slovak Republic'. *Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005,* ed International Geothermal Association. Available from: http://pangea.stanford.edu/ERE/pdf/IGAstandard/pdf/WGC/2005/0905.pdf [29 April 2010].

Jirijs, R 2009, *Bioenergy - technology and system*. *Bioenergy - fuel upgrading aspects,* Sverige Lantbruksuniversitet, Uppsala.

Klein, A, Pfluger, B, Held, A, Ragwitz, M, Resch, G & Faber, T 2008, *Evaluation of different feed-in tariff design options*. *Best practice paper for the International Feed-In Cooperation*. Available from: http://www.feed-in-cooperation.org/wDefault_7/wDefault_7/download-files/research/best_practice_paper_2nd_edition_final.pdf?WSESSIONID=e90611327e4360721b99425c7dc3ef83 [22 June 2010].

Kniffler, N 2004, *Systemkonzepte mit thermischen Kollektoren*, Hochschule Mannheim - Fakultät der Elektrotechnik. Available from: http://www.et.hs-mannheim.de/kni/ren/thermie/3_html/3_systeme.html [01 June 2010].

Lechner, P, 2004, *Kommunale Abfallwirtschaft,* UTB für Wissenschaft. Wien.

Ministry of Economy - Slovakia 2001, *Draft Energy policy of the Slovak Republic*. Available from: http://pdc.ceu.hu/archive/00003421/01/draft_energy_policy_of_the_slovak_republic.pdf [22 July 2010].

mecca 2008, *Raum und Energie Potenziale in der Ostregion*, PGO. Wien.

Mendonça, M 2007, *Feed-in Tariffs*. *Accelerating the Deployment of Renewable Energy,* Earthscan, London.

My Energy GIE 2009b, *Funktionsweise eines Solarkollektors*. Available from: http://www.myenergy.lu/files/Funktionsweise_Kollektor.pdf [01 June 2010].

My Energy GIE 2009a, *Photovoltaik*. Available from: http://www.myenergy.lu/de/besser_wohnen/strom/photovoltaik [01 June 2010].

My Energy GIE 2009c, *Solarthermie*. Available from: http://www.myenergy.lu/de/besser_wohnen/heizung/solarthermie [01 June 2010].

Myslil, V & Stibitz, M, 'Geothermal Resources of the Czech Republic - General overview'. *Proceedings World Geothermal Congress 2000. Kyushu - Tohoku, Japan, 28 May - 10 June, 2000,* ed International Geothermal Association. Available from: http://pangea.stanford.edu/ERE/pdf/IGAstandard/pdf/WGC/2000/R0823.PDF [31 May 2010].

Myslil, V, Stibitz, M & Frydrych, V 2005. *Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005,* ed International Geothermal Association. Available from: http://pangea.stanford.edu/ERE/pdf/IGAstandard/pdf/WGC/2005/0177.pdf [31 May 2010].

Nayono, S, *Anaerobic digestion of organic solid waste for energy production,* Universitätsverlag Karlsruhe. Available from: http://uvka.ubka.uni-karlsruhe.de/shop/download/1000015038 [22 July 2010].

Øgendal, L 2008, *Climate, weather and plants,* Faculty of LIFE - University of Copenhagen, Copenhagen.

Oke, TR 2003 [1987], *Boundary layer climates. 2nd Edition,* TJ International Ltd., Padstow, Cornwall.

PGO 2005b, *Agricultural landuse,* Centrope Map. Available from: http://www.centropemap.org/dmdocuments/2008/A3_1100000_LAWI6.pdf [17 July 2010].

PGO 2005a, *Agriculture and Forestry Landuse,* Centrope Map. Available from: http://www.centropemap.org/dmdocuments/2008/A3_1100000_LAWI4.pdf [15 July 2010].

PGO 2010, *Corine Landcover 2000,* Centrope Map. Available from: http://www.centropemap.org/mb242_pgo/frames/index.php?&gui_id=centrope_pgo_sld [10 July 2010].

Plha, S 2010, *The region Centrope*. pers. Comm., Vienna

Quaak, P, Knoef, H & Stassen, H 1999, *Energy from Biomass. A review of combustion and gasification technologies*.

Rutz, D & Janssen, R 2007, *Bio Fuel Technology Handbook*. Available from: http://www.compete-bioafrica.net/publications/publ/BioFuel_Technology_Handbook_1vs_WIP.pdf [21 July 2010].

Schaffer, H, 2010, *Feed-in tariffs and support duration*. pers. comm., Vienna.

Schuster, M, 2010. *Energieinitiativen Österreichs: Ein Wegweiser*. Vienna.

Springer (ed.), 2006, *Mitigation and Adaptation Strategies for Global Change* [19 July 2010].

Šúri, M, Huld, T, Dunlop, E & Ossenbrink, H 2007, 'Potential of solar electricity generation in the European Union member states and candidate countries', *Science Direct - Solar Energy*, no. 81, pp. 1295–1305. Available from: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V50-4N27D63-1&_user=10&_coverDate=10%2F31%2F2007&_rdoc=1&_fmt=high&_orig=search&_sort=d&_docanchor=&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=3f22cb3851f17e7f30a920fd3c9a66a9 [01 June 2010].

Tetzlaff, KH 2010, *Anbaumethoden von Energiepflanzen*. Available from: http://www.bio-wasserstoff.de/h2/Energiepflanzen/energiepflanzen.html [22 July 2010].

Uphoff, V & Brand, R 2008, *Windblatt. Enercon Magazin für Wind Energie*. Available from: http://www.enercon.de/www/de/windblatt.nsf/vwAnzeige/5E4606B6DF14DCE4C12573B400460FB7/$FILE/WB-0108-dt.pdf [05 July 2010].

8. Appendices

Appendix A

The Survey „Renewable Energy - Barriers and Potentials"

Question 1	**Which energy source except for energy savings appears to be the most promising one for your country in order to achieve EU-Energy Goals for 2020? *)**	
	Please rank the following renewable energy sources.	
	1= most promising 4= least promising *Use 5 as 'least promising' for ranking, if you add another energy source.*	*1= most promising 3= least promising* *Use 4 as 'least promising' for ranking, if you add another energy source.*
	SECTOR: ELECTRICITY	SECTOR: HEATING
	Rank ▼ BIOMASS	Rank ▼ BIOMASS
	Rank ▼ WIND POWER	Rank ▼ SOLAR ENERGY
	Rank ▼ SOLAR ENERGY	Rank ▼ GEOTHERMAL ENERGY
	Rank ▼ GEOTHERMAL ENERGY	
	*) The investigations focus on energy sources presented above and therefore exclude other sources like hydro power. Do you have a different opinion? Please make a note at the end of the questionnaire.	

Question 2	**Which sector will experience the strongest expansion of renewable energy by 2020 in your country?**	
	Please indicate the accordant sectors by marking. Multiple selection possible.	
	☐ Electricity	OR ☐ Heating
	☐ Housing ☐ Offices	☐ Housing ☐ Offices
	☐ Public Buildings ☐ Industries	☐ Public Buildings ☐ Industries
	☐ Other ____________________	☐ Other ____________________

Question 3	Which barriers do you see arising for the enhancement of renewable energy production on a national and cross-border level?
	Please name at least 3 barriers.
	1)
	2)
	3)

Question 4	Is in your opinion, centralized or decentralized energy policy more appropriate/more effective to achieve the set EU-Goals for 2020?
	Please mark your answer.
	☐ centralized energy policy ☐ decentralized energy policy

Question 5	Which actions are needed to facilitate considerable contribution of renewable energy sources?
	Please indicate by marking how important it is to take the following actions for a break through of renewable energy. Choose between very important - important - less important - not important.

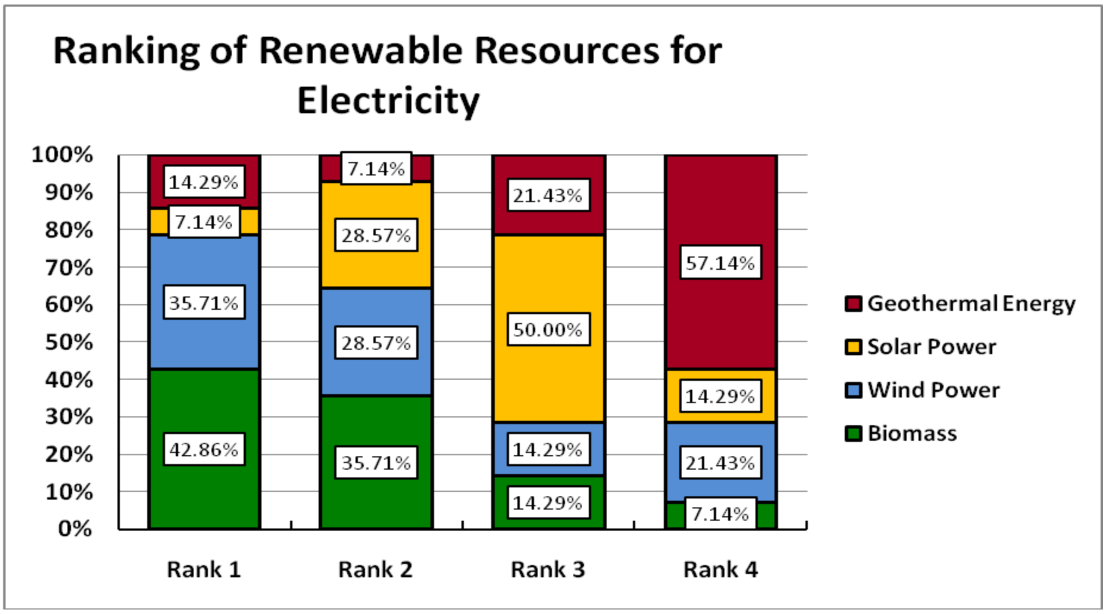
Actions	very important	important	less important	not important
Enforcement of energy saving to alleviate penetration of renewable energy	☐	☐	☐	☐
Promotion of renewable energy technologies as economic impulses	☐	☐	☐	☐
Expansion and improvement of the electricity grid	☐	☐	☐	☐
Implementation of profitable feed-in tariffs to enhance investments	☐	☐	☐	☐
Opposing lobbyism against renewable energy supply by electricity grid	☐	☐	☐	☐
Expansion of regional autonomy to facilitate renewable energy production	☐	☐	☐	☐
Harmonization of regulations (quotas, certificates, feed-in tariffs)	☐	☐	☐	☐
Consideration of spatial planning in renewable energy decisions	☐	☐	☐	☐
Increase of EU-funded projects to enforce renewable energy development	☐	☐	☐	☐
Strenghtening of cross-border co-operation in research, policy and economy	☐	☐	☐	☐
Establishment of energy regions	☐	☐	☐	☐
Rise of collective consiousness in society for more understanding and support	☐	☐	☐	☐

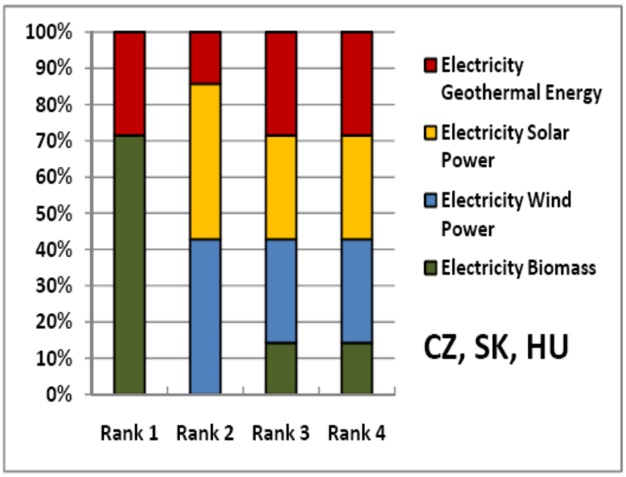
APPENDIX B

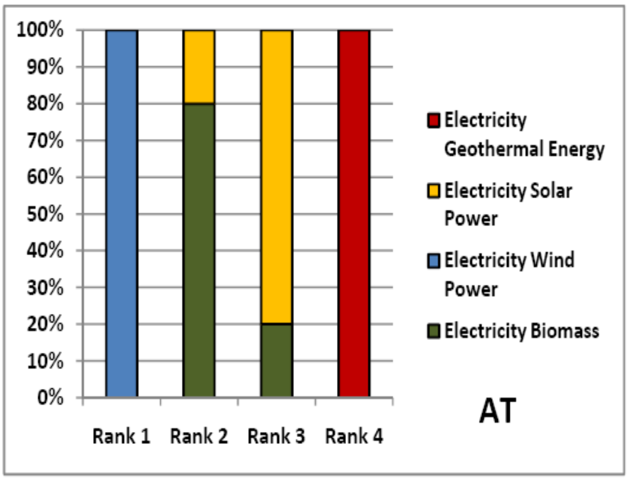
RESULTS OF THE SURVEY „RENEWABLE ENERGY - BARRIERS AND POTENTIALS"

AD QUESTION 1: ELECTRICITY

Ranking	Electricity			
	Biomass	Wind Power	Solar Power	Geothermal Energy
Rank 1	42.86%	35.71%	7.14%	14.29%
Rank 2	35.71%	28.57%	28.57%	7.14%
Rank 3	14.29%	14.29%	50.00%	21.43%
Rank 4	7.14%	21.43%	14.29%	57.14%

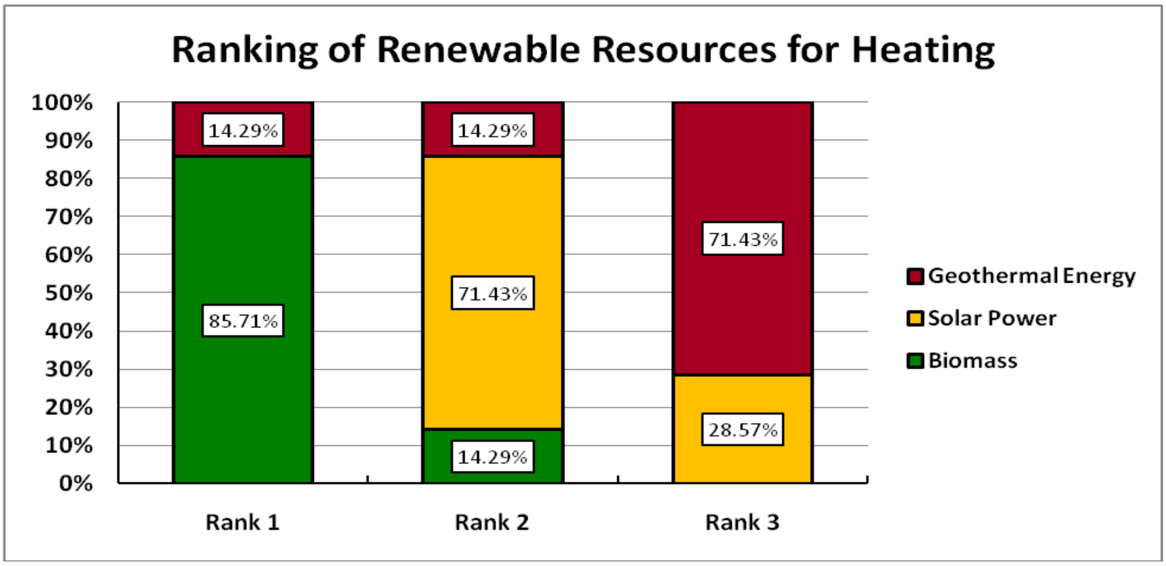


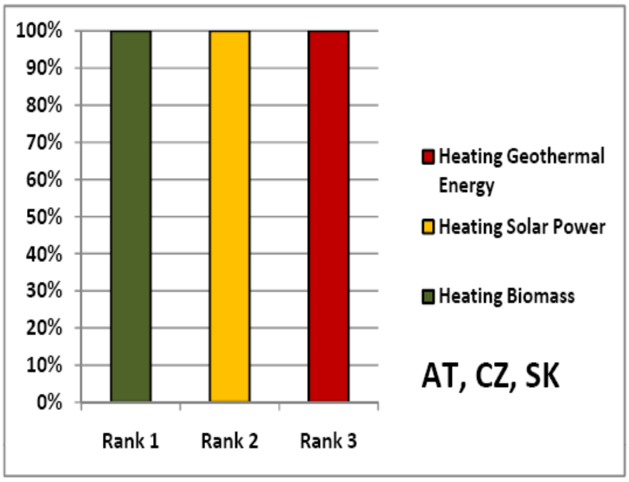


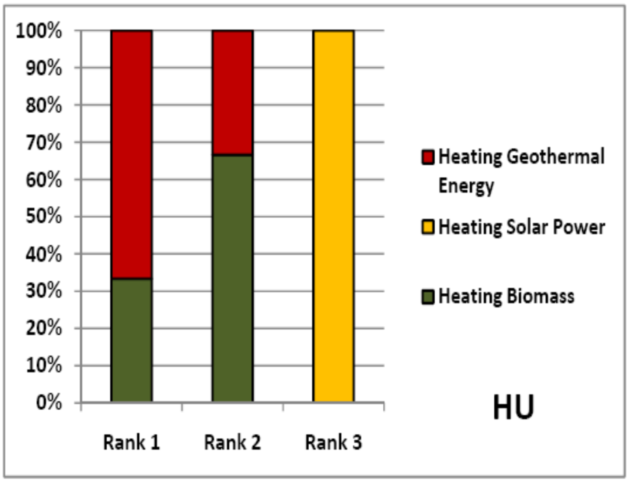


AD QUESTION 1: HEATING

Ranking	Heating		
	Biomass	Solar Power	Geothermal Energy
Rank 1	85.71%	0.00%	14.29%
Rank 2	14.29%	71.43%	14.29%
Rank 3	0.00%	28.57%	71.43%
Rank 4			



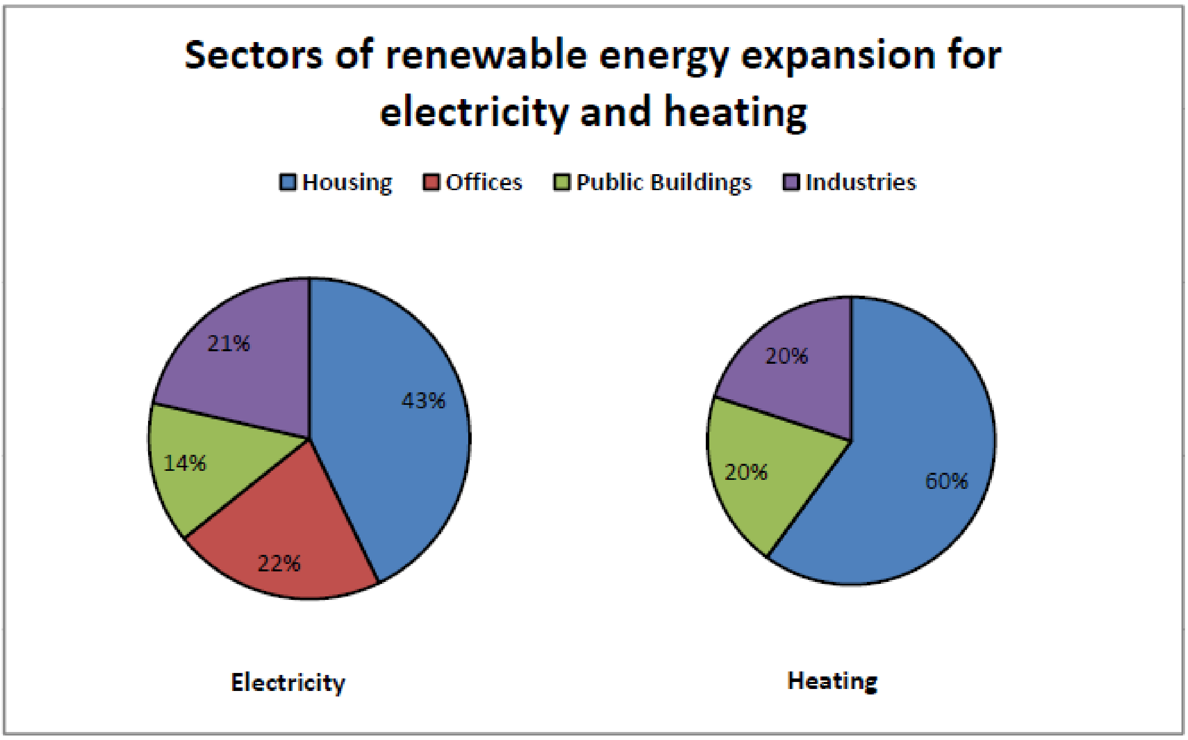




AD QUESTION 2:

Sector	Percentage
Electricity	57.14%
Heating	42.86%

Main Sector	Sub-Sector			
	Housing	Offices	Public Buildings	Industries
Electricity	42.86%	21.43%	14.29%	21.43%
Heating	60.00%	0.00%	20.00%	20.00%



AD QUESTION 3:

Barriers:

- Hydro power: only small remaining potential and social resistance, environmental protection; wind power: social resistance, consuming landscape, devalues space (e.g. for building constructions)

  Solar thermal: more or less without significant barriers, normal diffusion process;

  Photovoltaic: investment costs, energy policy measures (subsidies) required;

  Biomass solid: in medium to long run potential restrictions, sectoral barriers like dust emissions etc.

  Biomass liquid: embedded energy, fertilizer demand, impact on rain forest etc.

  biomass gas: potential restrictions, competition in use as energy, food or material;

  Geothermal energy: economic parameters of heat grids, competition to other options;

  Ambient heat: heat pumps, the need of electricity, efficiency restrictions;

- Development of costs for conventional (fossil) and renewable energies uncoordinated;

  Wide-spreaded and inconsequent executed state regulations;

  Short sight outlook of energy policies;

- Limited availability of resources;

  Market distortion due to inefficient support schemes;

  Different legal framework conditions overestimated potential to be harvest in a sustainable and cost-effective way; High costs for end users;

- Insufficient network for transport and distribution of energy;
- Natural conditions (no wind, no seashells, capacity of water power-stations almost exhausted), too expensive renewable energy;
- high investment costs; Bureaucratic barriers; technical barriers
- High initial investment costs; electricity transmission infrastructure; real possibility implementation of RES policies
- Lacking long term stable environment in the system on grid prices of electricity made from RE. Non-existence of support measures aimed at the general public.

  Lack of obligation to purchase electricity products from RE;

  Lack of technological development of equipment using RE;

  Inadequate structure of distribution networks;

  Lack of information to population on the strengths and weaknesses of RE;

- In the case of biomass (hard biomass) the collecting of it is expensive (high human-work intensity and its costs);

The oil lobby is very strong; In the case of photovoltaic systems, the return of the investment is long;

- The lack of the real engagements of the national government and the state owned energy public companies (like ELMU or PAKS) to open the market for the renewable energy production and take off the monopole situation of the classical type of the energy production.
- Lack of government commitments, thus ineffective renewable energy policies are difficult to bring through important legislative modifications or set up effective support systems.

  Currently the system of RES project authorisation is a hot issue. Authorisation is a long (several years), costly and complicated process. Biggest problem is to ensure investment security.

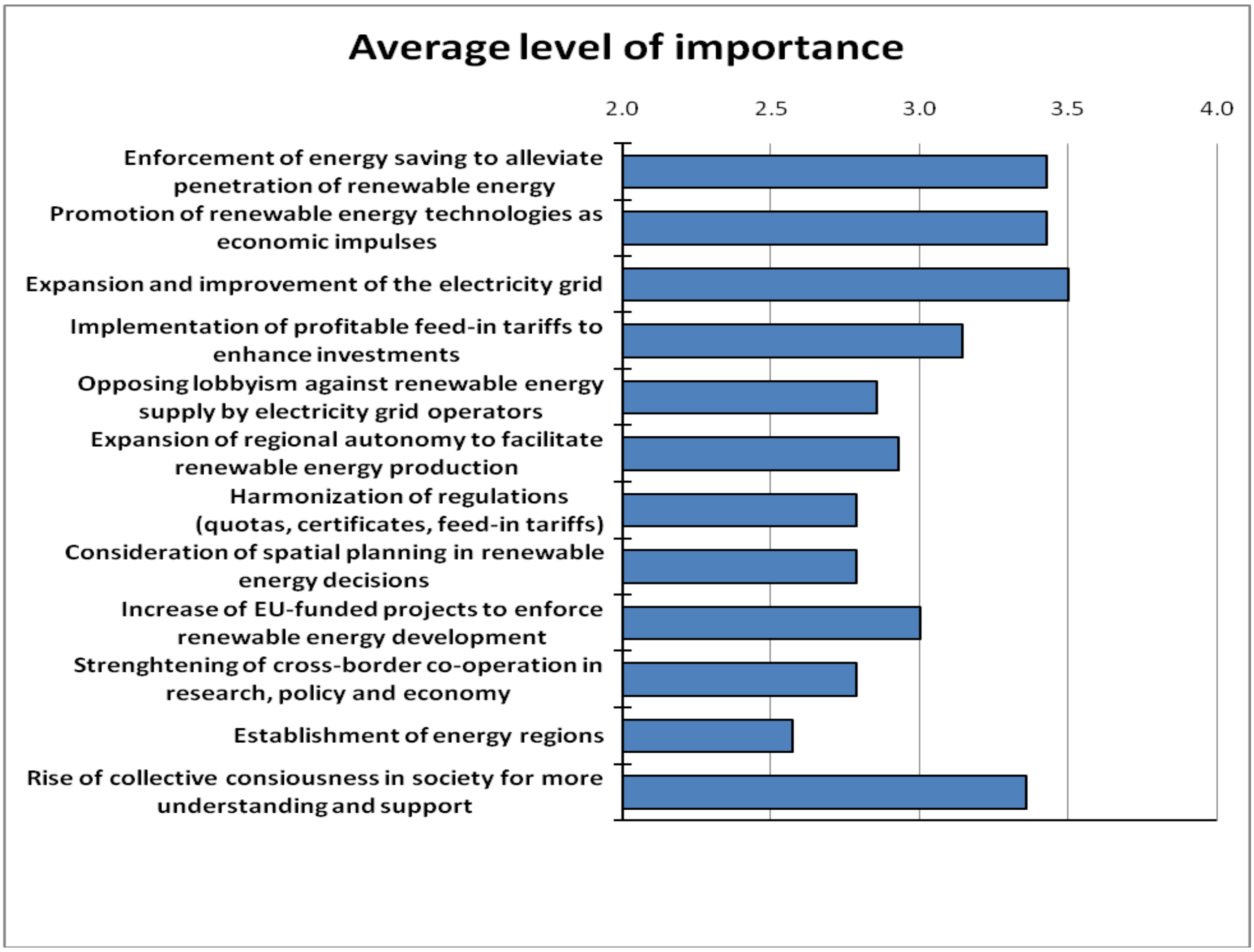
- lESS Furtherance; Competition between the nations; Low awareness

AD QUESTION 4:

Energy Policy	Percentage
centralized	21.43%
decentralized	78.57%

AD QUESTION 5:

very important	**important**	**less important**	**not important**
4	3	2	1



Level of importance		
very important	**important**	**less important**
Expansion and improvement of the electricity grid	Implementation of profitable feed-in tariffs to enhance investments	Harmonization of regulations (quotas, certificates, feed-in tariffs)
Promotion of renewable energy technologies as economic impulses	Increase of EU-funded projects to enforce renewable energy development	Consideration of spatial planning in renewable energy decisions
Enforcement of energy saving to alleviate penetration of renewable energy	Expansion of regional autonomy to facilitate renewable energy production	Strenghtening of cross-border co-operation in research, policy and economy
Rise of collective consiousness in society for more understanding and support	Opposing lobbyism against renewable energy supply by electricity grid operators	Establishment of energy regions