Stratego | ENHANCED HEATING & COOLING PLANS

PlanEnergi

Subcontract report for the STRATEGO-project

Estimating the Renewable Energy Resources Available in EU Member States

December 2014

NORTH JUTLAND
Jyllandsgade 1
DK–9520 Skørping
Tel. +45 9682 0400
Fax +45 9839 2498

CENTRAL JUTLAND
Vestergade 48 H, 2nd floor
DK–8000 Aarhus C
Tel. +45 9682 0400
Fax +45 8613 6306

ZEALAND
Postal address:
A.C. Meyers Vaenge 15
DK - 2450 København SV
Visitors address:
Frederikskaj 10 A, 1st fl, 1.143
DK -2450 Copenhagen SV
Tel.: +45 2224 2562

www.planenergi.dk
planenergi@planenergi.dk
VAT no.: DK7403 8212

Table of contents

Contact person at PlanEnergi:
Daniel Trier
Tel.: +45 9682 0400
e-mail: dt@planenergi.dk

Quality assurance
LLJ/DMS

1 Introduction

The purpose of the project "Multi level actions for enhanced Heating and Cooling plans – STRATEGO" is to bridge the gap between EU policy, national objectives and effective actions taken at regional and local levels. The STRATEGO project is a European co-funding project developed in the framework of the Intelligent Energy Europe Programme, having the contract no. IEE/13/650/SI2.675851. This report is the outcome of the subcontract under the second work package (WP2) in STRATEGO, "Supporting the development of enhanced NHCPs" in which PlanEnergi has been appointed to estimate the renewable heat and electricity potentials in 5 targeted EU member states.

WP2 in the STRATEGO-project specifies a need for identifying national energy data on the potentials of renewable energy, within Croatia, Czech Republic, Italy, Romania, and the UK. This information is compiled in the present report, *Renewable Electricity and Heat Potentials*.

The authors wish to thank those national contact-points, who have been kind enough to supply data during the process of estimating the potentials for renewable energy in the five target countries.

2 Methodology

No other comprehensive dataset on the potentials for RE heat and electricity has been identified for the countries in this study; hence, the compiled information is based on data from many different references. Consequently, discrepancies have been identified among the different references, when there have been mismatches between numbers. In these cases, the most probable number has been selected, while alternative numbers have been kept as secondary options. This methodology has been chosen, in order to accommodate for the sometimes very large differences between numbers. In the tables under each country is a version with the given energy-data – numbers in capacity [MW] and production [TWh]. A similar table describes the references in [square brackets], including the alternative numbers found. Where there has only been identified a single reference, this is indicated by a single bracketed number in the corresponding cell in the reference-table.

Some national partners in the STRATEGO-project have provided input to the data upon request. These data have been useful, since documentation on the national languages has often proven to be more detailed and plentiful than the more readily available English-language reports used in the screening.

2.1 Numbers and decimals

It is the intention to provide detailed and specific data with this report. Nonetheless, it has not always been possible to obtain precise numbers on all data points. Consequently, numbers without decimals in this report should be interpreted as approximate, while numbers with decimals can be considered more precise. While two decimals have been applied as a standard, it has been chosen to deviate from this rule, in cases where the original reference has only one decimal.

2.2 A note on a particular reference: Atlas of EU biomass potentials

A significant reference used as a supplement to the national sources when finding the future biomass potentials is "Atlas of EU biomass potentials - Spatially detailed and quantified overview of EU biomass potential taking into account the main criteria determining biomass availability from different sources". Will

hereafter be referred to as *Biomass Atlas*. It has been deemed relevant to describe this resource in further detail below, since its numbers and assumptions in some occasions is found to vary significantly from other sources. The information in this section is largely based on contents of the Biomass Atlas.

One purpose of the Biomass Atlas is to identify different biomass feedstocks and make an inventory of data to quantify and map the technically constrained biomass potentials. This also includes estimates of alternative uses of by-products and waste in order to estimate the share that is available for bioenergy purposes and the share that competes with other uses. From this, the 2020 and 2030 potentials are quantified in the report according to different scenarios.

The Biomass Atlas uses three main categories for biomass; Biomass from agriculture, Biomass from forestry and Biomass from waste. Under each of these categories, there is a range of subcategories of dedicated biomass production such as biofuel crops, woody and grassy crops, stem wood production and by-products and waste categorized in primary, secondary and tertiary levels. In the data for the STRATEGO project the following categories for biomass is used: Energy crops (residual), Energy crops (dedicated land), Wood, Waste (renewable and fossil) and Biogas. From the national sources used under each country, it has been difficult to find these exact categories, and many numbers are therefore sums from other categories found in the used sources. The numbers from the Biomass Atlas are therefore presented as a separate table in order to compare the found numbers from the national sources (when available) and in order to have a uniform approach to find the numbers under each category.

When estimating the future potential it should at first be realised that the EU policy ambitions go far beyond current consumption of renewable energy. From the report it is stated that the European Commission (2008) calculated that 17.5 million hectares of land would be required to reach the 10 % biofuels target, which would amount to about 10 % of the total Utilised Agricultural Area (UAA) in EU27[*]. The report further states,

"It is clear that the pressure on land will increase strongly under a growing biomass demand. This may cause adverse effects on biodiversity as it may lead to the further intensification of existing land uses, both in agricultural and forest lands, but also the conversion of non-cropped biodiversity-rich land into cropped or forest area. The conversion of biodiversity rich grasslands for example is meant to be prevented with the sustainability scheme for biofuels to be introduced together with the approval of the biofuels target of 10 %. The RES directive states that biofuels shall not be made from raw material obtained from land with recognized high biodiversity value, such as undisturbed forest, areas designated for nature protection purposes or highly biodiverse grasslands. However, the big question is how this land resource is exactly defined and identified (e.g. mapped) and whether not being accountable to the renewable energy target provides enough protection to valuable ecosystems in markets offering very high prices to biomass feedstock.

In addition, there is also an increasing resistance against using existing arable land for the production of biomass at the expense of food and feed production. There are indications that this will endanger the food security situation, especially in third world countries, and that indirect land use changes may take place by bioenergy production pushing food and feed production into uncultivated areas causing loss of valuable natural habitats (e.g. tropical rain forest and savannah) and tremendous releases of greenhouse gas (GHG) stocks in the soil."

[*] Their starting point was that 50 % of the production would come from cultivation of rotational biomass crops for 1st generation technology biofuels. The other 50 % would come from ligno-cellulosic by-products and perennial biomass crops or imports from outside the EU. For conversion of this ligno-biomass feedstock they assumed 2nd generation biofuel technology to become commercially available before 2020.

The estimations of biomass potential in the Biomass Atlas are made for different scenario situations taking into account different sustainability criteria. Two scenarios are applied for 2020 and 2030:

1. Reference scenario
2. Sustainable scenario

The sustainability criteria are applied in the reference storyline following the 'Directive on the promotion of energies from renewable sources'[†] and therefore only apply to biofuels and bioliquids. The potentials used in the datasheet are from the sustainable scenario from 2020. The potential is in both scenarios based on three main themes:

1. **Estimating the land potential for bioenergy cropping and for agro-waste potentials**
   The results are based on the CAPRI[‡] model, which predicts future land use changes in the EU-27 related to agricultural production including those for domestic biofuels. The CAPRI model's 2020 baseline runs with the EC report 'Prospects for Agricultural Markets and Income in the EU 2010-2020. This outlook takes into account the most recent Health Check reform, the 2020 RES targets and the most recent OECD-FAO projections on agricultural prices, population and development.

   In order to reach the EU 2020 targets, the mix of biofuel feedstock will change. A priority is given to the most sustainable crop mix per region, taking into account the mitigation requirements set in both the reference and sustainability scenario. The estimation of the mitigation requirement is described in the next step.

2. **Estimating the minimum GHG mitigation requirement per scenario for bioenergy cropping potential**
   First, in the reference scenario a minimal GHG mitigation requirement for biofuel of 50 % is assumed. A much stricter mitigation is assumed in the sustainable scenario as it should include the indirect land use change impacts of biofuels (iLUC) related emissions. The GHG mitigation is assumed to reach 70 % in 2020 and 80 % in 2030, which both applies on biofuels and on cropped biomass for heat and electricity production.

   The estimation of the minimal GHG requirement is built on the approach developed by EEA/ETC-SIA[§] study. An estimate of GHG payback and mitigation ability is made for all crops, including the iLUC effect and taking into account the type of feedstock and related bioenergy delivery pathway.

3. **Excluding high biodiverse land and land with high carbon stock**
   In the reference scenario biofuel crops cannot be cropped on highly biodiverse areas or area with high carbon stock. In the sustainable scenario this applies to all cropped biomass. The land available for biomass cropping is therefore reduced compared to the reference scenario. Both the Natura

[†] Directive 2009/28/EC - RES Directive

[‡] The CAPRI (Common Agricultural Policy Regionalised Impact) model is a tool for ex-ante impact assessment of agricultural and international trade policies with a focus on the European Union. It is an economic partial comparative static equilibrium model for agriculture. The core of the model consists of two interlinked modules: about 250 regional aggregate programming models covering the EU27, Norway and Western Balkans at the NUTS 2 level and a global spatial multi-commodity model for agricultural commodities. These together allow calculation of a wide range of economic and environmental indicators.

[§] EEA: European Environment Agency

ETC/SIA: The European Topic Centre for Spatial information and Analysis. ETC/SIA is supporting the European Environment Agency (EEA) in developing seamless European wide spatial reference data. ETC/SIA's main working area is the analysis of Land use and land cover.

2000[**] (farmland) and the HNV farmlands[††] were regarded as highly biodiverse areas and agricultural areas with high carbon stock. These areas were therefore not taken into account in biomass cropping areas in the sustainable scenario.

In short, the stricter sustainability criteria in the Biomass Atlas lead to a lower cropping potential in 2020 and 2030.

3 Countries

3.1 Croatia

On the 1st of July 2013, Croatia became the 28th member of the EU after a decade of carrying out all the reforms needed to bring it into line with EU laws and standards.

The energy statistics carried out within EU are mostly focused on EU27, while Croatia is not included. This can explain the difficulties finding Croatian energy data, which were encountered during this study.

The energy plans made for Croatia is limited to forecasts for 2020 or 2030, so the available numbers for these years have been used, where available. Elsewhere data from The European Commission report 'EU Energy, Transport and GHG Emissions - Trends to 2050 - Reference Scenario 2013' has been used.

It was not possible to collect any data for the biomass potential in the future. It is therefore agreed that AAU will collect remaining data through local contacts in Croatia.

Full-load hours (FLH) and solar performance are presented in the tables below.

	Full-load hours			
Type	2,010.00	2,050.00	Difference	Difference [>100 % means larger than 2010]
Onshore Wind	1,564.67	3,666.67	2,101.99	234%
Offshore Wind	1,544.12	3,666.67	2,122.55	237%
Photovoltaic	840.91	1,523.10	682.19	181%
Concentrated Solar Power				
Direct Geothermal				
Wave				
Tidal				
Hydro				
River Hydro				
Hydro	4,439.47	5,306.91	867.43	120%
Hydro Pump Back (if applicable)				
Type				
Individual Solar Thermal				
Solar Thermal	728.79			
Geothermal	535.38			

Solar-check						
Given information			Calculated	ESTIF 2012 numbers		
Capacity MW	Production TWh	Area m2	Performance kWh/m2	Capacity	Area	Solar Radiation MWh/m2
83.70	0.06	119,600	510.03	84.00	120,000	1.15 to 1.65

Assumptions and crosscheck results are described in the following.

[**] Natura 2000 is a network of nature protection areas in the territory of the European Union. It comprises various types of protected areas, mainly Special Areas of Conservation (SACs) and Special Protection Areas (SPAs), but it also includes Marine Protected Areas (MPAs) and some special forms defined on a national basis.

[††] High Nature Value Farmland. By definition, in HNV farmland agriculture supports, or is associated with, either a high species and habitat diversity or the presence of species of European conservation concern, or both.

Onshore/Offshore wind:
The accumulated wind capacity in [1] and [3] is 89 MW. From [4], the onshore/offshore distribution is given to be 3 % offshore, 97 % onshore, hence the results of 86 MW onshore and 3 MW offshore. Croatia has installed more wind capacity since 2010. According to [9], (from 2012), onshore wind power was 179.60 MW.

According to [1], the accumulated wind capacity in Croatia will be 1,079 MW in 2050. This is lower, than what is stated in the national plan for 2020 by [2] and in [HR5]: 1,200 MW in 2020 in total.

In [4], the onshore/offshore distribution is estimated to 71 % offshore, 29 % onshore. Therefore the results of 348 MW onshore and 852 MW offshore. The same method has been applied for the annual production shown in TWh.

From 2010 to 2050 there is seen an increase in FLH by more than 200 % for both onshore and offshore wind. The numbers are the same in the used references, so this can be explained due to technical development and higher share of offshore wind.

Photovoltaic:
The 2010 number from [1] states a capacity of 0 MW. Therefore, 2012 data from [7] has been used, which gives the following data: PV on grid = 3.9 MW and PV off grid = 0.5 MW, hence total = 4.4 MW. [7] has also been used for the production in 2010 with 2012 data.

For the capacity and generation from photovoltaics in 2050 [1] has been used for both numbers. For comparison, [HR4] states a number of 250 MW in year 2030. [HR1] states the technical potential to electricity generation from photovoltaics and solar thermal power plants to be around 33 TWh/year. The economic potential to produce solar electricity would amount to around 0.3 TWh/annum, which is the equivalent of around 200 MW of generating capacity.

The increase by 181 % in FLH may be due to technical development, since all used numbers are from [1].

Hydro:
The capacity in 2010 is from [1], whereas the production is from [HR2] and [2], given to be 8,309 GWh.

The capacity potential in 2050 is from [1]. In [1] the production potential is 8.74 TWh, but in [HR1] the technically exploitable water potential resources in Croatia are estimated at 12.45 TWh/year with a forecast for 2030 of 7.03 TWh (25.31 PJ).

An increase of 120 % in FLH can be explained by difference in use of source for 2010 and by technical development.

Individual solar thermal:
The numbers for individual solar thermal are in both 2010 and 2050 from [HR3]. For 2010, 2012 numbers are available with 0.5 PJ. In 2050 the potential in [HR3] is 12.21 PJ in 2030-numbers.

Solar thermal:
The capacity for 2010 is from [8] with 2012-data: 119,600 m^2 and 83.70 MW. The production in 2010 is taken from [HR2].

The potential for 2050 is from [HR1]. The technical potential to produce heat from solar collectors and the use of passive solar energy (solar architecture) amounts to 175 TWh/annum (630 PJ/year). The economic potential is stated to be 7 % of technical potential.

In the solar check, the performance is calculated to 510 kWh/m^2, which seems to be a reasonable number for the region, where the solar radiation is 1.15 to 1.65 MWh/m^2.

Geothermal:
The capacity is from [HR1] with 2007-data: Total installed heat capacity from supply of geothermal energy 2007 from space heating = 33.66 MW, from space heating and hot water preparation = 113.90 MW. From [HR1] the production in 2007 corresponded to 702.31 TJ = 0.2 TWh. In [HR2] the number is 0.08 TWh.

For the potential in 2050 [HR1] is used with 2030 forecast of 8.54 PJ.

Energy crops, residual:
In [HR1], the agricultural residue is given to be 22.93 PJ. AAU will find 2050-data through local contacts.

Energy crops, dedicated land:
In [HR4] and [HR2] a number for energy forests was given and used as 2010 data of 12.88 PJ. AAU will find 2050-data through local contacts.

Wood:
The number of 16 TWh in 2010 is given in [HR2]. From [HR1] the following numbers are listed, supporting the data:

- Cord wood = 24.33 PJ
- Wood residue = 8.65 PJ
- Abbaino = 2.01 PJ
- Wood industry residue = 17.89 PJ
- Roads, water management, etc. = 4.80 PJ
- Total = 57.68 PJ = 16.02 TWh

AAU will find 2050-data through local contacts.

Waste:
From [HR2] a production of 319 TJ is given. AAU will find 2050-data through local contacts.

Biogas:
The production of biogas in 2010 is in [HR2] = 298 TJ.

For the potential in 2050 data from [HR5] is used: Croatia sets up a goal by this Strategy of 20 % of total conditional cattle heads for energy purposes from agricultural production in 2020 and to produce around 2.6 PJ of energy from biogas, i.e. 100 million m^3 of biogas.

Total biomass:
The total biomass is the sum of the shown numbers. It is stated in [HR5] that Croatia defines a goal to use around 15 PJ of biomass for energy purposes in 2010, and 26 PJ in 2020. Part of this biomass shall be used in biomass-fired, preferably cogeneration, power plants with a collective electricity capacity of 85 MW in 2020.

3.1.1 Data on renewable electricity and heat potentials

Croatia: Renewable Energy Resources	

Renewable Energy Resources - HR						
	2010			Potential (2050)		
Renewable Electricity						
Type	*Capacity (MWe)*	*Annual Production (TWh/year)*		*Capacity (MWe)*	*Annual Production (TWh/year)*	
Onshore Wind	86.28	0.14		348.00	1.28	
Offshore Wind	2.72	0.00		852.00	3.12	
Photovoltaic	4.40	0.00		606.00	0.92	
Concentrated Solar Power	-	-		-	-	
Direct Geothermal	-	-		-	-	
Wave	-	-		-	-	
Tidal	-	-		-	-	
Hydro			*Hydro Storage (GWh)*			*Hydro Storage (GWh)*
River Hydro						
Hydro	1,900.00	8.44		2,346.00	12.45	
Hydro Pump Back (if applicable)						
Renewable Heat						
Type	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*	*Capacity (MWe)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*
Individual Solar Thermal	n/a	0.14		n/a	3.39	
Solar Thermal	83.70	0.06		n/a	12.25	
Geothermal	147.56	0.08		n/a	2.37	

Bienergy (All High Priority)			
	2010	Potential (2050)	
Type	*Annual Consumption (TWh/year)*	*Annual Consumption (TWh/year)*	
Energy Crops: Residual	6.37		AAU collects through contact in Croatia
Energy Crops: Dedicated Land	3.58		AAU collects through contact in Croatia
Wood	16.02		AAU collects through contact in Croatia
Waste: Renewable & fossil	0.09		AAU collects through contact in Croatia
Biogas	0.08	0.72	
Total	26.14		

3.1.2 References

Croatia: Renewable Energy Resources	

Renewable Energy Resources - HR						
	2010			Potential (2050)		
Renewable Electricity						
Type	*Capacity (MWe)*	*Annual Production (TWh/year)*		*Capacity (MWe)*	*Annual Production (TWh/year)*	
Onshore Wind	[1]+[3] [4]: Onshore/off shore distribution 3% off shore, 97% onshore [9]: (2012-data) Wind power (On shore): 179,6 MW	[1]+[2] + [3]: 139 GWh in total [4]: Onshore/off shore distribution 3% off shore, 97% onshore [9]: (2012-data) Wind power: 0,329 TWh (total) [HR1]: Total wind production 2007 = 125,67 TJ		[1]: 1079 MW cumulated [2]: National plan 2020: 1200 MW in 2020 in total [4] Onshore/off shore distribution: Estimated 71% off shore, 29% onshore [HR5]: 2020: 1,200 MW	[1]: 2291 GWh in total [4] Onshore/off shore distribution: Estimated 71% off shore, 29% onshore [HR1]: Forecast 2030 = 15,84 PJ wind energy -> 4,4 TWh in total	
Offshore Wind	[1]+[3] [4]: Onshore/off shore distribution 3% off shore, 97% onshore [9]: (2012-data) Wind power (On shore): 179,6 MW [9]: (2012-data) Wind power (Off shore): Not on the list.	[1]+[3] [4]: Onshore/off shore distribution 3% off shore, 97% onshore		[1] [4] Onshore/off shore distribution: Estimated 71% off shore, 29% onshoreshore, 29% onshore [HR5]: It is expected that the installed capacity of the wind power in the Republic of Croatia in 2020 amount 1,200 MW	[1] [4] Onshore/off shore distribution: Estimated 71% off shore, 29% onshore	

Photovoltaic	[1]: 0 MW [7]: (2012-data) PV on grid: 3,9 MW PV off grid: 0,5 MW Total: 4,4 MW	[1]: 0 TWh [7]: PV (2012-data) 3,7 GWh		[1] [HR4]: 250 MW till year 2030	[1] [HR1]: The technical potential to electricity generation from photovoltaic (PV) systems and solar thermal power plants amounts to around 33 TWh/annum. The economic potential to produce solar electricity would amount to around 0.3 TWh/annum, which is the equivalent of around 200 MW of electricity-generating capacity	
Concentrated Solar Power	[8]: Not on the list	[8]: Not on the list		[10]: Solar radiation in Croatia is between 1,200 and 1,600 kWh/m2 Areas of at least 2000 kWh/m²/y are needed for CSP plants due to economic constraints. Croatia is therefore unsuitable for CSP	[10]: Solar radiation in Croatia is between 1,200 and 1,600 kWh/m2 Areas of at least 2000 kWh/m²/y are needed for CSP plants due to economic constraints. Croatia is therefore unsuitable for CSP	
Direct Geothermal	[1]	[1]		[1]	[1]	
Wave	[1]	[1]		[1]	[1]	
Tidal	[1]	[1]		[1]	[1]	
Hydro			*Hydro Storage (GWh)*			*Hydro Storage (GWh)*
River Hydro						
Hydro	[1]	[HR2] [2] 8309 GWh		[1]	[1]: 8,744 TWh [HR1]: Technically exploitable water potential resources in Croatia are estimated at 12.45 TWh/annum Forecast 2030: 7,03 TWh (25,31 PJ)	
Hydro Pump Back (if applicable)						

Renewable Heat						
Type	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*	*Capacity (MWe)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*
Individual Solar Thermal*	n/a	[HR3]: 2012 0,5 PJ		n/a	[HR3]: 12,21 PJ in 2030	
Solar Thermal	[8]: (2012-data) Solar Thermal: 119600 m2 83,7 MWth	[HR2]		n/a	[HR1]: The technical potential to produce heat from solar collectors and the use of passive solar energy (solar architecture) amounts to 175 TWh/annum. (630 PJ/annum) Economic potential = 7% of technical potential	
Geothermal	[HR1]: Total installed heat capacity from supåply of geothermal energy 2007: Space heating = 33,66 MW Space heating and hot water preparation = 113,9 MW	[HR2]: 0,079 TWh [HR1]: 702,31TJ = 0,195 TWh (2007)		n/a	[HR1]: Forecast 2030: 8,54 PJ	
Large-scale heat pumps						

Bioenergy			
	2010	Potential (2050)	
*Type**	*Annual Consumption (TWh/year)*	*Annual Consumption (TWh/year)*	
Energy Crops: Residual	[HR1]: Agro residue = 22,93 PJ		AAU collects through contact in Croatia
Energy Crops: Dedicated Land	[HR4]+[HR2]: Energy forests = 12,88 PJ		AAU collects through contact in Croatia
Wood	[HR2] [HR1]: Cord wood = 24,33 PJ Wood residue = 8,65 PJ Abbaino = 2,01 PJ Wood industry residue = 17,89 PJ Roads, water management, etc. = 4,80 Total = 16,022 TWh		AAU collects through contact in Croatia
Waste: Renewable & fossil	[HR2] 319 TJ Production		AAU collects through contact in Croatia

Biogas	[HR2]: 298 TJ Production	[HR5]: Croatia sets up a goal by this Strategy of 20% of total conditional cattle heads for energy purposes from agricultural production in 2020 and to produce around 2.6 PJ of energy from biogas, i.e. 100 millions m3 of biogas.
Total	[HR5]: Croatia defines a goal to, along with the existing incentive measures and removing the existing administrative barriers, use around 15 PJ of biomass in energy purposes in 2010, while in 2020 double, around 26 PJ. Part of this biomass shall be used in many biomass fired power plants of total power of 85 MW in 2020, preferably cogeneration plants.	

3.2 Czech Republic

For Czech Republic, several references were necessary to use to find the needed data. Both national and EU references have been used. It was necessary to use three national references on biomass data in order to get an overview of the data available.

FLH and solar performance are presented in the tables below.

	Full-load hours			
Type	2010	2050	Difference	Difference [>100 % means larger than 2010]
Onshore Wind	1,562.79	1,502.14	-60.65	96%
Offshore Wind				
Photovoltaic	314.49	1,069.27	754.77	340%
Concentrated Solar Power				
Direct Geothermal				
Wave				
Tidal				
Hydro				
River Hydro				
Hydro	2,590.53	3,111.28	520.75	120%
Hydro Pump Back (if applicable)				
Type				
Individual Solar Thermal*				
Solar Thermal	220.11	1,859.44	1,639.33	845%
Geothermal	5,427.33	13,880.00	8,452.67	256%
Large-scale heat pumps	1,232.50			

Solar-check						
Given information			Calculated	ESTIF 2012 numbers		
Capacity MW	Production TWh	Area m^2	Performance kWh/m^2	Capacity	Area	Solar Radiation MWh/m^2
463.40	0.10	661,969	154.09	299.13	427,327	

Assumptions and crosscheck results are described in the following.

Onshore wind:
Czech Republic does not have a shoreline; therefore all wind capacity is onshore. In [1] and [2], the wind capacity in 2010 is 215 MW. In [5] the wind capacity is 218 MW. The production in 2010 was 0.34 TWh, according to [1], [2] and [5].

The potential for wind capacity and production in 2050 is both from [1].

There is no positive development in FLH, which might be explained by the lack of shoreline in Czech Republic. Hence, it might be difficult to utilize the wind technology more than it is today. The FLH in 2010 are relatively low, but the used references have more or less the same numbers. Local wind conditions might be the reason for this, but an exact explanation has not been identified.

Photovoltaic:
In [1] the 2010 capacity is 1,959 MW. From [5] there is in (2010):

- PV on grid: 1,958.7 MW
- PV off grid: 0.4 MW
- Total: 1,959.1 MW

The potential for 2050 is from [1].

The used numbers are from the same reference, [1]. Therefore, an assumption on technical development might be the explanation for the increase in FLH by 340 %.

Hydro:
The 2010 data from [1] gives a number for the capacity of 1,077 MW. From [CZ1] the number is 1,048 MW from 2009.

The production in 2010 from [1] is 2.79 TWh. In accordance with this, 2.79 TWh is also given by 'Ministry of Industry and Trade and Energy Regulatory Office Data 2013 preliminary for 2007 to 2013'. In [CZ1] the number is 2.17 TWh in 2009/28/EC.

The potential for 2050 is in [1] equal to 1,330 MW. To support this, the 2020 target in [CZ2] is 1,097 MW. It should be noted that this target does not raise capacity significantly, compared to the installed capacity in 2010. The production potential in 2050 is also given by [1] to 4.14 TWh/year. To compare, the following targets are given in [CZ2] to be:

- 2.53 TWh/year in 2040
- 2.53 TWh/year in 2030
- 2.61 TWh/year in 2020-target

The FLH for use of hydro increase by 120 %. The numbers used for the calculation are from [1] – the difference is therefore attributed to technical development.

Hydro pump back:
The hydro pump back for 2010 is given in [CZ1]. No sources were available for the potential in 2050.

Solar thermal:
In [5] the thermal solar collector area is given to be 661,969 m^2 with a capacity of 463 MW. In [CZ1] the number is only 216 MW. The production is given from [CZ1] to 273 TJ (0.08 TWh).

For the potential of capacity in 2050 only 2020 data is available from [CZ2], with 747 MW as 2020 target. The production potential for 2050 is also from [CZ2] with the following national targets:

- 1.39 TWh/year 2040
- 0.97 TWh/year in 2030
- 0.38 TWh/year (2020-target)

The number for FLH in 2010 is very low. There has been used two different references, which might explain the rather large increase in FLH of 845 %. The difference in references also explains the very low performance of solar thermal in 2010.

Geothermal:
In [5] the geothermal capacity is 4.50 MW, but in [CZ1] the number is 0 MW in 2010. For the production in 2010 in [1] and [CZ1] the number is 0 TWh. In [5] the geothermal energy is equivalent to 2.10 ktoe (0.02 TWh).

For the 2050 potential, [CZ2] have been used with 50 MW as the 2020-target. For the production the following data is given by [CZ2]:

- 0.69 TWh/year (2040)
- 0.47 TWh/year (2030)
- 0.18 TWh/year (2020-target)

The FLH in 2010 seem reasonable, despite two different sources have been used. The too large number of FLH in 2050 is due to the capacity is 2020-data, while the production is the 2040-target.
Large scale heat pumps:

The capacity and production in 2010 is given by [CZ1]. Again is [CZ2] used for the potential of 2050 with the following data for production:

- 4.36 TWh/year (2040)
- 3.72 TWh/year (2030)
- 1.83 TWh/year (2020 - target)

Energy crops, residual:
The residual energy crops is given from [CZ4], Table 16: 13.50 PJ agricultural residues. The potential for 2050 is from [CZ5] with a residual of 35 PJ. In [11], the residual related biomass is 1,510 ktoe in 2030, which corresponds to 17.56 TWh.

Energy crops, dedicated:
The data for 2010 are taken from [CZ4], Table 17: 161.17 PJ biomass potential from energy crops. In [CZ5], the potential for dedicated land in 2050 is 214 PJ. In [11], related to dedicated land (without forests) = 539 ktoe = 6.27 TWh.

Wood:
In [CZ3] the 2010 data is given:
Wood for electricity and heat 2008: 16.11 PJ or 4.48 TWh (wood for electricity alone in 2010 is 0.64 TWh).

Some additional data for 2010 is given in [5] for solid biomass:
Primary energy production: 2.09 Mtoe (24.31 TWh)
Heat consumption: 1.64 Mtoe (19.07 TWh, whereof 0.06 Mtoe to DH)
Gross electricity production:

- Electricity only plants: 0.6 TWh
- CHP plants: 0.9 TWh
- Total: 1.5 TWh

For the 2050 [CZ5] is used with a potential from wood (forestry) of 50 PJ. In [11], the wood related data is 6.22 Mtoe in 2030, equal to 72.29 TWh.

Waste:
The number for 2010 is from [CZ3], with waste = 0.73 TWh/year of which municipal solid waste (MSW) is 59 GWh and industrial waste is 2 GWh.

In [CZ1] waste = 0.82 TWh/year (2009) and in [5], the Municipal Waste (Renewable share) is from Primary energy production equal to 62.70 ktoe (0.73 TWh) with gross electricity production:

- Electricity only plants: 11 GWh
- CHP plants: 25 GWh
- Total: 36 GWh

In [11] the total MSW in 2030 is 806 ktoe = 9.37 TWh.

For the potential in 2050 data from 2020 – 2040 were available from [CZ2]:

- 6.14 TWh/year (2030+2040)
- 1.45 TWh/year (2020)

In [11] the following data for 2050 potential is available:

- MSW = 220 ktoe in 2030 = 2.56 TWh
- MSW landfill = 360 ktoe in 2030 = 4.19 TWh

- In total 6.75 TWh

Biogas:
In 2010 the data from [CZ3] is used with biogas = 2.06 TWh/year. Biogas solely for electricity production is 266.87 GWh.

In [CZ2], the biogas = 1,329 TWh/year in 2009.

From [5] a more detailed division for biogas is given:

- Landfill gas: 29.5 ktoe (0.34 TWh)
- Sewage sludge: 35.9 ktoe (0.42 TWh)
- Other biogas: 111.3 ktoe (1.29 TWh)

With gross electricity production:

- Electricity only plants: 361 GWh
- CHP plants: 275 GWh
- Total: 636 GWh
- The potential for 2050 is from [CZ2]

Biomass Atlas:
The results from the Biomass Atlas are seen in the table below. The numbers here are higher than the numbers shown from the national references from Czech Republic, describes in the biomass categories above. An explanation to this can be that the numbers in the national references are less detailed than the numbers in the Biomass Atlas.

	Biomass Atlas (TWh/year)			
	REF2020	**SUS2020**	**REF2030**	**SUS2030**
Energy crops, residual	24	24	28	27
Energy crops, dedicated	1	0	1	0
Wood	68	59	66	59
Waste	12	12	11	11
Biogas	27	27	21	21
Total	131	121	127	119

3.2.1 Data on renewable electricity and heat potentials

Czech Republic: Renewable Energy Resources	

Renewable Energy Resources - Czech Republic						
	2010			Potential (2050)		
Renewable Electricity						
Type	*Capacity (MWe)*	*Annual Production (TWh/year)*		*Capacity (MWe)*	*Annual Production (TWh/year)*	
Onshore Wind	215.00	0.34		468.00	0.70	
Offshore Wind	n/a	n/a		n/a	n/a	
Photovoltaic	1,958.70	0.62		2,180.00	2.33	
Concentrated Solar Power	-	-		-	-	
Direct Geothermal	-	-				
Wave	-	-		-	-	
Tidal	-	-		-	-	
Hydro			*Hydro Storage (GWh)*			*Hydro Storage (GWh)*
River Hydro						
Hydro	1,077.00	2.79		1,330.00	4.14	
Hydro Pump Back (if applicable)		0.59				
Renewable Heat						
Type	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*	*Capacity (MWe)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*
Individual Solar Thermal	n/a			n/a		
Solar Thermal	463.40	0.10		747.00	1.39	
Geothermal	4.50	0.02	-	50.00	0.69	
Large-scale heat pumps	400.00	0.49			4.36	

Bioenergy		
	2010	Potential (2050)
Type	*Annual Consumption (TWh/year)*	*Annual Consumption (TWh/year)*
Energy Crops: Residual	3.75	9.72
Energy Crops: Dedicated Land	44.77	59.44
Wood	4.48	13.89
Waste: Renewable & fossil	0.73	6.14
Biogas	2.06	7.53
Total	55.78	96.72

3.2.2 References

Czech Republic: Renewable Energy Resources	

Renewable Energy Resources - Czech Republic						
	2010			Potential (2050)		
Renewable Electricity						
Type	*Capacity (MWe)*	*Annual Production (TWh/year)*		*Capacity (MWe)*	*Annual Production (TWh/year)*	
Onshore Wind	[1] + [2]: 215 MW [5]: Wind power: 218 MW	[1] + [2]: 0.335 TWh [5]: Wind power: 0.336 TWh		[1]	[1]	
Offshore Wind	n/a	n/a		n/a	n/a	
Photovoltaic	[1]: 1,958.7 MW [5]: (2010) PV on grid: 1,958.7 MWp PV off grid: 0.5 MWp Total: 3,483.5 MWp	[1] + [2] + [5]: PV: 615.7 GWh (2010)		[1]	[1]	
Concentrated Solar Power	[8]: Not mentioned	[8]: Not mentioned		[10]: Solar radiation in Czech Republic is around 1000 kWh/m²/y Areas of at least 2000 kWh/m²/y are needed for CSP plants due to economic constraints. Czech Republic is therefore unsuitable for CSP	[10]: Solar radiation in Czech Republic is around 1000 kWh/m²/y Areas of at least 2000 kWh/m²/y are needed for CSP plants due to economic constraints. Czech Republic is therefore unsuitable for CSP	
Direct Geothermal	[5]: Geothermal electricity plants: Capacity installed: 0 MW	[1]: Geothermal (and other renewables): 0 GWh				
Wave	[1]	[1]		[1]	[1]	
Tidal	[1]	[1]		[1]	[1]	
Hydro			*Hydro Storage (GWh)*			*Hydro Storage (GWh)*
River Hydro						

Hydro	[1]: 1.077 MW in 2010 [CZ1]: 1.048 MW in 2009	[1]: 2.79 TWh in 2010 2.79 TWh in Ministry of Industry and Trade and Energy Regulatory Office Data 2013 preliminary for 2007 to 2013, production in GWh [CZ1]: 2.17 TWh in 2009/28/EC		[1]: 1,330 MW [CZ2]: 1,097 MW in 2020 target	[1]: 4.138 TWh/year [CZ2]: 2.53 TWh/year in 2040 2.53 TWh/year in 2030 2.61 TWh/year in 2020-target	
Hydro Pump Back (if applicable)		[CZ1]				
Renewable Heat						
Type	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*	*Capacity (MWe)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*
Individual Solar Thermal	n/a			n/a		
Solar Thermal	[5]: Thermal solar collectors: 661,969 m2 463.4 MWth [CZ1]: 216 MW	[CZ1]: 273 TJ = 0.1 TWh		[CZ2]: 747 MW 2020 target	[CZ2]: 1.39 TWh/year 2040 0.972 TWh/year 0.375 TWh/year (2020-target)	
Geothermal	[5]: Geothermal Capacity: 4.5 MW [CZ1]: 0 MW	[1]: 0 TWh [5]: Geothermal Energy using: 2.1 ktoe [CZ1]: 0 TWh/year	[1]: 0 GWh [CZ1]: 0 GWh	[CZ2]: 50 MW 2020-target	[CZ2]: 0.694 TWh/year (2040) 0.472 TWh/year (2030) 0.175 TWh/year (2020-target)	
Large-scale heat pumps	[CZ1]	[CZ1]			[CZ2]: 4.361 TWh/year (2040) 3.722 TWh/year (2030) 1.826 TWh/year (2020 - target)	

Bioenergy		
	2010	Potential (2050)
Type	*Annual Consumption (TWh/year)*	*Annual Consumption (TWh/year)*
Energy Crops: Residual	[CZ4]: Table 16: 13.5 PJ agricultural residues	[CZ5]: Residual 35 PJ [11]: Residuel related: 1510 ktoe in 2030 = 17.56 TWh

Energy Crops: Dedicated Land	[CZ4]: Table 17: 161.17 PJ biomass potential from energycrops	[CZ5]: Dedicated land 214 PJ [11]: Related to dedicated lan (without forests) = 539 ktoe = 6.27 TWh
Wood	[CZ3]: Wood for elctricity and heat 2008: 16.11 PJ or 4.48 TWh (wood for electricity alone in 2010 is 0.642 TWh) [5]: Solid biomass: Primary energy production: 2.09 Mtoe (~24.4 TWh) Heat consumption: 1.64 Mtoe (0.06 Mtoe to DH) Gross electricity production: Electricity only plants: 0.595 TWh CHP plants: 0.898 TWh Total: 1.493 TWh	[CZ5]: Wood (forestry) 50 PJ [11]: Wood related: 6,216 ktoe in 2030 = 72.29 TWh
Waste: Renewable & fossil	[CZ3]: Waste = 0.73 TWh/year of which: Solid municipal waste 59,000 MWh Industrial waste 2,000 MWh [CZ1]: Waste = 0.82 TWh/year (2009) [5]: Municipal Waste (Renewable share): Primary energy production: 62.7 ktoe (~ 0.7 TWh) Gross electricity production: Electricity only plants: 11 GWh CHP plants: 25 GWh Total: 36 GWh [11]: Total MSW in 2030: 806 ktoe = 9.37 TWh	[CZ2]: 6.14 TWh/year (2030+2040) 1.45 TWh/year (2020) [11]: MSW = 220 ktoe in 2030 = 3 TWh MSW landfill = 360 ktoe in 2030 = 4.19 TWh In total 6.75 TWh (Fall in MSW landfill potential)

Biogas	[CZ3]: Biogas = 2,06 TWh/year Biogas solely for electricity production 266.868,3 MWh [CZ2]: Biogas = 1,329 TWh/year (2009) [5]: Landfill gas: 29,5 ktoe (~0,3 TWh) Sewage sludge: 35,9 ktoe (~0,4 TWh) Other biogas: 111,3 ktoe (~1,3 TWh) Gross electricity production: Electricity only plants: 361 GWh CHP plants: 275 GWh Total: 636 GWh	[CZ2]

3.3 Italy

Data from Italy has been collected from national data, the national STRATEGO partner and EU-28 statistics and projections.

FLH and solar performance are presented in the tables below.

	Full-load hours			
Type	2010	2050	Difference	Difference [>100 % means larger than 2010]
Onshore Wind	1,569.66	1,868.45	298.79	119%
Offshore Wind		3,157.89		
Photovoltaic	549.28	1,774.42	1,225.14	323%
Concentrated Solar Power	1,800.00	2,333.33	533.33	130%
Direct Geothermal	6,963.73	6,000.00	-963.73	86%
Wave				
Tidal				
Hydro				
River Hydro	4,300.16	4,300.16	0.00	100%
Hydro	1,965.17	1,899.18	-65.99	97%
Hydro Pump Back (if applicable)	1,197.99	1,262.14	64.15	105%
Type				
Individual Solar Thermal*				
Solar Thermal	878.14	1,094.26	216.12	125%
Geothermal	3,875.74	2,367.42	-1,508.31	61%
Large-scale heat pumps				

Solar-check						
Given information			Calculated	ESTIF 2012 numbers		
Capacity MW	Production TWh	Area m2	Performance kWh/m2	Capacity	Area	Solar Radiation MWh/m2
1,743.00	1.50	2,503,949	599.05	2,356.01	3,365,730	

Assumptions and crosscheck results are described in the following.

Onshore wind:
Two different references were used between 2010 [5] and 2050 [1]. Despite this, the 19 percentage-points increase in FLH of onshore wind seems plausible.

Offshore wind:
FLH not calculated due to lack of installed offshore wind capacity in 2010.

Photovoltaic:
Differences in the assumptions of the two different references (2010: [5] 2050: [1]), might explain the significant increase in FLH. The 2010-numbers on FLH seem quite low.

Concentrated solar power:
A moderate, but not unrealistic increase in FLH, despite three different references (2010: [5] and [IT4] 2050: [IT6])

Direct Geothermal:
The decrease in FLH could be caused by the deployment of geothermal resources with lower yield and/or different operating pattern than current installed capacity. Since [5] is used for 2010-numbers and [IT3] is used for 2050 (although the projection is limited to 2030), the explanation might simply be the difference in assumptions between the references.

River Hydro:
Since numbers on hydro were limited for 2050, and aggregated in the references, it has been necessary to extract these using a combination of different references. The results are in the same order of magnitude, but different from, the numbers provided by the Italian STRATEGO partner.

Hydro:
An aggregate number for hydro was given in the reference. This is subtracted the numbers found in the category "River Hydro". The results are in the same order of magnitude, but different from, the numbers provided by the Italian STRATEGO partner.

Hydro pump back:
Minor difference between 2010 [IT5] and 2050-numbers [IT9] and [IT10], despite applying three different references.

Solar thermal:
2020-numbers have been applied for 2050, due to lack of data. Additionally, the solar thermal categories have been merged, since it has not been possible to distinguish between individual and large-scale solar thermal. The performance of 599 kWh/m^2/year appears reasonable, and the difference in FLH can be attributed to the three different references applied, [5], [IT1] and [IT2].

Geothermal:
As with geothermal electricity, the FLH for geothermal heat decreases. The reason can be that two different references are used, but might also be explained as described above: The deployment of geothermal resources with lower yield and/or different operating pattern than current installed capacity.

Large-scale heat pumps:
References are limited to the assumed production in 2050, specifically connected to geothermal heat.

Biomass Atlas:
All biomass categories are aggregated under this description. The Biomass Atlas has been applied as main reference for all biomass-categories. It is worth noticing the significant differences between these numbers, and numbers found in [IT11]. Generally, the focus on sustainable cropping is visible in the numbers from the Biomass Atlas, which tends to be higher than [IT11], when utilising residual and waste-resources, and lower when utilising dedicated land.

	Biomass Atlas (TWh/year)			
	REF2020	**SUS2020**	**REF2030**	**SUS2030**
Energy crops, residual	128	114	126	82
Energy crops, dedicated	42	0	4	0
Wood	74	69	75	69
Waste	19	19	15	15
Biogas	67	67	76	76
Total	329	269	296	242

3.3.1 *Data on renewable electricity and heat potentials*

Italy: Renewable Energy Resources	

Renewable Energy Resources - IT						
	2010			Potential (2050)		
Renewable Electricity						
Type	*Capacity (MWe)*	*Annual Production (TWh/year)*		*Capacity (MWe)*	*Annual Production (TWh/year)*	
Onshore Wind	5,814.00	9.13		29,031.00	54.24	
Offshore Wind	0.00	0.00		1,900.00	6.00	
Photovoltaic	3,470.00	1.91		45,505.00	80.75	
Concentrated Solar Power	5.00	0.01		3,000.00	7.00	
Direct Geothermal	772.00	5.38		2,000.00	12.00	
Wave	-	-		-	-	
Tidal	-	-		-	-	
Hydro			*Hydro Storage (GWh)*			*Hydro Storage (GWh)*
River Hydro	4,902.80	21.08		5,593.63	24.05	
Hydro	12,303.70	24.18		14,037.37	26.66	
Hydro Pump Back (if applicable)	7,659.10	9.18	96.00	10,300.00	13.00	125.00
Renewable Heat						
Type	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*
Individual Solar Thermal	1,752.80	1.54		39,551.08	43.28	
Solar Thermal						
Geothermal	418.00	1.62		8,800.00	20.83	
Large-scale heat pumps					4.17	

Bioenergy		
	2010	Potential (2050)
Type	*Annual Consumption (TWh/year)*	*Annual Consumption (TWh/year)*
Energy Crops: Residual	185.38	126.16
Energy Crops: Dedicated Land	41.69	3.73
Wood	16.25	75.37
Waste: Renewable & fossil	46.42	15.31
Biogas	96.06	75.68
Total	385.80	296.25

3.3.2 References

Italy: Renewable Energy Resources	

Renewable Energy Resources - IT						
	2010			Potential (2050)		
Renewable Electricity						
Type	*Capacity (MWe)*	*Annual Production (TWh/year)*		*Capacity (MWe)*	*Annual Production (TWh/year)*	
Onshore Wind	[5]: Wind power: 5,814.3 MW	[5]		[1]	[1]	
Offshore Wind	[IT4] [6]: (2010-data) Wind power (Off shore): Not on the list.	[IT4]		[IT6]	[IT6]	
Photovoltaic	[5]: (2010) PV on grid: 3,470 MWp PV off grid: 13.5 MWp Total: 3,483.5 MWp	[5]		[1]	[1]	
Concentrated Solar Power	[5]: 5 MW (Archimede (prototype), commissionning date 2010)	[IT4]		[IT6]	[IT6]	
Direct Geothermal	[5]: Geothermal electricity plants: Capacity installed: 882.5 MW Net capacity: 728.1 MW	[5]		[IT3]: 2030-numbers. In a favorable scenario [1]: 1,353 Mwe	[IT3] 2030-numbers. In a favorable scenario [1]: 12.181 TWh	
Wave	[1]	[1]		[1]	[1]	
Tidal	[1]	[1]		[1]	[1]	
Hydro			*Hydro Storage (GWh)*			*Hydro Storage (GWh)*
River Hydro	[IT5]	[IT5]		Scaled according to 2050 numbers from [1] and 2010 numbers from [IT6] Italian partner: 7,800 MW	Scaled according to 2010-production and 2050 capacity Italian partner: 33 TWh	
Hydro	[IT5]	[IT5]		[1]: Subtracted the calculated river hydro Italian partner: 17,000 MW	[1] subtracted river hydro Italian partner: 31.7 TWh	
Hydro Pump Back (if applicable)	[IT5]	[IT5]	[IT7] [IT8]	[IT9]	[IT10]	[IT10]

Renewable Heat						
Type	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*
Individual Solar Thermal	[5]: Thermal solar collectors: 2,503,949 m2 1,752.8 MWth	[5] and [IT1] 2,413 MWth in 2012 and 2.12 TWh 1,752.8 MWth in 2010 and unknown TWh Scaled according to 2012-numbers: 1.54 TWh		[IT2] Based on 2020-numbers	[IT2] Local partner. Based on 2020-numbers	
Solar Thermal						
Geothermal	[5]	[5]		[IT3]	[IT3]	
Large-scale heat pumps					[IT3] Number only refers to heat pumps connected to geothermal	

Bioenergy		
	2010	Potential (2050)
Type	*Annual Consumption (TWh/year)*	*Annual Consumption (TWh/year)*
Energy Crops: Residual	[11]	[11] Note large difference from [IT11]: 108.2 TWh
Energy Crops: Dedicated Land	[11]	[11] Note large difference from [IT11]: 46.5 TWh
Wood	[11] Note large difference - [5]: 38.9 TWh	[11] Note large difference from [IT11]: 35 TWh
Waste: Renewable & fossil	[11] Note large difference - [5]: 9.1 TWh	[11] Note large difference from [IT11]: 3.5 TWh
Biogas	[11] Note large difference - [5]: 5.2 TWh	[11] Note large difference from [IT11]: 127.9 TWh
Total	Note large difference to [1] 7,033 ktoe - 81.8 TWh production	Note large difference to [1] 2050: 10,050 ktoe - 116.9 TWh

3.4 Romania

Five different references have been used on national basis, but international reports have also been used in order to collect the data.

FLH and solar performance are presented in the tables below.

	Full-load hours			
Type	2010	2050	Difference	Difference [>100 % means larger than 2010]
Onshore Wind	662.44	1,994.04	1,331.60	301%
Offshore Wind	659.11	1,996.65	1,337.55	303%
Photovoltaic	769.23	1,178.96	409.73	153%
Concentrated Solar Power				
Direct Geothermal				
Wave				
Tidal				
Hydro				
River Hydro				
Hydro	3,111.24	3,828.48	717.25	123%
Hydro Pump Back (if applicable)				
Type				
Individual Solar Thermal*	15.01			
Solar Thermal				
Geothermal	2,436.83			

Solar-check						
Given information			Calculated	ESTIF 2012 numbers		
Capacity MW	Production TWh	Area m^2	Performance kWh/m^2	Capacity	Area	Solar Radiation MWh/m^2
73.00	0.00	104,700	9.55	77.49	110,700	

Assumptions and crosscheck results are described in the following.

Onshore/Offshore wind:
From [1] the cumulated wind in 2010 is 462 MW. In [4], the onshore/offshore distribution is 3 % offshore and 97 % onshore. Comparable numbers are found in [2] with 400 MW cumulated and [5] with 388 MW cumulated wind power. The same references are used for the production in 2010 with [1] as main source. From [4] the onshore/offshore distribution is assumed to be 3 % offshore and 97 % onshore. From [5] the production is 0.31 TWh.

The potential for 2050 is from [1]. Where [4] is used for distribution of onshore 20 % and 80 % offshore. The offshore is lower than Croatia due to short shoreline in Romania. Therefore, the numbers in [4] from 2020 have been used.

The FLH in 2010 are rather low. The increase in FLH can be explained with an expectation of better utilization of wind in the potential. The used numbers are from [1] in both 2010 and 2050.

Photovoltaic:
In [5] 2010-data is found for the capacity: PV on grid = 1.3 MW, PV off grid = 0.6 MW, in total = 1.9 MW. The production is also found from [5].

The potential for 2050 is found in [1] with 3,788 GWh. In [RO1] the number is 1.2 TWh electricity from solar energy.

The used reference in 2010 is [5], whereas the used reference for the 2050-data is [1]. This may explain the increase in FLH together with technical development.

Direct geothermal:
From [1] the potential for geothermal (and other renewables) is 18 GWh. In the table, this is not included since the share of geothermal is unclear.

Hydro:
The capacity and production in 2010 is from [1] with [2] supporting the production found in [1].

Reference [1] is also used for the potential in 2050 with 25,169 GWh. In [RO1] the Romanian technically developable hydropower potential is 36,000 GWh/year from which, 30,000 GWh/year (taking into consideration the economic potential) can be exploited.

Individual solar thermal and solar thermal:
It was not possible to find any data on individual solar thermal, therefore the data for the individual solar thermal and solar thermal has been merged. In [5] for 2010 capacity, the thermal solar collector area is 104,700 m^2 with a capacity of 73.3 MW.

The production in [RO2] is 4 TJ from solar thermal. The very low performance seen in the crosscheck table can be explained by use of different sources.

For the 2050 potential [RO1] gives a number for solar energy of 60 PJ/year heat.

The performance of solar thermal is much too low to be realistic. This can only be explained by difference in references, since the capacity is given in [5] and the production in [RO2].

Geothermal:
From [5], the geothermal capacity is 153.2 MW. The production in 2010 is also from [5] with geothermal energy using of 32.1 ktoe, corresponding to 0.37 TWh. In [RO2], the 2010 number is 962 TJ.

In [RO1] the potential for 2050 is found to be for geothermal energy = 7 PJ heat.

Energy crops, residual:
For residual energy crops, reference [11] is used. However, this is only a number for the straw potential from 2004 of 1,351 ktoe = 15.71 TWh. The potential for 2010 might therefore be higher than this number.

In [RO3], the agricultural residues - biomass potential is in 2004 for the future in Romania to be 247.21 PJ. An alternative number is found in [11], where residues related biomass is 3,621 ktoe in 2030, which corresponds to 42.11 TWh.

Energy crops, dedicated:
In [RO5], biomass from agriculture in 2008 used for energy is 65 PJ, equal to 18.06 TWh. For the potential in 2050, the estimated biomass potential from agricultural biomass = 200,935 TJ in [RO3]. In [11] the number is much lower, where dedicated land (without forests) is 666 ktoe in 2030 = 7.75 TWh.

Wood:
The number for solid biomass in [5] is used as reference for wood, where solid biomass contributes to the primary energy production by 3,459 Mtoe (2011-data), which is 40.22 TWh.

The potential of wood in 2050 is found in [RO3], where the potential for biomass wood forestry = 49,241 TJ + wood waste = 20,432 TJ, which corresponds to 19.35 TWh.

In [11] the wood related in 2030 is much higher with 13,420 ktoe = 156.08 TWh.

Waste:
From [RO2] the energy production from waste is 1,284 TJ, which only equals 0.36 TWh. The number from [11] is much higher, where the total MSW in 2010 is 1,792 ktoe = 20.84 TWh.

In [RO3], the urban waste potential amounts to 22,805 TJ = 6.34 TWh. In [RO4], the municipal waste electricity CHP = 17 ktoe, municipal waste heat = 110 ktoe, which is 1.48 TWh/year

In [11] the number is much higher with total MSW = 940 ktoe in 2030, which is 10.93 TWh.

Biogas:
In [5] the following data is found on biogas:

- Landfill gas: 0 ktoe
- Sewage sludge: 0 ktoe
- Other biogas: 3.0 ktoe (0.03 TWh)

Gross electricity production:

- Electricity only plants: 0 GWh
- CHP plants: 1 GWh
- Total: 1 GWh

The future potential is found from [RO3], where the biogas potential = 24,620 TJ or 6.84 TWh

Biomass Atlas:
The data from the Biomass Atlas is seen in the Table below. The found data for the biomass in 2010 and the potential in 2050 deviates from the numbers given in the Biomass Atlas. More sources have been used in order to find data from national sources and these have not been as detailed as the data in the Biomass Atlas, i.e. there have not been the same detail level of categories. It has not been possible to find background data on the used sources in order to find which categories are behind each number.

	Biomass Atlas (TWh/year)			
	REF2020	**SUS2020**	**REF2030**	**SUS2030**
Energy crops, residual	83	77	55	53
Energy crops, dedicated	8	0	6	0
Wood	156	142	93	85
Waste	13	13	12	12
Biogas	6	6	17	17
Total	266	238	184	167

3.4.1 Data on renewable electricity and heat potentials

Romania: Renewable Energy Resources	

Renewable Energy Resources - RO						
	2010			Potential (2050)		
Renewable Electricity						
Type	*Capacity (MWe)*	*Annual Production (TWh/year)*		*Capacity (MWe)*	*Annual Production (TWh/year)*	
Onshore Wind	447.89	0.30		3,826.40	7.63	
Offshore Wind	14.11	0.01		956.60	1.91	
Photovoltaic	1.30	0.00		3,213.00	3.79	
Concentrated Solar Power	-	-		-	-	
Direct Geothermal	-	-			0.02	
Wave	-	-		-	-	
Tidal	-	-		-	-	
Hydro			*Hydro Storage (GWh)*			*Hydro Storage (GWh)*
River Hydro						
Hydro	6,275.00	19.52		7,836.00	30.00	
Hydro Pump Back (if applicable)						
Renewable Heat						
Type	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*	*Capacity (MWe)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*
Individual Solar Thermal	73.30	0.00		n/a	16.67	
Solar Thermal						
Geothermal	153.20	0.37		n/a	1.94	

Bioenergy		
	2010	Potential (2050)
Type	*Annual Consumption (TWh/year)*	*Annual Consumption (TWh/year)*
Energy Crops: Residual	15.71	68.67
Energy Crops: Dedicated Land	18.05	55.82
Wood	40.22	19.35
Waste: Renewable & fossil	0.36	6.33
Biogas	0.03	6.84
Total	56.32	157.01

3.4.2 References

Romania: Renewable Energy Resources	

Renewable Energy Resources - RO						
	2010			Potential (2050)		
Renewable Electricity						
Type	*Capacity (MWe)*	*Annual Production (TWh/year)*		*Capacity (MWe)*	*Annual Production (TWh/year)*	
Onshore Wind	[1]: 462 MW cumulated [4]: Onshore/off shore distribution 3% off shore, 97% onshore [2]: 400 MW cumulated [5]: Wind power: 388 MW	[1] [4]: Onshore/off shore distribution 3% off shore, 97% onshore [5]: Wind power: 0.306 TWh		[1] [4]: Distribution of onshore 20 % and 80 % offshore (lower than Croatia due to short shore line, numbers from 2020)	[1] [4]: Distribution of onshore 20 % and 80 % offshore (lower than Croatia due to short shore line, numbers from 2020)	
Offshore Wind	[1] [4]: Onshore/off shore distribution 3% off shore, 97% onshore [6]: (2010-data) Wind power (Off shore): Not on the list.	[1] [4]: Onshore/off shore distribution 3% off shore, 97% onshore		[1] [4]: Distribution of onshore 20 % and 80 % offshore (lower than Croatia due to short shore line, numbers from 2020)	[1] [4]: Distribution of onshore 20 % and 80 % offshore (lower than Croatia due to short shore line, numbers from 2020)	
Photovoltaic	[5]: (2010) PV on grid: 1.3 MWp PV off grid: 0.6 MWp Total: 1.9 MWp	[5]: PV: 1.0 GWh (2010)		[1]	[1]: 3,788 GWh [RO1]: 1.2 TWh electricity from solar energy	
Concentrated Solar Power	[8]: Not on the list	[8]: Not on the list		[10]: Solar radiation in Romania is between 1000 and 1500 kWh/m²/y Areas of at least 2000 kWh/m²/y are needed for CSP plants due to economic constraints. Romania is therefore unsuitable for CSP	[10]: Solar radiation in Romania is between 1000 and 1500 kWh/m²/y Areas of at least 2000 kWh/m²/y are needed for CSP plants due to economic constraints. Romania is therefore unsuitable for CSP	
Direct Geothermal	[1]: 0 MW [5]: Geothermal electricity plants: Capacity installed: 0 MW	[1] + [RO2]: 0 GWh [5]: Geothermal electricity plants: 0 GWh		[1]: Geothermal (and other renewables): 18 GWh Not included since it is questionable whether or not it is Geothermal.	[1]:	

Wave	[1]	[1]		[1]	[1]	
Tidal	[1]	[1]		[1]	[1]	
Hydro			*Hydro Storage (GWh)*			*Hydro Storage (GWh)*
River Hydro						
Hydro	[1]	[1] + [2]		[1]	[1]: 25,169 GWh [RO1]: The Romanian hydraulic potential technically developable is 36,000 GWh/year from which, 30,000 GWh/year (taking into consideration the developable economic potential) can be exploited	
Hydro Pump Back (if applicable)						
Renewable Heat						
Type	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*	*Capacity (MWe)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*
Individual Solar Thermal	[5]: Thermal solar collectors: 104,700 m2	[RO2]: 4 TJ solar thermal production		n/a	[RO1]: Solar energy 60 PJ/year heat	
Solar Thermal						
Geothermal	[5]: Geothermal: Capacity: 153.2 MW	[5]: Geothermal: Energy using: 32.1 ktoe [RO2]: 962 TJ		n/a	[RO1]: Geothermal energy = 7 PJ heat	

Bioenergy		
	2010	Potential (2050)
Type	*Annual Consumption (TWh/year)*	*Annual Consumption (TWh/year)*
Energy Crops: Residual	[11]: Straw potential from 2004: 1,351 ktoe = 15.71 TWh	[RO3]: Agricultural residues - biomass potential in 2004 in Romania = 247.21 PJ [11]: Residues related = 3,621 ktoe in 2030 = 42.11 TWh
Energy Crops: Dedicated Land	[RO5]: Biomass from agriculture in 2008 used for energy = 65 PJ = 18.06 TWh	[RO3]: Agricultural biomass = 200,935 TJ [11]: Dedicated land (without forests) 666 ktoe in 2030 = 7.75 TWh

Wood	[5]: Solid biomass: Primary energy production: 3,459Mtoe Heat consumption: 3,942 Mtoe (0,035 Mtoe to DH) Gross electricity production: Electricity only plants: 0,048 TWh CHP plants: 0,062 TWh Total: 0,110 TWh	[RO3]: Biomass wood forestry = 49 241 TJ + Wood wastes = 20 432 TJ [11]: Wood related in 2030: 13420 ktoe = 156.08 TWh
Waste: Renewable & fossil	[5]: Municipal Waste (Renewable share): Primary energy production: ktoe Gross electricity production: Electricity only plants: GWh CHP plants: GWh Total: GWh [RO2]: 1284 TJ = 0,357 TWh [11]: Total MSW in 2010: 1792 ktoe = 20.84 TWh	[RO3]: Urban Wastes potential: 22 805 TJ = 6,335 TWh [RO4]: Municipal waste electricity CHP = 17 ktoe, municipal waste heat = 110 ktoe --> 1,48 TWh/year [11]: Total MSW = 940 ktoe in 2030 = 10.93 TWh
Biogas	[5]: Landfill gas: 0 ktoe Sewage sludge: 0 ktoe Other biogas: 3,0 ktoe (~0,035 TWh) Gross electricity production: Electricity only plants: 0 GWh CHP plants: 1 GWh Total: 1 GWh	[RO3]: Biogas potential = 24 620 TJ = 6,84 TWh
Total	Note large difference to [1] 7033 ktoe - 81.7937 TWh production	

3.5 United Kingdom

In order to find the resource potentials for renewables in United Kingdom, it has been necessary to use several references to find the needed data. Most references have been from government publications, but also references from EU and other references from the United Kingdom have been used.

It was necessary to use two governmental references on biomass data in order to get full overview of the potential.

Most 2010 data for United Kingdom is from the government publication "Digest of United Kingdom energy statistics (DUKES) 2011" [UK4]. These data are deemed highly reliable.

FLH and solar performance are presented in the tables below. For onshore wind production in 2050 only the capacities has been found in the references, so the FLH has been assumed based on 2020 numbers [UK8]. For offshore wind production, the FLH has been estimated based on [1]. For marine energy, the production has been estimated based on [UK8].

	Full-load hours			
Type	2010	2050	Difference	Difference [>100 % means larger than 2010]
Onshore Wind	1,768.03	2,300.00	531.97	130%
Offshore Wind	2,271.10	3,000.00	728.90	132%
Photovoltaic	429.13	1,009.35	580.23	235%
Concentrated Solar Power				
Direct Geothermal				
Marine Energy		3,000.00		
River Hydro				
Hydro	2,185.89	3,046.35	860.47	139%
Hydro Pump Back (if applicable)				
Renewable Heat				
Individual Solar Thermal				
Solar Thermal				
Geothermal	4,652.00	4,652.00	0.00	100%
Large-scale heat pumps				

Solar-check						
Given information			Calculated	ESTIF 2012 numbers		
Capacity MW	Production TWh	Area m2	Performance kWh/m2	Capacity	Area	Solar Radiation MWh/m2
374.00		534,043		496.77	709,673	

Assumptions and crosscheck results are described in the following.

Onshore wind:
The potentials for onshore wind in 2050 have been deduced from the total wind potential of 67,334 MW from [1] where the offshore potential in 2030 of 40,000 MW from [UK8] has been deducted. FLH for 2020 (2,300 hours) have been used to calculate the annual production on 63 TWh/year.

Offshore wind:
The potential for offshore wind of 40,000 MW in 2030 [UK8] have been used for the 2050 potential. FLH from [1] (3,000 hours) have been used to calculate the annual production on 120 TWh/year.

Marine energy:
For United Kingdom is has been difficult to find potentials divided into wave and tidal, since most references aggregate them into marine energy or ocean energy. The potential for marine energy production in 2050 has been estimated based on a capacity potential on 27,000 MW from [UK8] and 3,000 FLH for marine energy in 2020.

Hydro:
For United Kingdom is has been difficult to find present capacities and productions divided into river hydro and hydro (reservoir), so the data has been aggregated into hydro. The potentials for 2050 on 1,769 MW and 5.4 TWh/year are from [1].

Hydro pump-back and hydro storage:
The hydro pump back capacity for 2010 from [UK5] is used for 2050 since no usable references where found for the potential in 2050. The hydro storage for 2010 on 3,139 GWh/year is also used for 2050. For the hydro storage on 3,139 GWh/year there were used 4,212 GWh of electricity. It is assumed that the 2010 numbers will be valid for 2050 since the technical potential for hydro in the United Kingdom seems to be utilised, especially when considering environmental concerns.

Solar thermal:
In [5] the solar thermal collector area is stated to be approximately 534,000 m^2 with a capacity of 374 MW. It has been difficult to find other present capacities and productions as well as potentials for 2050. However, it is assumed that the technical and economic potential for solar thermal is higher for 2050 than 2010. Data on the 2012 capacity from the European Solar Thermal Industry Federation (ESTIF) also suggest that the potential is higher.

Geothermal:
In [5] the geothermal capacity is 2 MW thermal in 2010 and the production is 0.01 TWh/year. The thermal capacity potential in 2050 from [1] is 26 MW, where [UK9] is much higher with 100,000 MW. The potential for 2050 from [1] is deemed the most plausible. This potential and FLH in 2010 [5] on 4,652 hours have been used to calculate the annual production on 0.1 TWh/year.

Large-scale heat pumps:
It has not been possible to find any data on capacity nor production in 2010 from large-scale heat pumps, and it is likely that it is due to the lack of any large-scale heat pumps in the present system. In [UK6] the production potential for 2050 is 12 TWh/year.

Energy crops, residual & dedicated:
The consumption of residual and dedicated energy crops on 5.5 TWh/year in 2010 is from [UK4] and consists of the categories straw, short rotation coppice (SRC), and other plant-based biomass. For 2050 the potential on 18.3 TWh/year is from [UK2] and consists of the category perennial energy crops. The alternative potential on 152.7 TWh/year for 2050 from [UK3] seems very high.

Wood:
The consumption of wood on 6.7 TWh/year in 2010 is from [UK4] and consists of the categories wood and wood waste. For 2050 the potential on 20.7 TWh/year is from [UK2] and consists of the categories forestry and forestry waste. The alternative potential on 6.9 TWh/year for 2050 from [UK3] seems very low.

Waste:
The consumption of renewable and fossil waste on 11.7 TWh/year in 2010 from [UK4] consists of the categories waste (municipal solid waste, general industrial waste and hospital waste) and tyres. The potential on 97.3 TWh/year in 2050 is from [UK3].

Biogas:
The present consumption in 2010 is on 24.4 TWh/year cf. [UK4] if combining the categories landfill gas, sewage gas, and poultry litter, meat and bone, and farm waste. The categories poultry litter, meat and bone, and farm waste is allocated to biogas since it is deemed the best use of the “resource”. For 2050 the potential on 38.3 TWh/year is from [UK2] and consists of the category “agricultural residues”. The alterna-

tive potential on 20.8 TWh/year for 2050 from [UK3] seems too low compared to the present consumption on 24.4 TWh/year.

Biomass Atlas:
The results from the Biomass Atlas are seen in the Table below. The numbers here are a bit higher compared to the numbers shown from the governmental references for the United Kingdom. The total potential for 2050 from the governmental references is 175 TWh/year, which is relatively close to 198 TWh/year for the sustainable 2030 potential from the Biomass Atlas.

	Biomass Atlas (TWh/year)			
	REF2020	**SUS2020**	**REF2030**	**SUS2030**
Energy crops, residual	69	62	60	42
Energy crops, dedicated	5	0	6	0
Wood	67	63	66	62
Waste	47	47	36	36
Biogas	43	43	58	58
Total	232	215	226	198

3.5.1 Data on renewable electricity and heat potentials

Red numbers indicate that 2010-numbers are used, due to lack of available data

United Kingdom: Renewable Energy Resources	

Renewable Energy Resources - UK						
	2010			Potential (2050)		
Renewable Electricity						
Type	*Capacity (MWe)*	*Annual Production (TWh/year)*		*Capacity (MWe)*	*Annual Production (TWh/year)*	
Onshore Wind	4,036.70	7.14		27,334.00	62.87	
Offshore Wind	1,341.20	3.05		40,000.00	120.00	
Photovoltaic	76.90	0.03		9,193.00	9.28	
Concentrated Solar Power	-	-		-	-	
Direct Geothermal	-	-		9,500.00		
Marine Energy	3.05			27,000.00	81.00	
			Hydro Storage (GWh)			*Hydro Storage (GWh)*
River Hydro						
Hydro	1,648.30	3.60		1,769.00	5.39	
Hydro Pump Back (if applicable)	2,800.00		3,139.44	2,800.00		3,139.44
Renewable Heat						
Type	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*
Individual Solar Thermal	373.80					
Solar Thermal						
Geothermal	2.00	0.01		26.00	0.12	
Large-scale heat pumps					12.00	

Bioenergy		
	2010	Potential (2050)
Type	*Annual Consumption (TWh/year)*	*Annual Consumption (TWh/year)*
Energy Crops: Residual		
Energy Crops: Dedicated Land	5.51	18.31
Wood	6.73	20.67
Waste: Renewable & fossil	11.65	97.33
Biogas	24.35	38.25
Total	48.25	174.56

3.5.2 References

United Kingdom: Renewable Energy Resources	

Renewable Energy Resources - UK						
	2010			Potential (2050)		
Renewable Electricity						
Type	*Capacity (MWe)*	*Annual Production (TWh/year)*		*Capacity (MWe)*	*Annual Production (TWh/year)*	
Onshore Wind	[UK4]: Wind Onshore (DUKES): 4,036.7 MW [1]: Wind (On- & Offshore): 5,204 MW [5]: Wind power (On- & Offshore): 5,378 MW. [6]: Wind power (Offshore): 1,341 MW = 4,037 MW.	[UK4]: Wind Onshore (DUKES): 7,137 GWh [1]: Wind (On- & Offshore): 10,183 GWh [5]: Wind power: 10.18 TWh		67,334 MW [1] - 40,000 MW [UK8]= 27,334 MW [1]: Wind (On- & Offshore): 67,334 MW [UK8]: Offshore Wind: >40 GW in 2030. Onshore Wind: 10-19 GW (23-45 TWh) in 2020.	Based on 2300 full load hours per MW in [UK8] for onshore wind in 2020.	
Offshore Wind	[UK4]: Wind Offshore (DUKES): 1,341 MW [6]: (2010-data) Wind power (Off shore): 1,341.2 MW [1]: Wind (On- & Offshore): 5,204 MW	[UK4]: Wind Offshore (DUKES): 3,046 GWh [4]: Wind (On- & Offshore): 10,183 GWh		[UK8]: Offshore Wind: >40 GW in 2030. [1]: Wind (On- & Offshore): 67,334 MW	Based on 3000 full-load hours per MW in [1] for on- and offshore wind in 2050. Wind (On- & Offshore): 204340 GWh (67334 MW)	
Photovoltaic	[UK4]: (DUKES) Solar photovoltaics: 76.9 MW [1]: (2010) Solar: 77 MWp [5]: (2010) PV on grid: 77 MWp PV off grid: 2 MWp Total: 79 MWp	[UK4]: (DUKES) Solar photovoltaics: 33 GWh [4]: Solar: 33 GWh (2010) [5]: PV: 33.2 GWh (2010)		[1]: Solar: 9,193 MW	[1]: Solar: 9,279 GWh	
Concentrated Solar Power	[8]: Not on the list	[8]: Not on the list		[10]: Solar radiation in UK is below 1000 kWh/m2 Areas of at least 2000 kWh/m²/y are needed for CSP plants due to economic constraints. UK is therefore unsuitable for CSP	[10]: Solar radiation in UK is below 1000 kWh/m2 Areas of at least 2000 kWh/m²/y are needed for CSP plants due to economic constraints. UK is therefore unsuitable for CSP	
Direct Geothermal	[5]: Geothermal electricity plants: Capacity installed: 0 MW	[1]: Geothermal (and other renewables): 0 GWh		[UK9]	[1]: Geothermal (and other renewables): 8,898 GWh Not included since it is questionable whether or not it is Geothermal.	

Marine Energy	[5]: Ocean energy: Wave: 0.5 MW Limpet 0.8 MW Oyster 2 0.75 MW E.ON Pelamis P2 Tidal: 0.25 MW Open Center Turbine 1.2 MW SeaGen 0.1 MW Pulse Stream 100 1 MW Atlantis AK 1000 0.5 MW DeepGen Tidal Generation [1]: Other renewables (tidal etc.): 0 MW	Only test sites		[UK8]: Marine energy: 27 GW in 2050 [1]: Other renewables (tidal etc.): 3,536 MW	Based on 3,000 full load hours per MW in [UK8] for marine energy in 2020.	
			Hydro Storage (GWh)			*Hydro Storage (GWh)*
River Hydro						
Hydro	[UK4]: (DUKES) (Small scale & Large scale excl. pumped storage): 195.4 MW + 1,453 MW = 1,648 MW [1]: Hydro (pumping excl.): 1,595 MW	[UK4]: (Small scale & Large scale excl. pumped storage): 511 GWh + 3,092 GWh = 3,603 GWh [1]: Hydro (pumping excl.): 3,604 GWh 2010 seams to be a dry year in UK, based on the data in DUKES [UK5].		[1]: Hydro (pumping excl.): 1,769 MW	[1]: Hydro (pumping excl.): 5,389 GWh	
Hydro Pump Back (if applicable)	[UK5]		[UK5]: (DUKES) Pumped Storage: 3,139 GWh (Electricity used in pumping at pumped storage stations: 4,212 GWh)	No reference found. 2010-data is used.		No reference found. 2010-data is used.
Renewable Heat						
Type	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*	*Capacity (MWth)*	*Annual Production (TWh/year)*	*Thermal Storage (GWh)*
Individual Solar Thermal	[5]: Thermal solar collectors: 534,043 m2 373.8 MWth					
Solar Thermal						
Geothermal	[5]: Geothermal: Capacity: 2 MW	[5]: Geothermal: Energy using: 0.8 ktoe		[1]: Geothermal: 26 MWth [UK9]: 100 GWth	Same full load hours as in 2010, and capacity based on [1].	
Large-scale heat pumps					[UK6]: Large scale heat pumps (either ground source or marine) in the RESOM model: 12 TWh/yr	

Bioenergy		
	2010	Potential (2050)
Type	*Annual Consumption (TWh/year)*	*Annual Consumption (TWh/year)*
Energy Crops: Residual Energy Crops: Dedicated Land	[UK4]: (DUKES) Straw, SRC, and other plant-based biomass: 474 ktoe (~5.51 TWh/yr) [UK1]: Perennial Energy Crops: 2.2 PJ Biodiesel from oilseed rape, tallow and used cooking oil: 2.2 PJ Bio-ethanol from sugar beet: 0.8 PJ Straw: 3.0 PJ	[UK2]: Perennial energy crops: 65.9 PJ/yr (assumed 2030) Alternative: [UK3]: Perennial energy crops: 550 PJ/yr
Wood	[UK4]: (DUKES) Wood waste: 220 ktoe Wood: 359 ktoe Total: 579 ktoe (~6.73 TWh/yr) [UK1]: Wood: 15.0 PJ Wood waste: 4.5 PJ [5]: Solid biomass: Primary energy production: 1.32 Mtoe (~15.35 TWh) Heat consumption: 0.81Mtoe (- Mtoe to DH) Gross electricity production: Electricity only plants: 4.68 TWh CHP plants: 0.58 TWh Total: 5.25 TWh	[UK2]: Forestry and forestry residues: 74.4 PJ/yr (assumed 2030) Alternative: [UK3]: Forestry and forestry residues: 25 PJ/yr

Waste: Renewable & fossil	[UK4]: (DUKES) Waste* and tyres: 1002 ktoe () *Municipal solid waste, general industrial waste and hospital waste. [UK1]: MSW, Tyres and "other" plant based biomass: 54.6 PJ [5]: Municipal Waste (Renewable share): Primary energy production: 557,6 kt Gross electricity production: Electricity only plants: 1157 GWh CHP plants: 441 GWh Total: 1598 GWh	[UK3]: Wastes: 350.4 PJ (assumed 2030)
Biogas	Landfill gas: 1574 ktoe (~18,31 TWh/yr) Sewage gas: 224 ktoe (~2,61 TWh/yr) Poultry litter, meat and bone, and farm waste: 296 ktoe (~3,44 TWh/yr) Total: 24,35 TWh/yr [UK1]: Landfill methane: 65.0 PJ Sewage gas: 10.2 PJ Poultry litter: 5.9 PJ Other Meat, bone & farm waste: 6.5 PJ [5]: Landfill gas: 1492,6 ktoe (~17,4 TWh) Sewage sludge: 258 ktoe (~3,0 TWh) Other biogas: 0 ktoe Gross electricity production: Electricity only plants: 5137 GWh CHP plants: 575 GWh Total: 5712 GWh	[UK2]: Agricultural residues: 137.7 PJ/yr (assumed 2030) Alternative: [UK3]: Agricultural residues: 75 PJ/yr.

4 References

4.1 General

[1] European Commission. 2013. EU Energy, Transport and GHG Emissions - Trends to 2050 - Reference Scenario 2013. http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2050_update_2013.pdf.

[2] EWEA European Wind Energy Association. 2013. Eastern winds - Emerging European wind power markets. http://www.ewea.org/fileadmin/files/library/publications/reports/Eastern_Winds_emerging_markets.pdf

[3] EWEA, The European Wind Energy Association. Annual Report 2010. Powering the energy debate.

[4] EWEA, The European Wind Energy Association. 2011. EU Energy Policy to 2050 - Achieving 80-95 % emissions reduction

[5] EurObserv'ER. 2012a. The State of Renewable Energies in Europe 2012 Edition. http://www.eurobserv-er.org/pdf/press/year_2012/bilan/english.pdf.

[6] EurObserv'ER. 2012b. Wind power barometer. http://www.eurobserv-er.org/pdf/press/year_2012/bilan/english.pdf.

[7] EurObserv'ER. 2014a. Photovoltaic Barometer. http://www.eurobserv-er.org/pdf/windpower_2012.pdf

[8] EurObserv'ER. 2014b. Solar thermal and concentrated solar power barometer. http://www.energies-renouvelables.org/observ-er/stat_baro/observ/baro221_en.pdf

[9] EurObserv'ER. 2014c. Wind energy barometer. http://www.energies-renouvelables.org/observ-er/stat_baro/observ/baro-jde14-gb.pdf

[10] Breyer, Christian & Gerhard Knies. 2009. "Global Energy Supply Potential of Concentrating Solar Power." In Proceedings SolarPACES 2009, Berlin, 2009. http://www.trec-uk.org.uk/reports/Breyer_paper_SolarPACES_GlobalEnergySupplyPotentialCSP_final_090630_proc.pdf

[11] Alterra & IIAS. 2012. Biomass Futures - Atlas of EU biomass potentials.

4.2 Croatia

[HR1] AgriPolicy - Enlargement Network for Agripolicy Analysis. 2009. Analysis of Renewable Energy and its Impact on Rural Development in Croatia

[HR2] IEA. 2014. International Energy Agency Statistics Database. http://www.iea.org/statistics/statisticssearch/report/?country=CROATIA&year=2010&product=RenewablesandWaste

[HR3] Embassy of Belgium in Croatia - Economic and Commercial Office. 2012. Renewable Energy in Croatia.

[HR4] Inteligentna Energija. Biomass EuVET 2012. BIOMASS IN CROATIA Report on the situation of biomass (production, supply, use) as fuel in Croatia, and RES in education as an answer to renewable market demands

[HR5] Croatia. Ministry of Economy, Labour and Entrepreneurship. 2009. Energy Strategy of the Republic of Croatia. http://www.mingo.hr/userdocsimages/White%20Paper%20Energy%20Staregy%20of%20the%20Republic%20of%20Croatia.pdf

4.3 Czech Republic

[CZ1] Czech Republic. Ministry of Industry and Trade. 2010. National Renewable Energy Action Plan for the Czech Republic. http://ec.europa.eu/energy/renewables/transparency_platform/doc/dir_2009_0028_action_plan_czechrepublic.zip
[CZ2] Association for the District Heating of the Czech Republic (ADH CR). 2014. State energy concept data (version September 2013). Data sent 17th of September 2014 via email.
[CZ3] Czech Biomass Association (CZ Biom). 2011. 4Biomass - Study on Biomass Trade in the Czech Republic. http://www.central2013.eu/fileadmin/user_upload/Downloads/outputlib/4Biomass_Trade_study_Czech_Republic_uploaded.pdf
[CZ4] BSREC, BIOMASA, CRES, Innoterm, ISPE & SEVEn. n.d.. Accelerated Penetration of Small-Scale Biomass and Solar Technologies - Maps and databases on the biomass potential in BULGARIA, CZECH REPUBLIC, HUNGARY, ROMANIA, SLOVAKIA + Greece. http://www.fao.org/uploads/media/biomass_maps_databases.pdf
[CZ5] Czech Biomass Association (CZ Biom). 2009. 4Biomass - Country Study on Political Framework and Availability of Biomass. The estimated maximal technical potential will be reached in the year 2050. http://www.central2013.eu/fileadmin/user_upload/Downloads/outputlib/4biomass_country_study_Chech_Republic.pdf

4.4 Italy

[IT1] IEA SHC. 2014. Solar Heat Worldwide. http://www.iea-shc.org/solar-heat-worldwide.
[IT2] CNES. 2008. Rapporto prelimiare sullo stato attuale del solare termico nazionale. http://www.regione.sicilia.it/industria/use/Documenti%20ufficiali%20energia/Nazionali/rapporto_preliminare_cnes_solare_termico.pdf
[IT3] UGI. 2011. Previsioni di crescita della geotermia in Italia fino al 2030. http://www.unionegeotermica.it/pdfiles/stime-sommario.pdf
[IT4] GSE. 2009. Piano di Azione Nazionale per le energie rinnovabili. http://approfondimenti.gse.it/approfondimenti/Simeri/AreaDocumentale/Documenti%20Piano%20di%20Azione%20Nazionale/PAN%20DETTAGLIO.pdf
[IT5] Terna. 2010. Impianti di generazione. http://www.terna.it/LinkClick.aspx?fileticket=%2Bh7uq4IGmE8%3D&tabid=418&mid=2501
[IT6] ENEA. 2010. Le fonti rinnovabili. http://www.fire-italia.it/20_20_20/FontiRinnovabili_enea.pd
[IT7] ENEL. 2014. ENEL website. http://www.enel.it/it-IT/impianti/
[IT8] ProgettoDighe. 2014. ProgettoDighe website. http://www.progettodighe.it/main/le-centrali/
[IT9] RSE. 2011. Valutazione del potenziale dei sistemi di accumulo di energia mediante centrali di pompaggio idroelettrico per il sistema idroelettrico italiano. http://doc.rse-web.it/doc/doc-sfoglia/11000299-314162/11000299-314162.html
[IT10] Italian District Heating Association (AIRU). 2014. Data sent 19th of September 2014 via email.
[IT11] ITABIA. 2008. Goals of bioenergy in Italy. http://www.itabia.it/pdf/rapporto2008eng.pdf

4.5 Romania

[RO1] Harghita Energy Management Public Service & UEM-CARDT. Romania National Report. http://www.southeast-europe.net/document.cmt?id=311
[RO2] IEA. 2014. International Energy Agency Statistics Database. http://www.iea.org/statistics/statisticssearch/report/?country=ROMANIA&product=renewablesandwaste&year=2010

[RO3] BSREC, BIOMASA, CRES, Innoterm, ISPE & SEVEn. n.d.. Accelerated Penetration of Small-Scale Biomass and Solar Technologies - Maps and databases on the biomass potential in BULGARIA, CZECH REPUBLIC, HUNGARY, ROMANIA, SLOVAKIA + Greece. http://www.fao.org/uploads/media/biomass_maps_databases.pdf
[RO4] Romania. Ministry of Economy, Trade and Business Environment. 2010. Biomass Master Plan for Romania. http://www.enero.ro/en/projects/StudiiBiomasa/doc/Biomass%2520Master%2520Plan%2520Romania_EN.pdf
[RO5] ENERO - Center for Promotion of Clean and Efficient Energy in Romania. 2009. Market development biomass Romania survey: Scenarios Study Biomass Romania. http://www.enero.ro/proiecte/StudiiBiomasa/doc/Study%20on%20Scenarios_Biomass_Romania_2009.pdf

4.6 United Kingdom

[UK1] United Kingdom. UK Energy Research Centre. 2010. The UK bio-energy resource base to 2050: estimates, assumptions, and uncertainties. http://www.ukerc.ac.uk/support/tiki-download_file.php?fileId=727.
[UK2] United Kingdom. Department for Environment, Food & Rural Affairs. 2007. UK Biomass strategy 2007. Found in [1]. (Scenario: Future High (no date - assumed 2030))
[UK3] United Kingdom. Royal Commission for Environmental Pollution. 2004. Biomass as a renewable resource. Found in [1].
[UK4] United Kingdom. Department of Energy and Climate Change. 2011. Digest of United Kingdom energy statistics (DUKES) 2011. http://webarchive.nationalarchives.gov.uk/20130109092117/http://www.decc.gov.uk/media/viewfile.ashx?filetype=4&filepath=11/stats/publications/dukes/2312-dukes-2011--full-document-excluding-cover-pages.pdf
[UK5] United Kingdom. Department of Energy and Climate Change. 2014. Historical electricity data: 1920 to 2013. https://www.gov.uk/government/statistical-data-sets/historical-electricity-data-1920-to-2011
[UK6] United Kingdom. Department of Energy and Climate Change. 2013. The future of heating: meeting the challenge. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf (Explicit in [UK7])
[UK7] Redpoint. 2013. Modelling to support The future of heating: meeting the challenge - report by Redpoint. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/197562/baringa_heat_paper_analytical_support.pdf
[UK8] United Kingdom. Department of Energy and Climate Change. 2011. UK Renewable Energy Roadmap. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48128/2167-uk-renewable-energy-roadmap.pdf
[UK9] Renewable Energy Association. 2012. Deep geothermal resource has potential to produce up to 20 % of UK electricity and heat for millions. http://www.r-e-a.net/news/deep-geothermal-resource-has-potential-to-produce-up-to-20-of-uk-electricity-and-heat-for-millions