Analysis of the PanEuropean TIMES results for the EU27 countries, Iceland and Norway

Deliverable D.4.1
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Introduction

The RES2020 project aims at supporting the policy debate on renewable energy strategies in the EU until 2020. RES2020 aims at:

- Analysing the present situation in the RES implementation;
- Defining future options for policies and measures;
- Calculating concrete targets for the RES contribution that can be achieved by the implementation of these options;
- Examining the implications of the achievement of these targets to the European Economy.

Future options for policies and measures are studied with the use of the TIMES energy systems analysis model, in order to analyze the quantitative effects on the RES development. TIMES offers the possibility of developing an aggregate parameter in order to quantify the impact of a wide range of support schemes. The results will be combined to provide recommendations of optimal mix scenarios for policy measures, in order to ensure the achievement of the targets. An analysis of the existing situation of renewable energy in the EU countries and a description of the available policy options can be found in the document “Reference Document on Renewable Energy Sources Policy and Potential” (Deliverables D.2.2 and D.2.3) available on the project website.

This document presents the country reports, (Deliverable D.4.1) that describe the energy system, energy policies and modelling outcomes for individual EU member states, Norway and Iceland.

A brief description of the model, model updates, and the scenarios that have been analysed are given in the document “The Pan-European TIMES model for RES2020” that is available on the project website. A brief description of the scenarios is also given in the introduction of each country’s report. The detailed description of the scenario’s definition is given in Appendix I of the document “EU27 Synthesis Report” (Deliverable D.4.2) that can be found on the project website.

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AUSTRIA
1. Introduction

This chapter describes the modelling outcomes for Austria within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios\(^4\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on an EU level. For Austria this means 34% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO\(_2\) emissions reduction of 16% compared to 2005.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO\(_2\) emissions and system costs. Section 5 contains the key conclusions.

1.1 National energy system and RES policies

The following bullet points give a short overview about the current status of renewable energy sources within the Austrian energy system.

- Key figures:

  - The share of RES in total primary energy consumption was of 22.4 % in 2006. With a share of 42.2%, oil remains the most important energy source, followed by RES, natural gas with a share of 21.9% and coal (11.8%).
  - The share of RES in the gross final energy consumption was 23.3 % in 2005.
  - The share of RES in the gross electricity production was 57% in 2006. Most of the renewable electricity (RES-E) is produced by hydropower plants (2/3), followed by solid biomass and wind power.
  - The share of biofuels in the transport in 2006 was 3.54%.

\(^4\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
• Austria energy dependence on imports amounts to 54.5% in 2005

In the following, the main national targets and EU targets for Austria concerning the use of renewable energies are listed. Further details on these targets and on their implementation by the Austrian government can be found in the deliverables D.2.2 and D.2.3 of the RES2020 project (Reference Document on Renewable Energy Sources Policy and Potential).

- Mandatory targets set by the newly proposed RES Framework Directive from 2008:
  • 34 % share of RES on the final consumption of energy in 2020.
  • At least 10% share of biofuels of final consumption of energy in transport in that Member State in 2020.

- Indicative Target set by the RES- electricity European Directive from 2001:
  • 78.1 % Share of RES on gross electricity consumption by 2010.

- Indicative Target set by the European Biofuels Directive from 2003:
  • Biofuels consumption of 5.75% of petrol and diesel use for transport in 2010.

- National commitments
  • At least 25 % of RES in primary energy consumption by 2010.
  • 80 % in 2010 and 85 % in 2020 of RES-E in gross electricity consumption.
  • According to the Ökostromgesetz from 2002, and from 2006, 4% and 10% of all electricity delivered to end-consumers by the public distribution network in the year 2008, 2010 respectively, should be produced from indigenous biomass combustion and digestion, liquid biomass (i.e. plant oils, except black liquor and sewage), wind, solar and geothermal sources. Besides this target, there is an indicative minimum quota for small hydro (< 10 MWel) of 9% in the Ökostromgesetz 2002.
  • At national level, indicative targets for biofuels have been set at 2.5% in 2005, 4.3% in 2007 and 5.75% in 2008. (The government program goes even further: 10 % “alternative fuels” in 2010 and 20 % in 2020).
  • There is no national target/commitment for heating and cooling.
2. Renewable technology deployment

2.1 Primary and final energy use

The results in the following paragraphs show the outcome of a model based scenario analysis. Accordingly this is not an outlook showing the most probable development. Instead, the effects of different political measures on the energy system with this model are displayed. This should be taken into account while studying this report and analysing its results.

Taking a closer look at the primary energy consumption (PEC) of Austria, it can be observed that there’s a constant increase of the total amount in the reference scenario (BaU) (+156 PJ 2020 compared to 2000). While all scenario results are quite similar for the periods 2010 and 2015, there are clear differences in 2020 showing a decrease in the last model period compared to 2015 in all three RES-scenarios (RES, RES-T, RES-30%). The lowest total amount of all three RES-scenarios has the RES-30% (1244 PJ in 2020).

The increase in the BaU scenario is mainly based on a rise of renewables (+89 PJ 2020 to 2000) and electricity imports (+44 PJ). The decrease in the final period in the RES-scenarios is based on a reduced use of fossil energy carriers (-44 PJ of coal, gas and oil 2020 to 2015 in RES, -92 PJ in RES-T, -123 PJ in RES-30%).

Concerning the shares of the different energy carriers, the highest share in the base year (2000) is oil (39.6%), followed by renewables and gas. Compared to other countries, this means that Austria already in the base year has a relatively high use of renewable energy sources (303 PJ or 25.3%). In all scenarios, over the period of time, there’s a decrease of the share of coal, gas and oil, while the share of renewables increases in all scenarios. The strongest reduction of coal can be observed under the conditions of a strong...
emission reduction target (RES-30%). The decrease is -4.3 % in 2020 compared to 2000 (coal has a share of 7.5 in 2020 in RES-30% which is the lowest coal share of all scenarios). The share of renewables is of course in the RES-scenarios higher than in the BaU results. The highest one is in RES-T (35.3% and 454 PJ). This shows that Austria becomes an export nation of RES production rights.

Focusing on the import of electricity, Austria is an import nation in the BaU run (import of 42 PJ in 2020). Under the condition of a 20 % GHG reduction and 20 % RES share, Austria becomes and exporter (export of 8 PJ in 2020). This also happens in the RES-T case. While a moderate RES target increases the import independency (for electricity), a stricter GHG target of -30% makes Austria become an importer again (11 PJ in 2020).

The final energy consumption (FEC) of Austria and especially the use of renewable energy sources will be discussed in the next paragraph. The FEC is 924 PJ in 2000 and increases up to 1078 PJ in 2020 in the reference case. The three RES-scenarios show lower values in 2020 (-23 PJ in 2020 in RES compared to BaU, -80 in RES-T and -70 in RES-30). The lowest value is 999 PJ in 2020 at RES-T.

![Final energy use](image)

The share of RES is the highest one in the RES-30 scenario (35.4 % in 2020). This is due to the tight GHG reduction target. The climate target is thereby also a driver of the RES share (higher share than original target).

Comparing RES and RES-T, it can be observed that there’s higher share in RES-T (34.2 % RES-T in 2020 compared to 33.2% RES [using the balancing rules which correspond to the figure; they do not match with the PRIMES rules]). This shows that Austria is a seller of green certificates.

The next two figures describe the final energy consumption in detail. There’s a split up into non-renewables on the right side and renewables on the left. In sum, the two figures below are of course identical which the aggregated one above. Looking at the BaU results, there’s an increases use of non-
renewable sources in 2010 (+ 41 PJ compared to 2000) and 2015 (+69 PJ). The value of 2020 is still clearly higher than 2000 but a decrease between 2020 and 2015 even in the BaU run can be seen (- 17 PJ).

The RES-scenarios have a clearly lower use of non-renewable energy sources compared to BaU. The lowest one is in RES-30% (652 PJ in 2020), followed by RES-T (657 PJ) and RES (705 PJ). In 2020, the use in RES-T and RES-30% are even below the level of the base year.

The total use of renewable energy sources is the highest one under the conditions of a strict GHG reduction target (356 PJ in 2020 in RES-30%). Even though the share of renewables is higher in case of a trade regime (+1.2 % in 2020 RES-T to RES), the absolute use is higher in the RES-scenario (350 PJ in 2020 to RES-T 342 PJ in 2020).

The non-renewable use is dominated by oil (in 2020: 54.8% of non-renewable consumption in BaU, 53.6% in RES) and gas (between 33.8 % and 36.0 % of non-renewable FEC in 2020). To fulfil the climate protection targets, in the RES-30% scenario, the share of coal is the lowest (3.7% of non-renewables) and the share of gas the highest (36.0% non-renewables) of all scenarios in 2020.

The renewable consumption is clearly driven by the use of electricity from renewable sources and the use of bio energy.

2.2 Use of renewable energy sources

The next paragraph focuses on the use of renewables among the different sectors. In total, there’s an increase of the direct use of renewables in all scenarios (+ 50 PJ 2020 compared to 2000 in BaU, +106 PJ in RES). Almost no changes of the total use occur in the sectors agriculture and commercial.

The increase is clearly driven by the industry sector. The additional use of renewable energy sources in this sector differs between +31PJ (2020 to 200 BaU) and +61 PJ (2020 to 200 RES). Also the share of renewables used in industry is clearly higher than in 2000 (+6.9% BaU, +11.2% RES). In the transport sector, there’s also an increase in all scenarios. It differs between +16 PJ (BaU 2020 to 2000) and +25 PJ (RES and RES-T). Concerning the use of renewable energy sources for central heat and power generation, there’s a different behavior between the BaU and the three RES-scenarios. While there’s a growth in use of 10 PJ in RES, there’s a decline of 10 PJ in BaU. But in all scenarios, the share of renewables used for
central heat and power generation is lower than in 2000, while the shares in industry and transport are clearly higher.

Figure 2.4 Direct use of renewable energy sources in the different sectors
2.2.1 Electricity generation

The electricity generation in Austria is clearly based on the use of renewable energy sources. Already in the base year, the share is 77.1%. The other parts are covered by gas (14.1%) and coal (8.2%). There’s still a small amount of oil (0.4 PJ) used in the base year, but oil fired technologies are not used any longer in any of the scenarios.

The share of renewables increases in all scenarios. While the total amount is in all three RES-runs higher than in the base one, the share in BaU (89.0% in 2020) is higher than in RES (85.3%) and RES-T (87.7%). The reason is a switch to electricity based technologies and the demand sectors and thereby a higher total electricity generation in the RES cases (+9 TWh in RES in 2020 compared to BaU in 2020, +9 TWh in RES-T, +3 TWh in RES-30%).

The use of coal is quite constant and similar (for example 4 TWh in 2020 in RES). Only in case of a stricter GHG target, coal is no longer used for electricity generation.

The influence of a trade of green certificates on the total electricity generation is marginal. When the renewable target has be fulfilled stand alone, 54 PJ are used in 2020 (85.3% of total electricity generation), if the target can be reached not only domestically and a trade (export in case of Austria) is allowed, the total value is a little higher (56 PJ or 87.7%).

Key technology for the electricity generation from renewable energy sources in Austria is clearly hydro. The highest share is in the base year (91.6%). The use has a decline between 2000 (41PJ) and 2010 (36PJ), but is otherwise constant in all periods and among the scenarios. The additional renewable generation comes mainly from wind and biomass.
Figure 2.6  Electricity generation from renewable energy sources
2.2.2 Heat production

Between 2000 and 2015, there’s constant increase in Austrian total heat production in all scenarios (+9 PJ in BaU to +16 in RES). And the end of the modelling horizon, there’s a decline in the RES scenarios, especially if a trade of green certificates is allowed and when the GHG goal is stricter. This fall between 2020 and 2015 (-38 PJ RES-T 2020 compared to RES-T 2015, -33 RES-30%) in the scenarios RES-T and RES-30% is driven by a lower use of oil as input for heat generation. Compared to 2000, the share of oil is clearly lower (-7.7 % in RES-T and RES-30%).

Comparing the heat production from renewable energy sources among the four scenarios, a domestic target of RES has the highest heat production from renewables (194 PJ in 2020). The difference between the scenarios is based on a differing use of bio energy for heat generation and has its peak in the RES scenario (170 PJ in 2020).

Figure 2.7 Total input for heat production
2.2.3 Transport fuels

The transport sector is over the whole time horizon dominated by fossil fuels. But the share of non-fossil fuels used in transport sector increases constantly from 12 PJ (4.6%) in the base year to its maximum of 39 PJ (13.9%) in 2020 (RES scenario). The three RES scenarios are quite similar concerning total amount of fuels used in transport sector (276 RES-30% to 281 RES in 2020) and share of non-fossil fuels (13.8%-13.9%).
The above described use of non-fossil fuels in the transport sector could be split up into the use of electricity, hydrogen and biofuels. As already mentioned, there’s a continual growth of non-fossil fuels with a
clear higher use in all three RES scenarios compared to BaU. The use of electricity is almost the same in all scenarios (14 PJ in 2020). The difference between RES and non-RES scenario is thereby based on the use of bio fuels. The use of bio fuels is about 8 PJ higher if a renewable target is in use than in the reference case.

3. Trade and import dependency

The next figure shows the net import of the energy carriers coal, gas and oil. Displayed are the values in the base year and the scenario results for 2020. In sum, the highest imported amount is in the BaU case (866 PJ in 2020). The three RES scenarios show lower values, especially when a 30% GHG reduction target is mandatory (755 PJ in 2020 RES-30%).

Under the conditions of a reduction of -30% GHG, the reduced import is driven by a decline of coal (-36 PJ in 2020 compared to 2000) and oil (-25 PJ). While all three RES scenarios show a decline of oil in 2020 compared to 2000 (-9 PJ RES, -22 PJ RES-T), only the tightened climate goals lead to a decrease of coal imports.

Figure 3.1  Net import / export of fossil energy carriers

The next paragraph discusses the change in trades of electricity and bio fuels both inside the EU and outside. Outside the EU, the only Austrian trade connection is an import of bio fuels in 2020 (RES-T).
While in BaU there’s a clear import of electricity inside the EU (42 PJ in 2020), Austria exports electricity in case of a domestic or European RES directive (export of 8 PJ in 2020). An additional climate directive leads again to an electricity import (11 PJ in 2020).

To reach the RES-directive, in the RES-T scenario, a trade of green certificates is allowed. Austria sells certificates at the amount of 20 PJ in 2015 and even 86 PJ in 2020. This shows that it is useful for a cost effective burden sharing of a European RES directive to expand the Austrian target of 34%.
4. Impacts of policies on emissions and costs

4.1 Emissions

In general it could be stated out, that the total Austrian CO₂ emissions increase from the base year (57 Mio. t in 2000) to 2010 (between 61 Mio. t in RES and 62 in BaU) and again slightly to 2015 to decrease finally in 2020 (between 50 and 60 Mio. t). The CO₂ emissions are clearly similar among the scenarios in 2010 and 2015.

The Non-ETS-sector has clearly higher emissions. Between 2000 and 2015, about 60% of the emissions come from agriculture, residential, commercial, transport and non-energy intensive industry. These Non-ETS emissions are dominated by the emissions of the transport sector (26.2 % of total emission in 2015 in BaU) and the residential sector (16.9 % of total emission in 2015 in BaU).

The ETS-emissions reach a total value of about 24 Mio. t (2015 BaU). They consist mainly of the emissions of the energy intensive industry (22.2 % of total emission in 2015 in BaU) and also of the emissions from electricity (12.4 %) and transformation ETS (4.2%).

The total emission development in 2020 compared to the base year sees a slight increase in BaU (+3 Mio. t), constant in RES and a decrease in RES-T (-1 Mio. t) and RES-30% (-7 Mio. t). Compared to 2000, this is a reduction of 12.8% (RES-30%), respectively -2.2% (RES-T). This reduction is clearly based on lower emissions in the ETS-sector. In the RES-30% scenario, the GHG reduction target leads to reduced emissions from electricity generation of -72.5 %. Due to this reduction, the share of Non-ETS emissions goes up to 67.7% in 2020 (RES-T).
4.2 Costs

The system costs consist of the investment, fixed and variable costs, tax/subsidies, welfare loss and endogenous trade. The lowest total system costs occur in the reference case (663.7 billion €). Any additional restrictions lead to higher costs. The highest costs in investment are in the RES-T scenario. The total investment costs are about 318 billion € (RES-T), the total system costs about 664.3 billion € (RES-T). Compared to a renewable directive which has to be reached domestically (no trade allowed), the total system cost are lower due to the trade by 1.0 billion €.

5. Conclusions

Austria is even in the base year and in the BaU scenario characterized by an electricity generation, which is clearly based on renewables (mainly hydro). Therefore, its share of renewables and RES target is compared to other countries relatively high (34%).

Due to the mentioned structure of electricity generation, the emissions are dominated by the Non-ETS sectors. A further reduction potential is seen even more in the ETS-sector by an extended use of wind energy and biomass.

In the base year, the share of renewables is 25.3 % of total primary energy consumption. This share increases up to 28.9 % (2020, BaU) respectively 35.3 % (2020, RES-T). In case of allowing a trade of renewables, Austrian share of renewables is higher than without trade and the country becomes a seller of green certificates. The rise of the use of renewables is driven on the final energy level by the industry sector and the use of bio fuels in the transport sector (additional use in the RES scenarios compared to BaU). A strong impact on the level of primary energy consumption has the central heat and power generation. Compared to BaU, there’s an additional use of renewable energy sources for electricity generation mainly.
by using wind. In the scenario RES-T with the highest share of renewables, even bio gas is used for producing electricity.
BELGIUM
1. Introduction

This chapter describes the modelling outcomes for Belgium within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Belgium this means 13% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO₂ emissions cap of 55.2 Mtons.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

The current energy system of Belgium is dominated by the use oil, having a share of 50% of the total primary energy supply. Gas and coal have share of respectively 20% and 11%. In Belgium nuclear is also very important with a share 18%. The use of renewable energy is still very limited, contributing a 2.1% share of the primary energy in 2006.

On the demand side, the industrial sector is responsible for the largest share of the final energy demand, some 40%. The transport and the residential sector are with both 25% is the next largest consumers, followed by the commercial and services sector (10%) and agriculture with less than 5%.

60% of the electricity is produced in nuclear power plants. Gas and coal power plants produce respectively 25% and 15% of all the electricity, therefore bringing the share of fossil fuels in the power sector above 90%. The share of renewable electricity is not currently very significant (3% in 2006).

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5 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
The level of demand for energy services is strongly dependent on the level of population and GDP. In the beginning of 2000 Belgium had 10.2 million inhabitants, while the GDP was 251.7 billion Euros in 2000. The assumed developments of population and GDP growth in the Belgium are given assumed in Table 1.1

<table>
<thead>
<tr>
<th>Year</th>
<th>Population Growth (%)</th>
<th>GDP Growth (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.4%</td>
<td>1.3%</td>
</tr>
<tr>
<td>2010</td>
<td>0.6%</td>
<td>2.6%</td>
</tr>
<tr>
<td>2015</td>
<td>0.5%</td>
<td>2.7%</td>
</tr>
<tr>
<td>2020</td>
<td>0.5%</td>
<td>2.7%</td>
</tr>
</tbody>
</table>

Besides the European climate and renewable target the Belgian government has set some national aims on electricity production from wind, biomass use for heat and biofuels production. In order to fulfill these goals, the government has established a set of different kinds of obligation, subsidies and tax incentives, more detail on which can be found in deliverables D2.2 and D2.3.

2. Renewable technology deployment

2.1 Primary and final energy use

In Figure 2.1 the development of primary energy supply in Belgium is given. With a share of 50% oil use is currently dominating fuel in the Belgium energy system. Renewable energy sources obtain only a share of 1% in 2000. Due to improvements of efficient in fuel chains the total primary energy consumptions will first decrease a little. However, the continuing trend of increased final energy consumption will after 2010 lead to an increase of total primary energy consumption, 6% in 2020 compared to 2000. Oil will still be the dominating fuel in 2020. The model results show that the use of renewable energy sources will increase to a share of 4%.

The renewable and climate target implemented in the RES scenario lead as was expected to more renewable energy and reduce use of fossil fuels. Moreover they lead to a significant reduction of primary energy use (12%). In 2020 total primary energy use is even below the 2000 value.

Differences on primary energy level between the RES, RES-T and RES-30% scenarios are not very large; similar energy mix and energy use reductions. There are some differences which will be discussed in the rest of this chapter.
Figure 2.1  Primary energy supply

Figure 2.2  Final energy use
In Figure 2.2 and Figure 2.3 the development of the final energy use is given. In 2000 oil use covered 45% of the Belgian final energy use. Gas, electricity and coal had shares of respectively 27%, 17% and 9%. With a share of 1.5% the deployment of renewable energy was very limited. Between 2000 and 2020 final energy use will increase 20%. The share of renewable energy increases to 6%, mainly due to increasing share of renewable electricity production and increased of biofuels in the transport sector. Besides that also some renewable heat produced in the CHP will be used. The shares of the fossil energy carriers are almost the same as in 2000.

To reach the 2020 target set in the RES scenario, the use of renewable sources is increased, fossil fuel use is decreased, and compared to BaU scenario final energy use in 2020 is reduced with 18%. Oil is the fossil fuels that decrease most. Growth in renewable energy can be seen in bio-energy for heating and transportation purpose, and solar water heating (Other RES). Production of renewable heat by CHP is less as in BaU scenario.

In the RES-T scenario less renewable energy is used as in the RES scenario, instead of that green certificates are bought to reach the renewable target. So the statistical transfer is an economical mechanism for Belgium to reach the renewable targets.

Differences between the RES and RES-30% scenario are very minor. This means that the additional emissions reduction is not coming from changes at end-use level, but from changes in power and conversions sectors.

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a) Final energy use of non-renewables

b) Final energy use of renewables

Figure 2.3 Final energy use of a) non-renewables and b) renewables

---

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation

2.2 Use of renewable energy sources

In 2000 renewable energy was mainly used in the form of bio-energy for heating applications in the industrial sector. Some bio-energy was also used for heat production in households. Very minor renewable energy was used for electricity production. This amount will increase very fast the next years. In 2020 in the BaU scenario renewable energy for electricity and heat production counts for half of the total used renewable energy. Also the use of biofuels increases, this happens in all scenarios due to the implemented biofuels target.
To reach the renewable target and the climate targets in the RES scenario the use of renewable energy in residential and commercial and services sector is increased. Also the use of renewables in industry is much higher than in the BaU scenario. On the other hand renewable energy use in central heat and power sector is lower than in BaU. This will be discussed in more detail in the next section.

In the RES-T scenario the use the use of renewable energy in residential sector is the same as in the RES scenario. This means either that realizing share of renewable energy on final level in residential sector is cheaper than in other sectors (industry) and even cheaper than buying certificates or that the Non-ETS target is driving the employment of renewable energy in residential sector. Renewable energy use in industry is lower than in the RES scenario, which is probably compensated by buying green certificates. The use of renewable energy for central heat and power production is higher than in the RES scenario.

The RES and RES-30% scenario are very similar.

![Figure 2.4 Direct use of renewable energy sources in the different sectors](image)

**2.2.1 Electricity generation**

In 2000 most electricity in Belgium was produced by nuclear power plants. However, the importance of nuclear power will decline after 2015. Under policies in practice (BaU) in 2020 nuclear and gas both count for circa a third of the total electricity production. Coal and renewable energy sources will be used both for 15%. Wind is the most used renewable source. Biomass and biogas, however, have also a significant share.

In the RES scenario the amount of electricity produced from coal is decreased compared to the BaU scenario. The electricity production from gas and nuclear is almost the same. Renewable electricity has a share of 17%. Solar has penetrated the mix of renewable electricity and biomass has replaced some biogas. The latter goes together with a shift from central electricity production to production in industrial CHP plants. Electricity production in biomass fired industrial CHP plants is increased, whereas public electricity production from biogas and biomass is decreased.
In the RES-T scenario there are no industrial CHP plants and central electricity production from biogas and biomass is higher than in the RES scenario. However, it is not that high as in the BaU scenario, probably because it is more economical to use biomass for transport. Also the total renewable electricity is lower as in BaU. On the other hand for almost all electricity imported was certified as renewable.

As a result of the more stringent climate target in the RES-30% scenario, coal power plants will not be used anymore. The amount and mix of renewable electricity are similar to the RES scenario.

Figure 2.5  Total electricity generation
2.2.2 Heat production

Gas and oil are the dominating fuels for heat production in Belgium (Figure 2.7). In the BaU scenario both will be still the most used fuels towards 2020. In 2000 some bio-energy is used in industry for process heat and steam. This amount will decline a little in 2020. Renewable district heat produced in central CHP plants is not showed in Figure 2.8, but is certainly not negligible, see Figure 2.3.

Figure 2.6 Electricity generation from renewable energy sources
In 2020 the set targets of the RES scenario lead to an energy use reduction for heating of 23% compared to the BaU scenario. In particular the use of oil and gas is decreased. The huge increase of bio-energy for heating is partly due to increased use of biomass in industrial CHP plants as mention in the previous section. Increased bio-energy use in households counts for the rest of increase of heat production from bio-energy. Solar energy will also be used in households and commercial and services sector for water heating.

As seen in the previous sector there are no industrial biomass fired CHP plants in the RES-T scenario, so less bio-energy for industrial heat. On the other hand the use of biomass for heat production in the residential sector is two and a half times higher than in the RES scenario. The latter has replaced part of the solar water heating. It

The RES-30% scenario is again very similar to the RES scenario.
2.2.3 Transport fuels

Due to increasing demand for air planes the energy use of the transport sector will increase by 25%. The use of alternative fuels for transport in 2000 was limited to electricity for trains. The increase of biofuels in the BaU is in 2015 and 2020 driven by an implemented target and reaching a share of 7% of fuels use for road transport in 2020.

The increased amount of biofuels in 2010 in the RES scenario is driven by the biofuels target. In 2015 and 2020 the target is not binding and higher shares than required are reached. In 2015 the amount of biofuels is driven by the renewable target. In 2020 a share of 11% is reached. The final energy target as well as the emission cap for Non-ETS sectors are binding and both could be driven the higher amount of biofuels than required. The emission cap of Non-ETS sector is anyway the driving force behind the use of hydrogen. Hydrogen is produced in coal gasification plants with CO2 capture and used if small fuel cell vehicles.

In the RES-T scenario the biofuels target is binding in 2010 and 2015. In 2020 the same situation as in RES, however, with some more hydrogen.

In the RES-30% the share of biofuels is 12%.

Figure 2.8 Heat production from renewable energy sources
Figure 2.9 Conventional and non-conventional transport fuels

Figure 2.10 Development of non-conventional transport fuels
3. Trade and import dependency

All oil used in Belgium has to be imported. Since half of the total energy supply is oil, Belgium is strongly dependent of other countries. This is also the case for coal and gas. In the BaU this dependency on fossil fuels from other countries is increased due to increased use. In the renewable scenarios less fossil fuels are imported.

![Figure 3.1 Net import / export of fossil energy carriers](image)

The import of electricity will increase, however, in all scenarios it will be the same amount and corresponding to 12% of the total electricity consumption.

With increasing use of bio-energy, Belgium will in the future also import biofuels. In the renewable scenarios 71PJ bio-energy are obtained domestically. This includes the full potential of woody crops, wood wastes and forestry residues. Besides that also a lot of municipal waste and industrial sludge will be used. The use of other bio-energy like grassy crops and agricultural waste is apparently not economical. It is interesting to see that all biofuels imported are from outside Europe.
Figure 3.2 Inter-EU trade and import from outside EU27 of biofuels and electricity

As mentioned before statistical transfer is used in the RES-T scenario. In 2020 these are all green electricity certificates and corresponding to circa 3% of the total final energy use. This is quite a big share of 13% target. In 2015 7PJ of the certificates bought are green electricity certificates the rest are certificates on final energy level. In 2010 some renewable final energy certificates are sold.
Figure 3.3 Virtual trade of renewable energy in the RES Trade scenario
4. Impacts of policies on emissions and costs

4.1 Emissions

There is not one specific sector that emits most CO\textsubscript{2}. In the BaU scenario emissions in all sectors will grow gradually and reach a level of 140 Mton CO\textsubscript{2} per year in 2020. CO\textsubscript{2} emissions of the Non-ETS sectors are 78 Mton CO\textsubscript{2}, this is much higher than the by the climate target allowed 55 Mton CO\textsubscript{2}. In all three renewable scenarios the increased use of renewable energy is not enough to reach the required emission reduction and so the Non-ETS target is binding. Most emission reductions are realised in the residential sector and commercial and services sector due to huge energy savings and use of more renewable energy in. Demand reductions, the use of biofuels and hydrogen lead to emission reduction in the transport sector. Of the sectors that fall under the ETS, most emissions are reduced in the power sector. This is also the sector where some additional measures are taken to reach the more ambitious emission reduction on European level in the RES-30%. However, this additional emissions reduction is limited, so it seems it is cheaper to realise the additional emission reduction is other countries. The CO\textsubscript{2} that is captured from hydrogen production from coal is stored in depleted gas fields and deep saline aquifers. In the RES, RES-T and RES-30% scenarios this is respectively 2.0, 2.5 and 1.7 Mton CO\textsubscript{2}.

![CO\textsubscript{2} emissions](image)

Figure 4.1 \textit{CO\textsubscript{2} emissions}

4.2 Costs

The total costs for expenditures on renewable energy technologies are given in Table 4.1, both as an absolute number as well as a share of GDP. The expenditures on renewable technologies in the RES scenarios are significantly higher than in the BaU scenario. In 2020 the costs of the renewable technologies in the RES scenario are more than 3 times higher than in the BaU scenario and correspond to a share of 0.9% of the total GDP, a large increase compared to the 0.3% observed for the baseline. The introduction of green certificates trading reduces the domestic expenditures on renewable technologies significantly. However, costs for green certificates will replace some of the technology expenditures.
<table>
<thead>
<tr>
<th>Total costs of renewable energy technologies [M€]</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaU</td>
<td>403</td>
<td>605</td>
<td>1116</td>
</tr>
<tr>
<td>RES</td>
<td>492</td>
<td>1489</td>
<td>3498</td>
</tr>
<tr>
<td>RES-T</td>
<td>514</td>
<td>1439</td>
<td>2675</td>
</tr>
<tr>
<td>RES-30%</td>
<td>514</td>
<td>1478</td>
<td>3382</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total costs of renewable energy technologies per GDP</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaU</td>
<td>0.1%</td>
<td>0.2%</td>
<td>0.3%</td>
</tr>
<tr>
<td>RES</td>
<td>0.2%</td>
<td>0.4%</td>
<td>0.9%</td>
</tr>
<tr>
<td>RES-T</td>
<td>0.2%</td>
<td>0.4%</td>
<td>0.7%</td>
</tr>
<tr>
<td>RES-30%</td>
<td>0.2%</td>
<td>0.4%</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

5. Conclusions

With only current policies in place (BaU scenario), the model suggests that the share of renewable energy on the final level will be 4% in 2020. Increase of renewable energy can mainly be seen in wind power, bio-energy for district heat production and increase of biofuels due to implemented biofuels target. During the same time frame CO₂ emissions are expected to grow, being some 17% above the levels of 2000 in 2020.

The renewable and climate targets implemented in the RES scenario lead to a higher share of renewable energy and less CO₂ emissions. However, with many overlapping targets, it is difficult to establish the exact impact of individual targets; the renewable target, the national CO₂ emission reduction target on non-ETS sectors and also the biofuels target are all binding, i.e. none of these targets would be reached if no specific policies were established. What can be concluded is that demand reductions and energy saving measures are of high importance for reaching the targets. Furthermore, bio-energy is the most important renewable energy carriers to increase the share of renewables. Additional bio-energy is used for heating in industry and households. In the residential sector also solar heating starts to penetrate, used mainly for heating the domestic hot water. The use of bio-fuels is also increased in the transport sector, however, the amount of biofuels does not go beyond the target share of the biofuels constraint, implying that additional bio-fuels use is not the preferred option to reach the general national renewable target or emission reductions. In contrast to that, small hydrogen fuel cell cars are important technology to reach the national emission reduction target for non-ETS sectors.

Reaching the renewables target with the help of virtual green certificates is a lucrative option for Belgium; when given the chance in the RES-T scenario, Belgium is buying green certificates and the use of bio-energy use for heating and electricity production decreases.

In the RES-30% scenario the use of renewable energy in Belgium is not further increased significantly. Contributions of Belgium to reach 30% emission reductions on European level are mainly in the form of additional energy saving and complete phase out of coal power plants.
1. Introduction

This chapter describes the modelling outcomes for Bulgaria within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios\(^6\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the *Reference Document on Renewable Energy Sources Policy and Potential* (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Bulgaria this means 16% share of RES in the gross final energy consumption in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO\(_2\) emissions cap of 15.8 Mtons.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO\(_2\) emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

### 1.1 National energy system and RES policies

Bulgaria is a major electricity producer in the Balkan area (based on nuclear - 35% and solid fuels power plants – 45%) and is aiming at becoming one of the major electricity exporters in the region. The country agreed with the EU to shut down two nuclear blocks at Kozloduy (880 MW) and the plans to complete the nuclear plant of Belene (1GW) for an estimated cost of EUR 2 billion. The country has extensive deposits of lignite and brown coal and is in the fourth place of per capita electricity production in Eastern Europe. The overall hydro potential is not very big in the country and most of it is already exploited. About 40% of the gross inland consumption in 2000 was based on solid fuels 80% of which was domestic lignite.

Due to the lack of support mechanisms, in the last years, renewable energy sources (RES) in Bulgaria are not broadly developed. However, good potential exist for biomass, wind and geothermal energy. Solar potential exists in the East and South of Bulgaria. Bulgaria has recently adopted a new feed-in tariff, its effective implementation with measures to non-discriminatory access to the power grid and simplified licensing procedures will be the basis for a market uptake of RES in the country.

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\(^6\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
Around 43% of the final energy consumption in 2000 was in industry, 24% in the residential sector, 21% in transport and the remaining in the tertiary sector and agriculture. The breakdown of use per fuel in residential and commercial are shown in the figure below.

The transport sector in Bulgaria is dominated by road transport. The final energy consumption of the transport sector in 2005 in PJ [Eurostat] can be seen in the table below.

<table>
<thead>
<tr>
<th></th>
<th>LPG</th>
<th>Gas</th>
<th>Motor spirit</th>
<th>Kerosene-Jet fuels</th>
<th>Diesel Oil</th>
<th>Electricity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
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<td></td>
<td></td>
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<td>Total</td>
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<td>8,41</td>
<td>58,74</td>
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</tr>
</tbody>
</table>

The basic assumptions regarding annual population growth rates were taken from Eurostat’s forecasts and the GDP growth rates were taken from the GEME3 forecast.

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
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<tr>
<td>Annual population growth rates</td>
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<td>-0.6%</td>
</tr>
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<td>Annual GDP growth rates</td>
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<td>3.0%</td>
<td>2.8%</td>
<td>2.7%</td>
</tr>
</tbody>
</table>

In 2007 Bulgaria introduced a new feed in tariff for Renewable Electricity. The State Energy and Water Regulatory Commission has assumed the commitment to purchase alternative energy at a higher tariff and for the duration of 12 years. Suppliers refusing to accept renewably-produced electricity would be fined up to 500 000 (euros) in response to renewable power producers' reports of difficulty in grid connection. In order to promote RES, Bulgaria is currently implementing the Bulgarian Energy Efficiency and Renewable Energy Credit Line (BEERECL). RES projects are eligible for a 20% grant. Loans worth more than EUR 12.8 million have already been granted.
2. **Renewable technology deployment**

2.1 **Primary and final energy use**

The primary energy consumption of Bulgaria increases in the BaU scenario by 30% in 2020 compared to the level in 2000. The energy mix changes over the 20 years of the time horizon of the model, with the role of nuclear to increase the share of solid fuels decreasing and the share of oil increasing in the BaU scenario.

![Primary energy supply](image)

**Figure 2.1 Primary energy supply**

In the policy scenarios, the calculated primary energy is less than in the BaU in the year 2020 by 11% (in RES) to 12% in RES-30. The reduction is mainly due to the decreased use of solid fuels in electricity production (with the decommissioning of old inefficient lignite fired power plants), and the use of energy saving measures in the building sector and in industry.

On the final energy consumption level, the calculations for the BaU scenario lead to an increase in the share of renewables from 9.4% in 2005 to 10% in 2020, 6% short of the target set by the RES directive. The reduction in the final energy in 2020 compared to the BaU scenario, due to energy savings and demand elasticity is calculated to be 4% in the RES scenario and 5% in the RES-30 scenario. Regarding renewables on the final energy consumption level, in 2000 it was only biomass that was being used. In the development of the BaU scenario this is complemented by central heat general using renewables (bioenergy) and a small amount (4% of the renewables) from solar water heating in residential applications. The overall development in the policy scenarios follows the same trend but with higher quantities of the same renewable energy sources. So bioenergy (biomass, biogas and transport biofuels) increases by 83% in 2020 from 2000 level in the RES scenario, 125% in the RES-T and 85% in the RES-30 scenario. District heating using renewables (bioenergy) rises from zero in 2000 to 27% of the renewables part in 2020 in the RES and 29% in RES-30 scenarios.
Looking at the marginal prices of the constraints, the overall renewable target constraint, has very small values in the RES scenario (0.21€/GJ), which means that the overall target is driven by the transport target (which has a marginal prices of 5.1€/GJ in 2015 and 1€/GJ in 2020) and it driven by the emission reduction targets in 2020 (non-ETS constraint marginal cost 41€/mt of non-ETS CO2 in 2020 in the RES scenario). In the RES-T scenario the indigenously produced biomass is used in higher quantities in central and local heat production. This is due to the lower production costs of biomass in Bulgaria (compared to other EU countries) which leads the least cost solution to the production and use of higher quantities of biomass in the country and a corresponding export of statistical transfers. In the RES-30 scenario the higher use of biomass is forced from the lower emissions bounds that are set for the country and this leads to a share of renewables of 21% (instead of the set 16% target) in order to achieve the emission target.
2.2 Use of renewable energy sources

The situation in Bulgaria regarding renewable in consumption sectors in 2000, is that the largest amount comes from the residential sector (biomass use in households) and the second largest share from the central power production sector (electricity production from the existing hydro plants). The development of the all scenarios shows a rather constant share of renewables in residential and commercial. The largest observed increase comes from the transport sector (with the introduction of renewables according to the target). Industry shows a high response in 2020 (in the previous years the renewable consumption in industry is very similar across scenarios). The renewable consumption in industry refers to bioenergy. Finally, in the central heat and power sector, the use of renewables increases by 50% in 2020 in the policy scenarios, compared to the BaU scenario. The increase comes from the central district heating using bioenergy and electricity production from hydro, wind, biogas and biomass. So the increase in renewables comes through their use in sectors that were traditionally based on conventional fuels up to now. In the case of RES-T the least cost solution of the model shows that an increase of the use of bioenergy in industry is possible with the corresponding export of statistical transfers in 2020 from the country.

2.2.1 Electricity generation

In the BaU scenario the development of the electricity production sector follows an upward trend, with the solid fuels sector keeping a relatively high share, and the new nuclear plants dominating the scene in 2020. Renewable electricity generation in BaU increases from the installation of wind turbines (0.6 TWh in 2010 and 2.7 TWh in 2020).

In the policy scenarios the contribution of solid fuels is lower due to the combined effect of environmental and renewable energy targets.

Figure 2.4 Direct use of renewable energy sources in the different sectors
Renewable electricity production increases from 8% in 2000 to 12% in 2020 in the RES scenario, 25% in the RES-T and 21% in the RES-30 scenario. In the policy scenarios the main increase comes from biomass fired cogeneration units. In the RES scenario, 31% of the renewable electric energy or 1.5 TWh comes from this source in 2020, the contribution of wind covers 24% of the renewable electricity production (or 1.2 TWh in 2020) and hydro power covers the remaining 45% of renewable electricity in 2020. In the RES-T scenario, biomass fired electricity contribution increases to 48%, 1% comes from biogas fired installations and the share of wind is 26% and hydro 25%. In RES-30 biomass produced electricity covers 56% of a smaller quantity of electricity (since the overall electricity production is reduced due to energy savings). What is interesting is that in the RES scenario the amount of renewable electricity is lower and the model decided to achieve the target by focusing on the heat production sector with the use of bio-energy.

Figure 2.5  Total Net electricity generation
2.2.2 Heat production

In the heat production sector the share of renewables in the BaU scenario remains almost constant to around 11% in the time horizon of the model solution.

Figure 2.6 Net Electricity generation from renewable energy sources

Figure 2.7 Total input for heat production
The renewables that appear in BaU are basically biomass (which is the only renewable in the base year), and solar water heating in residential that appears in 2010 and increases to 2020. The same renewable sources appear in the policy scenarios as well, but with different degrees of penetration of bioenergy. In the RES scenario renewables cover 15% of input to heat production and this share increases to 18% in the RES-T scenario. The increase is a result of the fact that biomass production prices are lower in Bulgaria and this makes their use in CHP financially attractive. So the increase of the use of bioenergy by 55% in RES compared to BaU, by 80% in RES-T and 41% in RES-30 is all due to increased use on bioenergy in industrial applications. Solar energy covers 5.6% of the input to renewable heat production (a share that is almost constant across scenarios).

2.2.3 Transport fuels
The energy demand in the transport sector in Bulgaria is expected to rise substantially from the levels of 2000. The non-fossil part that appears in 2000 is electricity for trains. In the BaU scenario a small penetration of renewables appears, that reaches a share of 4% calculated according to the definition in the RE directive.
In the policy scenarios the target of 10% is imposed in the solution and is satisfied by the use of biofuels. There is no difference in the share between scenarios – since the transport constraint is the binding one in the solution in all scenarios.
In 2000, the ratio between diesel and gasoline is 54-46 which is changed dramatically in the future in the BaU scenario, since most of the increase in transport demand is expected to come from the increase in private cars for short and long distances that run on gasoline.

Regarding biofuels, about 80% of the biofuels in 2020 in all the policy scenarios is biodiesel, the remaining being bioethanol and locally produced biogas.
3. Trade and import dependency

The imports of oil products and gas show a tendency for reduction in the policy scenarios, compared to BaU in 2020, while solid fuels imports are very similar. The country is a net importer of fossil fuels.

Regarding the import of bioenergy one can see in Figure 3.2 that the country imports only a small quantity of biofuels in 2020 in the RES-T scenario, where larger quantities of locally produced biomass are used in the production of heat and electricity. The biomass potential and cost assumptions that have been used are such that it is the least cost solution for the country to produce all the required biofuels and biomass to reach the target locally in the scenarios RES and RES-30.

Another important feature is the amount of net exports of electricity that come from Bulgaria in the BaU scenario (Figure 3.3). The country is at the moment one of the major exporters of electricity in the region and this seems to continue in the BaU scenario. This trend is present in the policy scenarios as well in a varying degree.

![Figure 3.1 Net import / export of fossil energy carriers](image-url)
Figure 3.2  *Inter-EU trade and import from outside EU27 of biofuels and electricity*

Figure 3.3  *Virtual trade of renewable energy in the RES Trade scenario*
In the RES-T scenario the least cost solution over EU27 shows that there is a potential for the country to export statistical transfers. As was already mentioned this comes from the possibility of using locally produced biomass in industry and central heat and power production (see Figures 2.4, 2.6 and 2.8)

4. Impacts of policies on emissions and costs

4.1 Emissions

There is a reduction in overall emissions even in the BaU scenario that comes from the higher production of nuclear power plants, and the corresponding lower production of solid fired power plants, since the decisions for building nuclear power plants is included in the model. This trend is even more pronounced in the policy scenarios since it is enforced by the use of renewables.

The reduction of emissions in the ETS industry is 4% (compared to the BaU scenario) in RES and RES-E and 9% in RES-30. The non-ETS industry has higher reduction rates (20% across scenarios) and the commercial and residential sector show reductions of 17% to 19%, which come as a combined effect of the increases use of solar, biomass and energy savings due to insulation in buildings.

Figure 4.1 CO₂ emissions

5. Costs

In the BaU scenario the calculated cost for investment and operation of renewable energy technologies is of the order of 396 million Euros in 2020 corresponding to about 0.8% of the national GDP. In the RES
scenario this increases to 460 million and 0.9% of the projected GDP. A significant difference appears in the RES-T scenario where the costs increases to 796 million and 1.6% of the projected GDP (which is due to the fact that the country is overshooting the local production of renewables and transferring the credits). Finally in the RES-30 the costs are calculated at the order of 671 million, or 1.4% of the GDP in order to achieve the tougher emission targets set in this scenario.

6. Conclusions

The main sources that Bulgaria can use in order to achieve the renewables target for 2020 are biomass and wind. The hydro potential is almost all already exploited, and there is potential for the use of solar for hot water production in the residential and commercial sectors. However the main source that dominates the scenarios is biomass that is utilised in heat and power production and in the production of biofuels (the country imports only a small amount of biofuels in one scenario in order to achieve the transport target). The least cost solution of this model also shows that there is the possibility of the country becoming an exporter of statistical transfers for renewables.

7. References

1. Introduction

This chapter describes the modelling outcomes for Cyprus within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on an EU level. For Cyprus this means 13% share of RES in the gross final energy in 2020, and for all sectors which do not fall under the European Emissions Trading scheme, a CO₂ emissions cap of 3.9 Mtons.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% instead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Cyprus has no indigenous sources of energy and at the moment, it is almost entirely dependent on imported energy. In year 2006, imports of oil products, coal and pet coke for home consumption, amounted to 580 million Euros, representing approximately 18% of the country’s domestic imports. Energy is therefore, of vital importance to the island’s economy.

The energy consumption in Cyprus is predominantly oil-based and amounts to 92.6% of the total energy consumption. Other forms of commercial energy used are Solid Fuels (coal and pet coke) for the production of cement, amounting to 5.9% of the total energy consumption. The remaining 1.5% is mainly solar energy and at the moment is the only substantial contribution of renewable energy sources, in the country’s final energy consumption.

The breakdown of energy consumption between industry, transport and services and households shows a share of approximately 23% for industry, 52% for transport, whereas services and households cover 20%.

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7 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
Electricity is the main energy source in the residential sector, covering 42% of the energy demand. The remaining 38% is covered by oil and LPG, while renewable biomass and solar account for 20%. This is the indication for the large penetration of solar systems in the residential sector for hot water production. The largest contribution in the value added of the manufacturing industry in Cyprus comes from the food, beverages and tobacco industry, followed by the metal products, chemicals & plastics and textiles.

The transport sector in Cyprus is dominated by road and air transport since there is no internal navigation and also there is no railway on the island. The final energy consumption of the transport sector of Cyprus in 2000 in PJ [Eurostat] can be seen in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Gas</th>
<th>Motor Spirit</th>
<th>Kerosene – Jet fuels</th>
<th>Diesel Oil</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>-</td>
<td>9.04</td>
<td>14.40</td>
<td>-</td>
<td>23.45</td>
</tr>
<tr>
<td>Air</td>
<td>-</td>
<td>-</td>
<td>12.14</td>
<td>-</td>
<td>12.14</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>9.04</td>
<td>12.14</td>
<td>14.40</td>
<td>35.67</td>
</tr>
</tbody>
</table>

Cyprus has to diversify, to a great extent, to cleaner and safer forms of energy in order to meet the environmental criteria, set out by the European Union. As a result, the introduction of natural gas (mainly for electricity generation) is considered essential to the energy sector and beneficial for the Cyprus economy. A study, which was completed in November 2002, showed that the most economic and safe manner for the supply and transport of Natural Gas to Cyprus is in the form of Liquefied Natural Gas (LNG) and using vessels. The study also showed, that in the absence of a centralised distribution network, Natural Gas in Cyprus may at present be used for electricity generation by EAC and possibly at a later stage by other large consumers. In the framework of introducing Natural Gas in the energy system of Cyprus, the Government has set the following main objectives:
1. The construction of an Energy Centre at Vassilikos area for import and storage of Natural Gas in LNG form.
2. The effective implementation of the relative legislation, which is in line with the requirements Directive 98/30/EC, regarding the control and monitoring of the Natural Gas market.

Cyprus is one of the leading countries in the use and construction of solar water heating systems. 90% of households are equipped with solar water heaters and 53% of hotels have installed large solar water heating systems. Regarding the renewable energy sources potential, Cyprus has limited biomass potential, a rather small wind potential but rather high solar energy potential. For more details in the renewable energy policy of Cyprus please refer to the “Reference Document on Renewable Energy Sources and Potential”. For the analysis using the PET model the annual population growth rates where taken from Eurostat. The services sector is the most important in the country and has exhibited a high rate of increase over the last years.
2. Renewable technology deployment

2.1 Primary and final energy use

Cyprus is completely dependent on imported energy commodities, mainly oil products and a small amount of solid fuels used in industry. According to the energy plan of the country (Energy Service, Ministry of Commerce Industry and Tourism, 2007) the main change of the energy system in the coming years will be the introduction of natural gas in the electricity production of the island through the installation of an LNG terminal. The electricity system of Cyprus is not connected to any other grid.

![Electricity import](image)

**Figure 2.1 Primary energy supply**
The target for renewable energy sources set for Cyprus by the directive is 13% of the gross final energy in 2020. The reference scenario (with no extra measures) leads to a share of about 6% in 2020 from the 3% share of 2005. The RES target seems to be the binding one at all the intermediate years until 2020 compared to the climate target. Also the renewable transport fuels constraint seems to be the one that is binding in the period of 2010-2015, while at 2020 the overall renewables constraint has a shadow price as well. So in the RES scenario the overall renewable constraint marginal price is 6.6€/GJ, decreasing to 4.4€/GJ in the RES-T. The price of the transport constraint is 6.6€/GJ and 4.5€/GJ respectively. Finally the price of the non-ETS emissions constraint is zero in all the policy scenarios which means that it is the renewable targets that dominate the changes in the energy sector.

Figure 2.2 Final energy use

The sections below describe in more detail renewable and non-renewable electricity and heat generation.

Figure 2.3 Final energy use of a) non-renewables and b) renewables

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation.
2.2 Use of renewable energy sources

In the BaU scenario the existing measures are not adequate to reach the target. It is calculated that the existing policies approach will lead to a share of 6% of renewables in the gross final energy consumption. The residential sector has a rather high share in the use of renewable energy (mainly solar water heating systems and some biomass use for heating) even in the BaU scenario. In the policy scenarios, the use of renewable energy in the residential sector is important, and transport is the next most important sector with the target of 10% renewables in 2020. Central electricity production comes next with the use of all the potential of wind energy and the use of solar energy for electricity production. The sectoral split among the scenarios is similar. Compared to the year 2000, there is a dramatic change in the contribution of renewables in all the sectors (apart from the residential where the existing trend of solar water heaters continues). The achievement of the target, leads to the introduction of a high amount of renewables in sectors that were exclusively dependent on fossil fuels before (like electricity production and transport).

![Graph showing direct use of renewable energy sources in different sectors](image)

**Figure 2.4 Direct use of renewable energy sources in the different sectors**

2.2.1 Electricity generation

The electricity generation in Cyprus is completely based on oil products until now. The main change in country’s policy is the introduction of natural gas and the introduction of renewables (mainly wind and solar). The first option is the introduction of wind energy (even in the BaU scenario) which means that from a financial point of view the penetration of wind is economically viable with the existing feed-in tariff policies. The introduction of the more expensive solar electricity production option appears in order to reach the renewable target for 2020. RES electricity is 14% of the total net production in the policy scenarios while in the BaU scenario it covers 9% electricity. The largest part is wind produced electricity (72% of RES-E) while the remaining 28% is solar produced electricity (70MW solar thermal power plants and 13MW PV systems).
Figure 2.5  Total electricity generation

Figure 2.6  Electricity generation from renewable energy sources
2.2.2 Heat production

The input for heat production is dominated by oil products in 2000 and over the whole time horizon of the scenarios. Renewables account for 17% of the total input to heat production in the policy scenarios. Also in the policy scenarios there is a reduction of the overall demand for heat – mainly though the introduction of energy saving technologies (insulation etc) and through the elastic demand response.

Regarding the share of specific renewable sources in heat production, solar dominates the scene (following the current trend in the use of solar water heating systems). So 60% of the renewable heat comes from solar systems, 35% from the use of bioenergy and the remaining from the use of renewable electricity.

District heating is not an economically viable technology in Cyprus due to the low heating demand during the year. Solid fuels are used mainly in the Cement industry in the country and continue to occupy that share.

The marginal price of the constraints show that it is the renewable energy in transport constraint that is biding in 2010 and 2015, while in 2020 the price of this constraint is comparable with the price of the overall constraint. So it can be concluded that the renewable energy constraints are those that are driving the emission reduction targets except in the RES-30 scenario.

Figure 2.7 Total input for heat production
2.2.3 Transport fuels

Regarding renewable energy in transport, biofuels that dominate the scene. The share of 10% is imposed according to the new directive in 2020. The BaU scenario shows only a minimal 2% overall penetration of biofuels.

Figure 2.8  Heat production from renewable energy sources

Figure 2.9  Conventional and non-conventional transport fuels
In 2000 and 2005 there are no biofuels used in transport in Cyprus. The BaU scenario shows a small introduction of biodiesel from 2010 onwards. In the policy scenarios biodiesel covers 86% of the biofuels used and bioethanol the remaining 14%. The largest share of biodiesel (64% in 2020) and the whole of bioethanol is imported from outside the EU. The share of renewables in transport does not exceed the 10% foreseen by the Directive.

Figure 2.10 Development of non-conventional transport fuels

3. Trade and import dependency

As was already mentioned, Cyprus imports all the fossil fuels that are being used. The change in the import pattern is due to the introduction of natural gas from 2010 onwards. A reduction of 5-6% in the import of oil products is observed in the policy scenarios in 2020, which is due to a combination of the introduction of natural gas and the use of renewable energy sources. The import of solid fuels is almost constant in all scenarios, corresponding to the import of coal for industrial uses.
Figure 3.1  *Net import / export of fossil energy carriers*

Figure 3.2  *Inter-EU trade and import from outside EU27 of biofuels and electricity*
The country is a net importer of renewables, since the indigenous potential of solar and wind cannot be traded. In 2000 the trade of renewables was zero. In order to fulfil the renewable transport obligation, most of the biofuels need to be imported in the policy scenarios, while none is imported in the BaU. The potential of biofuels production in Cyprus is rather limited and covers only the small penetration that is observed in the BaY scenario. Only 36% of the used biodiesel is produced from local resources in 2020, in the policy scenarios, due to the limited land availability for non-food biomass cultivation and the special condition of water scarcity in the country.

**Figure 3.3 Virtual trade of renewable energy in the RES Statistical Transfer scenario**

The possibility of statistical transfers gives the possibility to export a very small amount which comes from the final energy sector, through the high use of solar water systems.

4. Impacts of policies on emissions and costs

4.1 Emissions

The CO₂ emissions from the power sector are reduced in all the scenarios as a result of the introduction of natural gas and the introduction of renewable electricity in the policy scenarios. In the non-ETS sectors most of the reduction in the policy scenarios is due to industry and transport (following the introduction of biofuels). The most inelastic sector appears to be the residential sector. CCS is not an option for Cyprus due to the small size of the island and the corresponding small amount of CO₂ generation. The reduction of CO₂ emissions is due to a combination of the reduction in final energy consumption due to the introduction of new – more efficient technologies, and the increase in the share of renewable energy sources.
4.2 Costs

In the BaU scenario the cost of investment and operation for renewable energy technologies is calculated to be 101 million Euros for 2020, corresponding to 0.4% of the expected GDP for that year. In the RES scenario this increases to 279 mil. Euros and 1.2% of the GDP. The largest share of this corresponds to investments in renewable technologies in the final energy consumption sector. In the RES-T scenario the cost is reduced to 257 milEuros (1.1% of GDP) due to not investing in solar PV for electricity production, while the investment in technologies used in final energy consumption remains the same as in scenario RES. Finally the cost in the RES-30 scenario is of the same order as the RES scenario, which means that the extra reduction in CO2 emissions does not require more investment in renewables.

5. Conclusions

Overall, Cyprus has a rather limited renewable energy potential with the exception of solar radiation, which is already used extensively in hot water production. In order to achieve the ambitious target of 13% gross final energy, all the estimated wind energy potential must be used, solar electricity production should reach 4% of the total, the use of solar collectors must double from the 2005 value, bioenergy use in industry should increase, and the 10% renewable target in transport must be met by the use of mainly imported biofuels.
6. References


CZECH REPUBLIC
1. Introduction

This chapter describes the modelling outcomes for the Czech Republic within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios\(^8\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).
- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For the Czech Republic this means 13% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a maximum increase of CO\(_2\) emissions of 9% compared to 2005.
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO\(_2\) emissions and system costs. Section 5 contains the key conclusions.

1.1 National energy system and RES policies

The following bullet points give a short overview about the current status of renewable energy sources within the Czech energy system.

- Key figures:
  - The share of RES in total primary energy consumption was 4.10 % in 2006
  - The share of RES in the gross final energy consumption in 2005 amounted to 6.1%
  - In 2006, renewable electricity accounted for 4.91% of gross inland electricity consumption, and 4.17% in gross inland electricity production
  - Biofuels represented in 2006 approximately 0.5% of the transport fuels
  - Dependence on external energy supplies is of about 37.6% in 2005

\(^8\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
Technology specific figures:

- The highest share of renewable electricity production in 2006 came from hydropower followed by biomass.
- Gross electricity production from hydro amounted to 2,550.7 GWh while the total installed capacity amounted to 1,028.5 MW.
- Gross electricity production from biomass amounted to 731 GWh in 2006. (annual increment 171 GWh).
- The exploitation of biogas (176 GWh) can also be viewed as a significant source of renewable electricity.
- Wind plants produced 49.4 GWh in 2006. By the end of 2006, 43.5 MW of wind power had been installed in the Czech Republic. Between 2005 and 2006, the total installed capacity almost doubled. In 2006, 45 projects with a total capacity of 18.5 MW were put into operation.
- Gross electricity production from photovoltaics was 0.2 GWh. Total installed capacity in October 2007 amounted to 2.9 MWp (only systems with licence).
- Energy production from solar thermal was circa 127 TJ. Total area of glazed collectors in 2006 was 105,000 m².
- Heat production from biomass amounted to 16,370 TJ (without households).
- Heat production from biogas amounted to 918,511 GJ. (including municipal and industrial waste treatments plants, biogas stations, landfill gas).
- In 2006, approximately six million tonnes of fuels for transport was placed on the market in the Czech Republic, of which 29,600 tonnes was made up of biofuels – i.e. 0.5%.

In the following, the main national targets and EU targets for the Czech Republic concerning the use of renewable energies are listed. Further details on these targets and on their implementation by the Czech government can be found in the deliverables D.2.2 and D.2.3 of the RES2020 project (Reference Document on Renewable Energy Sources Policy and Potential).

- Mandatory targets set by the newly proposed RES Framework Directive from 2008:
  - 13 % share of RES on the final consumption of energy in 2020
  - At least 10% share of biofuels of final consumption of energy in transport in that Member State in 2020

- Indicative Target set by the RES- electricity European Directive from 2001:
  - 8 % share of RES on gross electricity consumption by 2010

- Indicative Target set by the European Biofuels Directive from 2003:
  - Biofuels consumption of 5.75% of petrol and diesel use for transport in 2010.

- National Commitments:

In 2004, the parliament of Czech Republic approved the national energy strategy setting targets for 2030:
- RES share in electricity production should be 16-17% in 2030
- RES share in the primary energy sources 6 % in 2010 and 15 – 16 % in 2030
2. Renewable technology deployment

2.1 Primary and final energy use

The results in the following paragraphs show the outcome of a model based scenario analysis. Accordingly this is not an outlook showing the most probable development. Instead, the effects of different political measures on the energy system with this model are displayed. This should be taken into account while studying this report and analysing its results.

Primary energy consumption increases constantly in the BAU scenario from 1618 PJ in 2000 to 1841 PJ in 2020 (Figure 2.1). Renewables account for the greatest increase in absolute (+98 PJ) and relative (+415%) numbers. In 2020, their share in total primary energy consumption amounts to 7%. A growing consumption between 2000 and 2020 can also be observed with the energy carriers gas (+10%), nuclear (+30%) and oil (+29%). Only the consumption of coal shows a slight decrease (-3%).

The implementation of the renewable target and the CO2 emission limit set by the European commission for the Czech Republic (scenario RES) leads to a stronger penetration of renewables. In 2020, their share in total primary energy consumption adds up to 181 PJ, which is 50% more compared to the BAU scenario. The absolute primary energy consumption diminishes by 127 PJ compared to BAU in 2020, mainly due to a decreasing coal consumption (-140 PJ).

The virtual trade mechanism for RES production rights (scenario RES-T) leads to a lower consumption of renewables in 2020 than in scenario RES (-12PJ) although the total primary energy consumption grows slightly (+20%).

A more stringent reduction target for the emissions of CO2 in 2020 (scenario RES-30%) does not lead to a higher primary energy consumption of renewables compared to the scenario RES. Instead, the consumption of coal decreases drastically (-51% compared to BAU in 2020), mainly compensated by a higher gas consumption (+44%). Furthermore, the overall primary energy consumption diminishes by 254 PJ.

![Figure 2.1 Primary energy supply](image)
Final energy consumption increases in the BAU scenario from 984 PJ in 2000 to 1266 PJ in 2020 (Figure 2.2). At the same time, the consumption of renewables grows from 15 PJ to 72 PJ. In the other scenarios with RES targets on national or EU level, the consumption of renewables in 2020 is raised to 125 PJ (RES), 115 PJ (RES-T) and 128 PJ (RES-30%) respectively.

Among the different kinds of renewables, bioenergy represents the dominant share in all scenarios (Figure 2.3b) varying between 60% in the BAU scenario and 44% in scenario RES-T. The final energy consumption of electricity from renewables reaches market shares between 23% (BAU) and 37% (RES-30%) in 2020. The share of heat from renewables in 2020 is comparatively low in the BAU scenario (8%) but significantly higher in scenarios with RES targets and CO₂ emission limits (between 21% and 22%).
2.2 Use of renewable energy sources

Looking at the direct use of renewable energy sources in the different sectors (Figure 2.4), it becomes apparent that in the BAU scenario, renewables are preferentially used in the transport sector (42%) followed by central heat and power production (29%) and the industry sector (21%). In the other scenarios, a shift can be observed leading to a lower consumption of renewables in the transport sector (between 26% and 32%) and an increasing use especially in industry (between 32% and 38%) and in the residential sector (between 9% and 10%). The consumption of renewables for central heat and power production in 2020 is more or less constant in all scenarios (22 PJ). The lower direct use of renewables in scenario RES-T compared to RES indicates that the Czech Republic becomes a buyer of green certificates in order to fulfil its national renewable target. A stricter reduction target on CO₂-emissions (RES-30%) does not lead to a stronger direct use of renewable energy sources compared to scenario RES. This shows, that the emission reductions are achieved by other measures like an increasing use of gas instead of coal for electricity production (see chapter 2.2.1).

![Figure 2.4 Direct use of renewable energy sources in the different sectors](image)

2.2.1 Electricity generation

Total electricity generation increases in the BAU scenario from 69 TWh in the year 2000 to 88 TWh in 2020. In the scenarios RES and RES-T, the increase is slightly lower, reaching 78 TWh in 2020, in scenario RES-30% total electricity generation even decreases to 65 TWh in 2020. The production of electricity from renewables increases strongly even in the reference case from 2 TWh in 2000 to 9 TWh in 2020. In the other scenarios, renewables account for 12 TWh of electricity production in 2020.

The lower numbers of total electricity production in the scenarios RES, RES-T and RES-30% compared to BAU in 2020 are completely caused by a reduced utilization of coal for electricity production. While coal
accounts for 62 TWh of electricity production in 2020 in the reference case, it decreases to 46 TWh (RES) and 47 TWh (RES-T) respectively.

In scenario RES-30%, electricity production from coal diminishes even stronger to 12 TWh in 2020, mainly at the expense of a growing electricity production from natural gas (29 TWh).

Comparing the different renewable energy sources that are employed for electricity production (Figure 2.6), it can be observed that the use of hydro power and wind power in 2020 is almost the same in all scenarios. Both sources, each account for 3 TWh of electricity production. However, concerning the production of electricity from biomass, a much stronger growth occurs in the scenarios with RES targets and constraints on CO₂ emissions. The production increases from 1 TWh in 2000 to 6 TWh in 2020 in each of these scenarios, whereas in the reference case only 3 TWh are produced in 2020.
2.2.2 Heat production

The production of heat increases from 576 PJ in 2000 to 737 PJ in 2020 in the reference case. In the other scenarios, the increase is slightly lower as a consequence of an advanced implementation of energy saving measures. Renewable energy sources play a minor role in heat production. The highest share (8%) is achieved in scenario RES-30% in 2020, representing 52 PJ in absolute numbers. In the other scenarios with targets on the use of renewables the share is about 7% or 48 PJ (RES) and 45 PJ (RES-T) in absolute numbers, which is still considerably higher than in the reference case (3% and 24 PJ respectively).

All in all, heat production is dominated in all scenarios by the fossil energy carriers coal, gas and to a minor extend oil until 2020. Only in case of scenario RES-30%, the production of heat from coal decreases slightly (-37 PJ compared to BAU in 2020) in order to fulfil the stronger CO₂ emission target.
Among the renewable sources that are employed for heat production (Figure 2.8) bioenergy has by far the greatest market share. In the BAU scenario, heat production from bioenergy increases from 12 PJ in 2000 to 19 PJ in 2020. In the other scenarios the values in 2020 are even higher with 36 PJ (RES), 33 PJ (RES-T) and 39 PJ (RES-30%) respectively.

From 2015 onward, solar energy is also used for heat production in the scenarios with targets on the use of renewables. Until 2020, the share of solar energy among the total heat production from renewables grows to 7% in these scenarios. With a small delay, solar energy is also employed in the reference case and accounts for 2% of renewable heat production in 2020.

The growing use of renewables in electricity production leads to an also increasing heat production from renewable electricity. The production is 3 PJ in the BAU scenario, 5 PJ in RES and RES-T and 6 PJ in RES-30%
2.2.3 Transport fuels

As a consequence of the growing demand for mobility in personal and freight transport, the overall consumption of transport fuels increases from 198 PJ in 2000 to 238 PJ in 2020 in the scenarios BAU, RES and RES-T (Figure 2.9). Only in scenario RES-30%, fuel consumption diminishes slightly after 2015 as a consequence of the stronger constraint on CO₂ emissions and accounts for 233 PJ in 2020. The share of non-fossil fuels increases constantly from 4% in 2000 to 17% in 2020 in case of the scenarios BAU and RES. In the scenarios RES-T and RES-30%, the increase turns out lower, because the available biomass resources are preferentially used in other sectors than using them for the production of biofuels.
Looking at the development of the different non-conventional transport fuels (Figure 2.10) it becomes apparent that electricity is the only non-conventional fuel that is used in the base year 2000. Until 2020 the consumption of electricity, which is completely used for rail transport, grows slightly to 9 PJ in all scenarios. This implicates that the strong growth in the overall consumption of unconventional fuels is primarily caused by the increasing consumption of biofuels. As already mentioned, the highest consumption of biofuels in 2020 can be observed in the scenarios BAU and RES (32 PJ), whereas in the scenarios RES-T (22 PJ) and RES-30% (25 PJ) the consumption is lower because available biomass is used in other sectors instead of using them for the production of biofuels.
3. Trade and import dependency

As Figure 3.1 shows, the Czech Republic turns into a net importer of all fossil energy carriers until 2020. While in 2000, there were still net exports of coal in the order of 148 PJ, the domestic coal production in 2020 is not sufficient anymore to satisfy the demand. As a result, the net imports of coal add up to 31 PJ in all scenarios.

The import dependency on the other fossil energy carriers gas and oil increases, too in all scenarios. In the BAU scenario, gas imports increase by 10% from 297 PJ in 2000 to 325 PJ in 2020 and the imports of oil products by 31% from 316 PJ to 414 PJ. The target on the use of renewables leads to a considerably lower growth of net imports in case of scenario RES (+3% between 2000 and 2020 for gas and +20% for oil products) and RES-T (+9% between 2000 and 2020 for gas and +23% for oil products). Scenario RES-30% shows the lowest increase of the net imports of oil products until 2020 (+15%) but at the same time the strongest increase of the net gas imports. This is mainly a consequence of the rising electricity production from gas as explained in chapter 2.2.1.

![Figure 3.1 Net import/export of fossil energy carriers](image)
As Figure 3.2 shows, the Czech Republic was a net exporter of electricity in 2000 (-36 PJ). Until 2020, this situation does not change significantly in the scenarios BAU(-40 PJ), RES(-30 PJ) and RES-T (-34 PJ). Only in scenario RES-30%, the Czech Republic turns into a net importer of electricity in 2020 (1PJ). Concerning biofuels, the production exceeds the consumption of the domestic market in 2020 resulting in net exports of 8 PJ (BAU), 5 PJ (RES), 14 PJ (RES-T) and 11 PJ (RES-30%) respectively.

Figure 3.3 Virtual trade of renewable energy in the RES Trade scenario
According to Figure 3.3, the Czech Republic prefers to buy green certificates instead of fulfilling its target for the share of renewables in final energy consumption (13%) completely alone. However, the amount of green certificates that have to be bought reduces from an equivalent of 28 PJ of renewable energy in 2010 to 15 PJ in 2020.

4. Impacts of policies on emissions and costs

4.1 Emissions

In the reference case, the emissions of CO2 increase by 8% between 2000 and 2020 (Figure 4.1). The greatest increase in absolute numbers can be observed in the industry branches that are included under the European emissions trading scheme ETS (+6 Mt). The emissions from electricity production even decline slightly (-2 Mt). In case of the other scenarios, the emissions of CO2 are reduced until 6% (RES), 4% (RES-T) and -26% (RES-30%), respectively until 2020. The reduction is almost completely achieved in electricity production. Only in scenario RES-3ß%, the more stringent constraint on the emissions of CO2 leads to additional reductions in the non-ETS part of the industry sector (-2 Mt).

![Figure 4.1 CO2 emissions](image)

4.2 Costs

The system costs consist of investment costs, fixed and variable costs, taxes/subsidies, welfare loss and endogenous trade. The lowest total system costs occur in the reference case (639.1 billion €). Any additional restriction leads to higher costs. The introduction of the target for the minimum share of renewables in final energy consumption in scenario RES leads to overall system costs of 641.3 billion € or additional costs of 2.2 billion € compared to the BAU scenario respectively. In scenario RES-T, total system costs are 640.9 billion €, indicating that the possibility of buying green certificates reduces system costs slightly in comparison to scenario RES. The highest sum of total system costs can be observed in scenario RES-
30\% (643.9 billion €). The stronger constraint on the maximum emissions of CO₂ in this scenario mainly leads to a welfare loss of 10 billion € compared to BAU due to a reduced demand for energy services.

5. Conclusions

All in all, the development of the Czech energy system is characterized by a considerable extension of renewable energy sources. The share of renewables in total primary energy consumption increases from 2\% in 2000 to 7\% even in the BAU scenario. An additional promotion of renewables through the implementation of the target set by the European commission (13\% renewables in final energy consumption in 2020) increases the share of renewables in primary energy consumption to 11\%. However, if trade of green certificates is permitted, the Czech Republic prefers to use this instrument instead of fulfilling its target completely alone. A stricter limit on the emissions of CO₂ does not increase the use of renewable energy sources significantly. Instead, the additional reductions are mainly achieved by a switch in electricity production from coal to gas.
GERMANY
1. Introduction

This chapter describes the modelling outcomes for Germany within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios\(^9\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the *Reference Document on Renewable Energy Sources Policy and Potential* (Deliverables D2.2 and D2.3).
- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Germany this means 18% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO\(_2\) emissions reduction of 14% compared to 2005.
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO\(_2\) emissions and costs. Section 5 contains the key conclusions.

1.1 National energy system and RES policies

The following bullet points give a short overview about the current status of renewable energy sources within the German energy system

Key figures:
- The share of RES in total primary energy consumption was 5.8 % in 2006.
- The share of RES in the final energy consumption was 8.4% in 2007 compared to 7.8% in 200620.
- The share of RES in the gross electricity consumption was 14% in 2007. Compared to 11.5% in 2006 (in 2005: around 10.4%\(^{21}\)).
- The share of RES in total heat supply amounted to 6.5% was achieved in 2007, compared to 6% in 2006 and 5.3% in 2005.
- The share of biofuels in the transport fuels in 7% in 2007 compared to 4.7% in 2006 (and 3.8% 2005).
- Germany’s dependence on imported energy amounts to 65.1%.

\(^9\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
Technology specific figures:

- Wind energy is the largest contributor to electricity production from renewable energies in 2006 with 30.5 billion kWh (2005: 27.2 billion kWh). This equals a share in total electricity consumption in Germany of 5%. With a new installed capacity of 2,233 MW in 2006, the construction of wind energy plants increased by 23% compared with 2005. In total, at the end of 2006, 18,685 wind energy plants were in operation with an installed capacity of 20,622 MW. Germany thus remains world leader.
- Electricity production from hydropower remained stable in 2006 with 21.6 billion kWh (2005: 21.5 billion kWh).
- Electricity production from biomass (without gas from landfills and sewage treatment plants, biogenic wastes) amounts to approximately 13.1 billion kWh in 2006 (2004: approx. 8.6 billion kWh). This equals a share of around 2.2% in total gross electricity consumption.
- Electricity production from biogas almost doubled from 2.8 billion kWh in 2005 to around 5.4 billion kWh in 2006.
- The electricity production from photovoltaics increased from 1.3 billion kWh in 2005 to around 2 billion kWh in 2006.
- The annual increase in solar thermal exceeded the limit of 1 million square metres of solar panel area for the first time in 2006. At the end of 2006, over 8 million square metres were installed.
- Demand for biomass in the heating sector (especially wood) increased by an estimated 10% in 2006. In total around 84 billion kWh were supplied from biomass. This equals around 94% of heating supply from renewable energies.
- Biofuels sales increased from around 2.3 million tonnes in 2005 to at least 2.8 million tonnes in 2006. In addition to the dominant sale of biodiesel (2005: 1.8 million tonnes), significant volumes of bioethanol (0.5 million tonnes) and vegetable oil (0.3 million tonnes) were recorded.

In the following, the main national targets and EU targets for Germany concerning the use of renewable energies are listed. Further details on these targets and on their implementation by the German government can be found in the deliverables D.2.2 and D.2.3 of the RES2020 project (Reference Document on Renewable Energy Sources Policy and Potential).

- Mandatory targets set by the newly proposed RES Framework Directive from 200822
  - 18 % share of RES on the final consumption of energy in 2020.
  - At least 10% share of biofuels of final consumption of energy in transport in that Member State in 2020.

- Indicative Target set under the RES- electricity European Directive from 200323
  - 12.5% share of RES on gross electricity consumption by 2010

- Indicative Target set by the European Biofuels Directive from 200324
  - Biofuels consumption of 5.75% of petrol and diesel use for transport in 2010.

- National commitments
  - As part of the national integrated climate and energy package, the government intends to increase the share of renewable energies in the electricity sector from the current level of around 13 percent to 25-30 percent by 2020.
  - The government also committed to increase the share of renewable energies in the heat sector from the current 6 percent to 14 percent in 2020.
  - The “Biokraftstoffquotengesetz” set a target for biofuels of 8% of the transport fuels by 2015.
2. Renewable technology deployment

The results in the following paragraphs show the outcome of a model based scenario analysis. Accordingly this is not an outlook showing the most probable development. Instead, the effects of different political measures on the energy system with this model are displayed. This should be taken into account while studying this report and analysing its results.

2.1 Primary and final energy use

The primary energy consumption is generally characterized by a slight increase in all scenarios in the periods 2010 (14.4 EJ) and 2015 (14.1 – 14.3 EJ) compared to 2000 (14.0 EJ) and a declining consumption in 2020. Compared to the BaU scenario with 14.0 EJ in 2020, the primary energy consumption in the scenarios RES and RES-T is 1.4 EJ lower and in the RES-30 % 1.9 EJ. The dominant fuel is oil, which share remains over the time horizon relatively stable at 37 % - 40 %. Coal consumption decreases in all scenarios from 3.5 EJ (25 %) in the base year to 3.1 EJ (22 %) in 2015. Beyond 2015 coal consumption increases in the BaU scenario to 3.3 EJ (24 %) in 2020, whereas in the RES and RES-T scenario use of coal drops to 1.9 EJ (15 %) and in RES-30 % scenario to 2.3 EJ (19 %). Due to the nuclear phase out in Germany the share of nuclear energy declines from 1.7 EJ in 2000 to 0.3 EJ in 2020. Significant increase can be expected for the use of natural gas, independent from renewable or climate policy measures. The share of primary energy consumption develops from 20 % in 2000 to a maximum of 29 % (3.6 EJ) in the RES scenario. Under ambitious climate targets (RES-30 % scenario) natural gas looses market share in 2020 in favour coal use in carbon capture technologies in the electricity generation. Due to the implementation of support mechanisms by the German government renewable energies face a ramp up over the two decades, even in the BaU scenario. The share of total primary consumption in 2000 of 3 % increases to 8 % in 2010 and furthermore to 12 % (1.7 EJ) in 2020 in the BaU scenario. Comparing use of renewables in 2020 among the scenarios only little increase of absolute quantities can be observed for the RES scenarios compared to BaU (plus 100 PJ in RES and RES-30% and plus 200 PJ in RES-T). Caused by the reduction of the total primary consumption in 2020, renewables reach a share of 15 % in the RES scenarios.

Figure 2.1 Primary energy supply
The final energy consumption in 2000 (9.1 EJ) consists of 96.5% non-renewables and 3.5% renewables. In the BaU scenario the share of renewable energies grows to 13.8% (1.3 EJ) in 2020 and in the RES and RES-30% scenarios to 16.3% (1.5 EJ) and in the RES-T scenario to 17% (1.5 EJ) in 2020.

![Figure 2.2: Final energy use](image)

The non-renewable share of final energy consumption is dominated by oil products (4.1 EJ in 2000), which decrease slightly until 2020 to maximum 3.8 EJ in the BaU scenario and minimum 3.3 EJ in RES-T scenario. Thus the oil share of total final consumption does not change significantly over the time horizon and among scenarios. The natural gas increases in the end use sector from 26% share in 2000 to 33% in 2020 in the BaU scenario and 35% in the three RES scenarios. Fossil generated electricity decreases in all scenarios between 2000 and 2020, whereas the minimum is reached in the RES-30% scenario with 2.6 EJ in 2020. The comparison of the scenarios for the year 2020 shows a drop of demand for fossil fuels in the RES scenarios compared to BaU. In total almost 1 EJ fossil energy carriers can be saved or replaced, mainly petroleum products (-0.4 EJ – -0.5 EJ) and fossil generated electricity (-0.1 EJ – -0.2 EJ). The main driver for this effect is the changing of demands e.g. road transportation in 2020 minus 2.5% in RES-30% compared to BaU and residential warm water and heating demand up to minus 5%. The second driver is the substitution effect of fossil energy carriers by renewable ones. The additional consumption compared to BaU in 2020 amounts to 190 PJ for the RES-T scenario to, 130 PJ for the RES scenario and to 100 PJ for the RES-30% scenario. Renewable final energy consumption increases to a level of almost 800 PJ in 2010 and in the following period to 1200 PJ and in 2020 to a maximum in the RES-T scenario with 1500 PJ. The development of the final energy consumption of renewables in Germany is characterized by a massive ramp up of renewable electricity (+200 PJ in all RES scenarios) and biofuels (+170 PJ in all RES scenarios) from 2000 to 2010. The growth biofuels and renewable electricity continues in further periods, reaching a maximum in the RES scenario with trading scheme in 2020 with 660 PJ renewable electricity and 520 PJ biofuels. Beginning in 2010 and maturing in 2015 renewables for heating purposes gain significant market shares. In 2020 the share of renewable heat of total renewable final energy consumption amounts in all RES scenarios 22% with absolute quantities of at least 310 PJ.
2.2 Use of renewable energy sources

In 2000 44% of the renewables were used in the residential sector. This share reduces in favour of an increased consumption of renewable fuels in the public heat and power sector, in the industrial sector as well as in the transport sector. In 2020 38% of the direct use of renewables is consumed in public power and heating technologies. Industrial consumers hold a share of about 26% (RES-T) to 28% (BaU) in 2020.

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**Figure 2.3 Final energy use of a) non-renewables and b) renewables**

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation.

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**Figure 2.4 Direct use of renewable energy sources in the different sectors**
2.2.1 Electricity generation

The Electricity generation in Germany is mainly based on coal combustion. The electricity generated from coal declines in the BaU scenario slightly from 283 TWh (55%) in 2000 to 268 TWh in 2015 (47%) and increases to 308 TWh in 2020 (53%). For the RES scenarios a similar development for the periods until 2015 can be observed. In 2020 coal based electricity generation conflicts with the climate targets and faces a drop down to half of the BaU production in the scenarios RES and RES-T. In the RES-30% scenario coal use increases to 200 TWh compared to the RES scenarios with 20% climate target due to electricity production in CCS power plants. Natural gas gains importance over the model horizon in all scenarios contributing with about 12% to total electricity generation in 2010 and 2015. This share increases significantly in 2020 in the scenarios RES (25%) and RES-T (23%), replacing electricity from coal. Natural gas based electricity amounts in 2020 in the RES scenario 122 TWh and in the RES-T scenario 114 TWh. Nuclear production quantities reduce from 122 TWh in 2000 to 32 TWh in 2020 caused by the nuclear phase out decision, aiming the shut down of all nuclear power plants in Germany until 2023. Renewable energies face a strong growth in all scenarios, which is the consequence of the renewable support measures, like the feed in tariffs, which have been revised by the government in 2008. The 36 TWh renewable electricity in 2000 increase to 101 TWh in 2010 and 141 TWh in 2015, representing a growth compared to 2000 of almost 300%. In 2020 renewable generators reach in the BaU scenario 179 TWh, whereas in the RES scenario 9 TWh can be added and in RES-T 14 TWh and in RES-30% 8 TWh respectively. Renewable energy carriers contribute with 18% to total net electricity production in 2010 increasing this share to minimum 30% in the BaU scenario in 2020 and maximum 40% in the scenario with green certificate trade.

![Total electricity generation](image)

Figure 2.5 Total electricity generation

The composition of renewable electricity is shows an almost constant production of hydro power of about 20 TWh. Most of the hydro power potential has already been developed. Wind power faces the highest growth, especially from the base year (9 TWh) to 2010 (60 TWh). Onshore wind power dominates this rapid growth. For the time past 2010 further significant electricity quantities come from offshore wind power turbines, leading to a total wind power electricity of 96 TWh in 2020. Biomass based electricity is expected to reach 17 TWh in 2010 and increasing to 54 TWh in 2015. In 2020 biomass electricity generation differs among the Bau scenario and the RES scenarios. Compared to BaU (58 TWh in 2020) biomass
electricity generation can be extended by 9 TWh in the scenarios RES and RES-30 % and 14 TWh in the scenario RES-T. So it can be concluded that Germany reaches the renewable electricity target of 25-30 % of gross electricity consumption and profits from the implementation of a green certificate scheme with additional electricity quantities generated from biomass available on the market for green certificates.

Figure 2.6  *Electricity generation from renewable energy sources*

### 2.2.2 Heat production

According to the normalised heat demand of a standard year, the fuel input for heat generation remains stable at a level of 5000 PJ. Due to the use of better insulation and demand decreases in the RES scenarios a reduction of the total fuel used for heating can be observed (Figure 2.7). The heat production is dominated by natural gas appliances, which share increases from 48 % in 2000 to 55 % in the BaU scenario and 59 % in the RES scenarios. Oil products are expected to decline from 26 % in 2000 to 19 % in 2020 in the BaU scenario and a level of about 12 % in the RES scenarios. Heat production from coal reduces continuously, reaching 520 PJ in 2020 in the BaU scenario and about 460 PJ in the RES scenarios. The electricity consumption for heating purposes declines since electrical night storage devices will be phased out until 2020. Advanced electricity based technologies for heat generation like heat pumps enter the marked only slowly. In 2000 300 PJ renewable energy carriers are used for heat production, increasing to 505 PJ in 2010 and 520 PJ in 2015. In 2020 the BaU scenario shows a consumption of 620 PJ of renewables for heating, compared to 640 PJ in the scenarios and RES and RES-30 % and 660 PJ in RES-T. Thus renewables reach in the RES scenarios 14 % -- 15 % share of heat production in 2020. The main renewable fuel for heat production is bioenergy, doubling from 270 PJ in 2000 to about 540 PJ in 2020.
Figure 2.7 *Total input for heat production*

Figure 2.8 *Heat production from renewable energy sources*
2.2.3 Transport fuels

Driven by the growth of transport demand the final energy consumption of the transport sector develops from 2760 PJ in 2000 to 2960 PJ in 2020 in the BaU scenario. Due to the specification of the European Biofuel Directive in the RES scenarios the share of renewable energies in the transport sector increases to a level of about 315 PJ in 2020 in all RES scenarios, of which 250 PJ are biofuels, representing 10% renewable energy input for road transportation. Neither a trading scheme for green certificates nor the stronger climate target of -30% in 2020 compared to Kyoto base lead to additional consumption of renewable energies in the transport sector. Besides the growing quantities of biofuels renewable electricity contributes with 67 PJ in 2020 to transport final energy consumption.

Figure 2.9 Conventional and non-conventional transport fuels
3. Trade and import dependency

Germany depends to 65% on energy imports, of which oil and oil products represent almost two thirds (5.5 EJ in 2000). Additional 2.1 EJ of natural gas and 1.0 EJ of have been imported in 2000. Conversely to oil, which imports decrease in 2020 compared to 2000 in all scenarios (5% in BaU and 13% in RES scenarios), natural gas imports are expected to increase until 2020. In the scenarios RES and RES-T an increase of about 70% from 2000 to 2020 can be observed. The comparison of scenario RES-30% and RES shows a reduction of total imports of 450 PJ by implementation of the 30% climate target in 2020, whereas coal imports increase by 400 PJ and natural gas imports decrease by 790 PJ. Regarding the electricity trade Germany turn in case of all three RES scenarios to be net importer of electricity in 2020, conversely to BaU, in which Germany exports 62 PJ in 2020. Under ambitious climate targets Germany reduces electricity imports, since CCS power plants become competitive in the European electricity market. Compared to the RES scenario electricity imports in RES-30% scenario reduce in 2020 by 37 PJ. Concerning biofuels Germany depends on imports regardless the applied RES support scheme or climate target. Most import quantities in 2020 in the RES scenarios come from outside the EU (95 PJ in RES-T scenario).
Figure 3.1 Net import / export of fossil energy carriers

Figure 3.2 Inter-EU trade and import from outside EU27 of biofuels and electricity

Under the conditions of this analysis, Germany would be an exporter of certificates under a European green certificate scheme with an equivalent amount of 81 PJ.
4. Impacts of policies on emissions and costs

4.1 Emissions

In general it could be stated out, that the total German CO₂ emissions decrease from the base year (838 Mio. t in 2000) to about 830 Mio. t in 2010 and further to 819 Mio. t in the BaU scenario and a level of 800 Mio. t. in the RES scenarios in 2015. In 2020 the emissions in Germany amount to 825 Mio. t in the BaU scenario, 659 Mio. t. in the RES scenario, 653 Mio. t in the RES-T scenario and according to the scenario definition 534 Mio. t in the RES-30 % scenario.

The Non-ETS-sector represents approximately half of the total emissions until 2015 and even in the BaU scenario in 2020. These Non-ETS emissions are dominated by the emissions of the transport sector (22 % of total emission in 2015) and the residential sector (15 % of total emission in 2015).

The ETS-emissions reach a total value of about 402 Mio. t (2015 BaU). They mainly consist of the emissions from electricity generation (33 % of total emission in 2015) and also of the energy intensive industry (14 %) and transformation ETS (3 %).

The total emission development in 2020 compared to the base year sees a slight decrease in BaU (- 13 Mio. t), and a decline in RES (-178 Mio. t) in RES-T (-185 Mio. t) and RES-30% (-304 Mio. t). Compared to 2000, this is a reduction of 36 % (RES-30%), respectively -22% (RES-T). This reduction is clearly based on lower emissions in the ETS-sector. In the RES-30% scenario, the GHG reduction target leads to reduced emissions from electricity generation of -80 % in 2020.
Figure 4.1  \( \text{CO}_2 \) emissions

### 4.2 Costs

<table>
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<td>5830</td>
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</table>

In general, the total system costs are the lowest in the reference run. Any additional constraint leads to higher cost. The stricter the constraints the higher the total costs (RES-30% +41 billion € compared to BaU). There is few difference in system costs if a virtual trade of green certificates is allowed (+2 billion € compared to RES).

### 5. Conclusions

Germany is one of the European leaders concerning the growth of usage of renewable energies. Especially in the public electricity and heat generation Germany faced a strong growth over the past years and is expected to gain significant capacity additions, primary for the use of wind power and biomass. The target set by the German government of 25-30% of renewables of gross electricity generation is expected to be reached with the corresponding RES and climate measures analysed in this study.

Consequently the use of renewable electricity and heat, consumed in the end use sectors increases until 2020 and represents almost two third of final energy consumption of renewable energy carriers. Under the condition of renewable targets, Germany changes from an electricity net exporter to net importer. Under a strong climate target Germany can reduce electricity imports in favour of domestic electricity generation with technologies with carbon capture and storage. Additionally to increased of electricity imports under renewable targets, German biofuel imports switch from inter European trade to exchange with non-EU countries.
DENMARK
1. Introduction

This chapter describes the modelling outcomes for Denmark within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Denmark this means 30 % share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO₂ emissions cap of 21.2 Mtons.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Since the Mid 1970s the total primary energy consumption in Denmark has been about 800 PJ with annual variation that has been due mainly to variations in electricity trade with the hydro-based regions in Norway and Sweden. In the same period there has been a continuous development from about 90% imported oil to a more diversified supply of coal, oil gas and renewables.

Currently, Denmark is the only country within the EU that is a net exporter of oil and gas. Denmark’s primary energy production of oil and gas from the North Sea has continued to increase steadily from 1980 to 2005. However, the production has peaked about 2005 and will decrease in the coming years due to depletion of the resources in the North Sea.

The natural gas infrastructure was built up during the 1980s and 1990s with transmission lines for export to Sweden and Germany and seasonal storages. The gas distribution network covers most of the country with supply to power stations, district heating plants, industries and individual homes in areas less suitable for district heating. The district heating infrastructure covers all the more densely populated urban areas, including small towns and villages. Base load heat in nearly all district heating networks is supplied CHP.
plants, ranging from less than 1 MW gas motors to large-scale power plants). Waste incineration for CHP or heat-only is used as base-load in all urban areas using about 95% of the available urban waste. From about 1980 all new power station have systematically been located to supply district heating systems with co-generated heat.

Wind power has grown constantly during the 1990s and covers about 20% of the electricity demand in the years 2004-2008 on an annual basis.

The long-term vision of the Danish Government in the Energy Policy Statement 2009 is 100% independence of fossil fuels.

Further development of district heating system – including conversion of areas supplied by natural gas to district heating in areas where surplus heat is available – is one of the means to achieve the CO2 reduction target.

The Government’s new energy strategy supports the expansion of wind energy capacity both on- and off-shore. Location of sites for up to 5000 MW offshore wind farms have been identified, all with a potential of about 4000 full load hours. The target is to achieve 4 GW onshore and 2.5 GW offshore wind turbines until 2025.

Danish generators participate in demonstration projects for Carbon Capture and Storage (CCS), concerning a demonstration plant for carbon capture as well as investigations into geological structures with potential for storage. The Danish large-scale CHP plants and nearby storage potentials offers a potential for efficient implementation of CCS, because the energy lost in the carbon capture process can be utilised in district heating systems.

Under the new Danish energy policy agreement for 2008 to 2011 annual savings in final consumption will increase to 1.5 per cent. This places great demands for energy savings in all areas, not least in firms and buildings. Energy companies must ensure the fulfilment of a considerable part of the overall savings.

The annual population growth rate in the Eurostat projection is 0.3-0.4 % until 2020, and the annual GDP growth rate is 1.3-2.2 % according to the latest GEM-E3 runs. GDP in 2000 was 176.6 billion Euros.

In the assumptions for the Pan European model for 2020 the maximum onshore wind is set at 3.28 GW, offshore wind 2.1 GW, Solar PV 1.8 PJ, and hydro remains negligible. Geothermal is not considered. Maximum wave and tide is set at 9.3 PJ, maximum biomass, biogas and bio waste for electricity and CHP is set at 19 PJ, 6.8 and 3.7 PJ respectively. The following biomass production potentials by 2020 were estimated in the REFUEL project: Source: RES2020 Project (2009):

- Rape seed 41 PJ
- Starch crops 52 PJ
- Sugar crops 89 PJ
- Grass crops 106 PJ
- Woody crops 55 PJ
- Agricultural waste 24 PJ
- Forestry residues 35 PJ
- Wood waste 7 PJ
2. Renewable technology deployment

2.1 Primary and final energy use

The EU Energy and Climate packages of January 2008 means for Denmark 30% share of RES in final energy.

Using the method of the PRIMES model, the share of renewable was 9% in 2000. This figure will increase to 24% by 2020 in the BAU scenario, and 27% in the policy scenarios, with very little variations among these scenarios, mainly due to the planned increase in off-shore wind and biomass in the electricity and heat sector.

Also for primary and final energy the three policy scenarios give very similar results. The most important development of renewables is the further penetration of wind power, which is policy driven. Although electricity trade is important for Denmark on the daily and seasonal basis, the results on the annual basis mainly reflect the variation of precipitation in Norway and Sweden. However, these variations are not considered in the RES2020-TIMES model, which should consider a normal base year for the 5-year time steps.

Figure 2.1 *Primary energy supply*
There is a significant increase in bioenergy from 2000 to 2020 in the BAU scenario and some additional increase in the policy scenarios, but little difference among these scenarios. Some small variations among the policy scenarios are found in the central electricity and heat sector for 2020.

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1) The sections below describe in more detail renewable and non-renewable electricity and heat generation.
2.2 Use of renewable energy sources

Renewables in agriculture are mainly own use of agricultural waste, in particular straw and biogas in a small scale. However, the preferred use of agricultural waste is in the district heating sector, mostly for CHP supplying small district heating systems, although straw is also used in large-scale CHP units.

The results for industry are uncertain. There is little tradition for optimization modeling of large energy consuming industries in Denmark, because there are only few plants, one cement plant and one steel work. The latter have been closed several times in recent years and operated only in short periods.

The central electricity and heat is by far the most important user of renewables.

2.2.1 Electricity generation

The electricity generating system in Denmark is located at the border between the hydro power based systems in the North and the thermal system in Western Europe. These systems are connected by undersea cables, which are the basis for a considerable trade between the two systems, starting as early as 1915.

Coal and combustible renewable and waste are mainly used electricity and heat in large-scale combined heat and power (CHP) plants, waste incineration and district heating plants, while natural gas is used in smaller-scale (CHP), industry and individual boilers for space heating.

In the 1980s nearly all new capacity was medium-sized extraction-condensing units for large-scale CHP; in the 1990s a significant share was small-scale gas-fired CHP units for decentralised district heating systems. Wind power has grown constantly during the 1990s and covers about 20% of the electricity demand in the years 2004-2008 on an annual basis. The trade pattern is determined by the variations in hydro
power in Norway and Sweden and wind energy in Denmark. The remaining fossil electricity-only production has become the ‘swing producer’ on an annual basis, and in recent years this production has become larger than gross export.

Denmark is a European forerunner in both onshore and offshore wind and has compared to relatively low energy demand a high amount of wind with 2.8 GW installed and 6.6 TWh of wind generation, which could potentially cover approximately 20% of the nation’s demand (2005-2008). Denmark is also one of the first countries with a significant amount of offshore wind installed with 0.4 GW in 2005. After stagnation in installed capacity of wind power, when some 2000 small land-based wind turbines were replaced by wind farms and larger units, the government’s new energy strategy supports the expansion of wind energy capacity for on- and offshore.

In addition to 0.4 GW offshore wind capacity to be commissioned in 2009 and 2010, location of sites for up to 5000 MW offshore wind farms have been identified, all with a potential of about 4000 full load hours. The target is to achieve 4 GW onshore and 2.5 GW offshore wind until 2025. This could possibly yield a penetration of 3.3 GW onshore and 1.1 GW of offshore until 2015 (ENS, 2007). PV has not played a major role in installations so far and will continue to play a minor role in the next decade. Prospects for micro CHP seem to be limited due to the large role of district heating in heating of single-family houses. However, there is a potential market for micro CHP as replacement for gas-boilers that were installed in the 1980s and 1990s.

Industrial autoproducers have generated about 9% of the total demand after 2000.

![Figure 2.5](image)
2.2.2 Heat production

Figure 2.7 Total input for heat production
The district heating infrastructure covers all the more densely populated urban areas, including small towns and villages (22% of the heat supply for single family houses and 66% for multi-family houses). Base load heat in nearly all district heating networks is supplied CHP plants, ranging from less than 1 MW gas motors to large-scale power plants). Natural gas covers individual homes in areas less suitable for district heating (18% of the heat supply for single family houses and 9% for multi-family houses in 2005). All densely build up areas are zoned for district heating or natural gas depending on heat densities and access to networks.

Electric resistance, which covers about 5% of the heat market, is being phased out in areas zoned for district heating or natural gas. Outside these areas heat pumps or biomass renewables are encouraged.

As a consequence of the policy on heat supply the share of individual oil boilers was reduced from have been reduced from more than 60% in 1980 to 14% in 2005.

2.2.3 Transport fuels

The available biomass resources may be used for either transport or electricity and heat. The infrastructure for the use of biomass for electricity and heat is available, and it is being further developed. The key priority for new transport fuels is electricity for charge of batteries for electric vehicles. This technology will be needed for an efficient further penetration of wind power. Thus, electric cars supplied by wind power is seen as an important means to achieve the target of 10% renewable in transport. Biofuels for transport is mainly a Danish research priority, which is driven by the agricultural research tradition. Biomass availability in the agricultural sector is mainly based on animal products for export to the world market and large-scale import of fodder.
Figure 2.9 Conventional and non-conventional transport fuels

Figure 2.10 Development of non-conventional transport fuels
3. Trade and import dependency

Currently, the only import of fossil fuels to Denmark is coal for the central electricity and heat sector. There is no domestic mining of coal, so the expected shift away for coal will reduce imports. The current oil and gas production exceeds the national demand, so the surplus is exported. However, both oil and gas production has peaked about 2005 and is expected to decrease over the next decade. Figure 3.1 mainly reflects the uncertainty from the foreseen depletion of the resources in the North Sea. Newer estimates of reserves and new discoveries are likely to expand the time horizon for domestic supply of oil and gas.

The trading pattern for electricity as shown in Figure 3.2 explains the small differences among the policy scenarios that were described above. For electricity import the BAU scenario for 2020 is similar to 2000, while there is some net import of electricity in the policy scenarios. This is the net result of much larger variations of the model results for gross import and export between Denmark and the neighbouring countries. However, the difference in import for 2020 may be explained by less investment in new coal fired capacity in the policy scenarios compared to the BAU scenarios.

The variation in trade patterns for biofuels reflects the different scenario assumptions. The net import to Denmark – in particular in the RES-T scenario – is most likely due to the large district heating infrastructure in Denmark, which offer a market for a wide range of technologies using biofuels.
Figure 3.2 *Inter-EU trade and import from outside EU27 of biofuels and electricity*

There are no model results for Denmark concerning virtual trade of renewable energy in the RES trade scenario. So no results are shown in Figure 3.3.

Figure 3.3 *Virtual trade of renewable energy in the RES Trade scenario*
4. Impacts of policies on emissions and costs

4.1 Emissions

The model results for 2020 show reductions for both the ETS sectors and the Non-ETS sectors for the policy scenarios compared to the BAU scenario. The reductions in the residential and industry are mainly due to increased use of RES in these sectors, which is the same for all policy scenarios. For the central electricity and heat sector increased use of wind power and biomass as combustible renewable lead to reduction of CO2. The reduction is largest in the scenario with the most ambitious CO2 reduction target. The impact of biomass import is seen in the RES-T scenario.

![CO2 emissions](image)

Figure 4.1 CO2 emissions

4.2 Costs

The total investment costs and operational costs of renewable technologies are calculated by the model between 500 M€ and 1000 M € by 2020, or about 0,01 % of GDP with no significant difference among the BAU scenarios.

5. Conclusions

The BAU scenario for Denmark shows a significant increase in renewable energy sources in mainly the central electricity and heat sector until 2020. This leave little room for further penetration of renewable in the policy scenarios, and even less room for optimisation results of different policy scenarios. However, the results achieved so far seems explainable within the logic of the optimisation model.
The first set of results from the Pan European model – as a result of the NEEDS project – from the autumn of 2007 was presented primarily as European totals as a long-term reference until 2050 for the selection of new technologies. These results were developed from a set of harmonised national models, which allows comparative analyses based on the individual national models (see Grohnheit, 2008).

The next step has been the RES2020 project with enhancements of some of the model sectors and the much shorter time horizon until 2020, which much less room for large-scale penetration of new technologies. The current results shall be improved by further analysis of the assumptions and results in the individual national models. The common structure of models for 30 European countries will allow accumulation of model experience, and thus improve the conclusions that may be drawn from the results.

The common calibration and optimisation of a model covering 30 countries has made it possible to develop a set of harmonised national models for most European countries, which may be used for national as well as European studies. The current results for biomass trade indicate that the Pan European model may be used to disclose a trade pattern that will benefit from the differences in infrastructure and existing equipment among the European countries.

6. References


ESTONIA
1. Introduction

This chapter describes the modelling outcomes for Estonia within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios\(^\text{11}\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Estonia that means 25% share of RES in 2020 and for all sectors, which do not fall under the European Emissions Trading scheme a CO2 emissions, cap of 4 Mtons.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% instead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO\(_2\) emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Estonian national energy system is mainly based on the oil shale combusting power plants; it makes about 94 of the total electricity production. Two power plants with a capacity about 2 GW are located on the east of the country, whereas the main electricity consumption is located in the western part. There exist a transmission network of 330 kV lines connecting east and west parts of the country. Similar lines with a transmission capacity about 1.5 GW are connecting Estonia with Russian and Latvian power systems, and through them is Estonia connected to the Lithuanian and Byelorussian power systems. From the 2008 there exist a DC link to Finland’s power system with a transmission capacity of 0.35 GW, which enables connection to the Nordpool market place. Besides of the two larger plants combusting oil shale the exist a smaller (0.2 GW) CHP plant using natural gas, and some smaller plants on natural gas or wood. Future development of Estonian energy system is oriented towards implementation of new oil shale combustion technology – fluidized bed combustion, with limitation of the use of oil shale and essential increase of the use of renewable energy sources. As main sources of renewable energy there are wind and biomass energy considered

\(^{11}\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
2. Renewable technology deployment

2.1 Primary and final energy use

Main sources of the primary energy in Estonia are oil shale (here could be presented as coal), natural gas, oil products and renewable. As renewable energy in the base year the biomass is used only.

![Primary energy supply](image)

Figure 2.1 *Primary energy supply*

From the energy carriers on the figure above, the oil shale is a local energy carrier, and this gives to Estonia a certain independence from the energy import. Oil products and natural gas are imported from Russia mainly and in this part the primary energy supply depends on the security of the Russian supply chain.
The share of renewable in the base year is 19% of final energy. This share will increase to 26% by 2020 up to 26% by scenario RES R_ref and to 34% by scenario RES 30.

The share of renewable by all scenarios does not involve the problem of RES trade for Estonia. There is sufficient RES resource in Estonia, however, not so much to enable some trade with it.
2.2 Use of renewable energy sources

Main consumption of renewable sources occurs in the residential sector, where biomass as wood is widely used as for heating and for water heating also. In some extent the same happens in the commercial sector, but on much lower level. With the development of energy supply there are built first CHP using biomass, and with it there arises some generation of electricity from biomass also. By 2020 the electricity production from wood could be about 4 PJ. And this belongs already to the power sector. Nevertheless, residential sector remains the main consumer of wood.
Figure 2.4  *Direct use of renewable energy sources in the different sectors*

### 2.2.1 Electricity generation

Figure 2.5.  *Total electricity generation*
### Figure 2.5  *Electricity generation from renewable energy sources*

It must be said, that what is presented as coal in the figures above corresponds to oil shale that is used in Estonia.
2.2.2 Heat production

![Bar chart showing heat production from 2000 to 2020 for baseline (BaU) and renewable energy (RES) scenarios.](image)

Figure 2.6 Total input for heat production

![Bar chart showing heat production from renewable energy sources for 2000 to 2020.](image)

Figure 2.7 Heat production from renewable energy sources
Heat production in the base year is based on different carriers, where gas and wood are dominating. What about the heat production from coal it must be said the same as it was said about electricity production from coal – it is not acceptable for Estonia. If in all plans coal will be replaced by local energy source oil shale (lignite), then the last results become acceptable for Estonia.

About the relations of RES-directive and Climate directive it could be said, that they coincide and would be impossible to say which from them is dominating.

2.2.3 Transport fuels

There are no RES fuels used in transport fuels up to 2005. Small consumption of RES fuels begins in 2010, and has to take a share of 10% in 2020. There could be not made any difference between first and second generation biofuels in Estonia up to now.

![Bar chart showing conventional and non-conventional transport fuels](image)

Figure 2.8 Conventional and non-conventional transport fuels

There have not been any mixes in use till 2000. Although there are some ideas to use blends written in the Energy development plans.

The RES-directive and Climate directive are somehow considering in Estonian transport sector also there are not enough domestic biofuels production planned in Estonia and an import problem has to be considered. Although there are capacities for biodiesel production in Estonia, its production has been exported so far and not sold in domestic market. Biofuels like bioethanol are to be imported from neighbours.
3. Trade and import dependency

There will be small changes in the import of energy carriers, if we expect that coal will not be imported to Estonia. Some decrease in the gas import occurs due to increasing use of biomass in boiler-houses and CHP-s, and also the total heat consumption has decreasing trend. Some decrease of the import of oil products is due to increasing role of biofuels in the transport sector mainly. Comparing different scenarios it is clear, that the scenario RES-30% gives the minimal amounts of energy carriers import.
Figure 3.1  *Net import / export of fossil energy carriers*

Figure 3.2  *Inter-EU trade and import from outside EU27 of biofuels and electricity*
Estonia is not an importer not an exporter of renewable. Climate and renewable targets do not influence it essentially.

Estonia is able to produce its own biofuels, there is land available for it and the regulation support biofuels production. However, it is possible to import raw materials for biofuels, and that will be a market problem.

![Graph showing virtual trade of renewable energy in the RES Trade scenario]

Figure 3.3 *Virtual trade of renewable energy in the RES Trade scenario*

There is no virtual trade of renewable energy in Estonia

4. Impacts of policies on emissions and costs

4.1 Emissions

Total CO₂ reduction will be achieved first with closing down old oil shale consuming power plants and general reduction of oil shale consumption for electricity generation. Second will be the increasing consumption of renewable energy sources like biomass and wind. It all concerns the ETS sector, which is the main pollutant in Estonia; non-ETS sectors produce less than third of the ETS one. Carbon capture and storage is not considered in Estonian Electricity Development Plans. The RES target for all final energy does not lead to the emission reductions in the heating sector being more than the required by the specific emission reduction requirement.
The emissions in the Estonian region are considered in classical way in the RES2020 model and the country modellers haven’t find any position worth of special interest.

4.2 Costs

The REF Scenario gives total system costs by 144.6 Bill. € for 2020, with investment costs in 55.4 Bill. € and operational costs in 59.8 Bill. €. Comparing total costs of different scenarios it could be concluded, that the difference of the total costs by different scenarios does not exceed 0.4 Bill.EUR, by the level of total cost of 55.7 Bill.EU by the scenario RES-30%. It means, that the accuracy of the projection is expected to be in the range of 1% accuracy. The share of renewable cost in the Estonian GNP could be described by the following table.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EE-REF</td>
<td>0.1%</td>
<td>0.3%</td>
<td>0.6%</td>
<td>1.5%</td>
<td>1.6%</td>
</tr>
<tr>
<td>EE-2020</td>
<td>0.1%</td>
<td>0.9%</td>
<td>1.5%</td>
<td>1.6%</td>
<td>1.9%</td>
</tr>
<tr>
<td>EE-2020T</td>
<td>0.1%</td>
<td>0.6%</td>
<td>1.5%</td>
<td>1.9%</td>
<td>2.1%</td>
</tr>
<tr>
<td>EE-4S</td>
<td>0.1%</td>
<td>0.9%</td>
<td>1.5%</td>
<td>1.8%</td>
<td>2.4%</td>
</tr>
</tbody>
</table>

5. Conclusions

If to exclude the use of coal for the electricity and heat production in Estonia for coming years, and its import from EU (Poland?), then in all the rest, the RES2020 last solution could be acceptable for Estonia.
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Kalvi (Estonia) on August, 28, 2006.
1. Introduction

This chapter describes the modelling outcomes for Finland within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

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- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Finland this means 38% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO\(_2\) emissions cap of 21.3 Mtons.
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
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1.1 National energy system and RES policies

National energy system of Finland is quite diversified as can be seen from total primary energy supply presented in Table 1.1 (Statistics Finland, 2008). Finnish energy system is also fairly decentralised with geographic characteristics in energy production: gas pipeline reaches southern parts of Finland, big coal plants are situated on coastal area, main wood fuel and peat resources are in Central, Eastern and Northern Finland.

End use of energy is characterised by two main consumers: energy-intensive industry (49% share in 2005) and space heating (21%). Pulp and paper production is the main industrial energy consumer, especially subject to electricity and process heat, followed by iron and steel industry and chemical industry. However, byproducts from pulp and paper industry constitute a major part of Finnish renewable energy sources. Space heating is also quite energy consuming sector due to the northern climate. Major energy sources for space heating are district heat (111 PJ in 2005), electricity (48 PJ), fuel oil (61 PJ) and wood fuel (50 PJ) (Statistics Finland, 2008). Increasing cost of oil and electricity can cause shift to district heat and wood, but district heating requires expanding infrastructure and wood fuel resources are increasingly

\(^{12}\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
used also in energy production, industry and biofuels production. Fuel consumption in road transportation is divided evenly by diesel fuel and motor gasoline.

Table 1.1. Total Primary Energy Supply (TJ) of Finland in 2000, 2005 and 2006.

<table>
<thead>
<tr>
<th>Primary energy</th>
<th>2000</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>150 625</td>
<td>134 214</td>
<td>218 913</td>
</tr>
<tr>
<td>Oil and petroleum products</td>
<td>388 870</td>
<td>401 366</td>
<td>420 710</td>
</tr>
<tr>
<td>Natural gas</td>
<td>143 640</td>
<td>151 020</td>
<td>162 684</td>
</tr>
<tr>
<td>Nuclear</td>
<td>235 640</td>
<td>243 887</td>
<td>240 040</td>
</tr>
<tr>
<td>Hydro and wind power</td>
<td>52 306</td>
<td>48 947</td>
<td>41 277</td>
</tr>
<tr>
<td>Peat</td>
<td>57 959</td>
<td>68 784</td>
<td>93 600</td>
</tr>
<tr>
<td>Wood and recycled fuels</td>
<td>278 976</td>
<td>316 617</td>
<td>296 463</td>
</tr>
<tr>
<td>Electricity</td>
<td>42 768</td>
<td>61 255</td>
<td>41 042</td>
</tr>
</tbody>
</table>

Electricity and heat production sector consists mainly of nuclear power, hydro power and quite diverse thermal power production using natural gas, coal, peat fuel and biomass. Consumption of district heating guides CHP production with 72% of district heat produced by CHP in 2005 and vast autoproduction capacity supplies process heat and electricity to industrial sector. Finland is a member of Nord Pool power exchange with Sweden, Norway and Denmark, and electricity is thus produced, imported and exported depending on Nordic electricity market prices. Therefore, e.g. conditions on Norwegian hydro power production affect Finnish condensing power production. Main import source of electricity outside of Nord Pool is Russia with 35 PJ in 2005. Since emission trading has increased production cost of coal and peat fuel based power, investments in condensing power, excluding nuclear power, are decreasing with share of CHP increasing due to its high efficiency and growing popularity of district heating.

Share of RES in total primary energy consumption in Finland was 25% in 2005 and share in gross final energy consumption 28.5% (EREC, 2008). The main renewable energy sources are wood fuels (143 PJ in 2005), black liquor (132 PJ), hydro power (48 PJ) and waste fuel (5 PJ) (Statistics Finland, 2008). One third of wood fuels is consumed in small scale combustion e.g. in space heating. Wood fuel used in energy production is based on forest residues and industrial residues from e.g. mechanical pulp production. Black liquor resources depend directly on chemical pulp production and are consumed by autoproducers of pulp and paper industry. Round wood used as raw material in pulp production is not currently available for energy production, since its price is too high for energy sector. Wind power production is still marginal in Finland (0.6 PJ in 2005).

Future development of renewables is not that straightforward in the case of Finland. Potentials of hydro and wind power are presented in detail in (EREC, 2008). Wind power capacity can be 3000 MW in 2020, but future capacity of hydro power is restricted to 3437 MW due to environmental legislation. Availability of wood based biomass depends mainly on development pulp and paper industry and trade of wood fuel from e.g. Russia. Finnish biomass resources are vast, but utilisation of this renewable energy source can be limited by cost efficiency and also environmental issues. However, feed-in tariffs imposed in (Ministry of Employment and the Economy, 2008a) can increase use of biomass in the future. Estimated future development of potentials of agricultural bioenergy is illustrated in detail in (EREC, 2008).

Country specific demand projections used in the TIMES model are based on economic growth and GDP growth estimated by the macroeconomic GEM-E3 model and population growth estimates from Eurostat. These figures are illustrated in Table 1.2:

Table 1.2. Growth rate of population and GDP in Finland in years 2005-2030.

<table>
<thead>
<tr>
<th>Growth rate</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>0.3%</td>
<td>0.4%</td>
<td>0.3%</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
<tr>
<td>GDP</td>
<td>2.0%</td>
<td>2.6%</td>
<td>2.7%</td>
<td>2.7%</td>
<td>2.5%</td>
<td>2.3%</td>
</tr>
</tbody>
</table>
Growth rates of demand projections obtained from figures above seem quite high considering the current economic situation, but they are though fair estimates. One demand projection, namely paper demand, requires though a correction. Considering the current turbulence in Finnish pulp and paper industry, paper demand projection must be tuned down in accordance with demand projection figures of With Measures scenario from energy and climate strategy report of year 2005 (Ministry of Trade and Industry, 2005). Scenarios of development of paper industry are even more conservative in (Ministry of Employment and the Economy, 2008a), but this current energy and climate strategy report was published too late to have these projections used in the early TIMES model calibration.

Policies for renewables in Finland are explained in detail in (EREC, 2008). In brief, main renewable policy tools are investment subsidies for wind power and tax refunds for the producers of renewable electricity. New energy and climate strategy (Ministry of Employment and the Economy, 2008a) imposes feed-in tariffs and green certificates for renewable energy, but planning of implementation and details is not finalised yet.

Capacity of nuclear power is growing as new nuclear unit of 1600 MW is estimated to be in operation by year 2012. National energy policy does not exclude further construction of nuclear power but potential new capacity limited to one unit of about 1600 MW would not be operational until year 2020 due to the licence application process (Ministry of Employment and the Economy, 2008a).

Details of national targets of the RES scenarios are presented in (EREC, 2008). Share of RES in final energy consumption should be 38% in year 2020, whereas it was 28.5% in year 2005. Trajectory of RES target towards 2020 is presented in Table 1.3. Share of biofuels of gasoline and diesel use should be 10% in 2020 and 5.75% in 2010, whereas in 2005 share was 0%. Climate policy targets consist of ETS sectors participating in the full trade of CO₂ emission permits and 16% reduction of emissions of non-ETS sector from year 2005 to target year 2020. This non-ETS sector emission reduction results an upper limit for CO₂ of 21.3 Mt in year 2020.

Table 1.3. Member state specific policies in the different scenarios

<table>
<thead>
<tr>
<th>Element</th>
<th>BaU</th>
<th>RES Reference</th>
<th>RES Transfer</th>
<th>RES 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>RES policy targets</td>
<td>As is</td>
<td>38% RES by 2020</td>
<td>As RES Reference</td>
<td>As RES Reference</td>
</tr>
<tr>
<td></td>
<td></td>
<td>31.5% RES-E by 2020</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10% biofuels by 2020</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.75% biofuels by 2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Target trajectory of RES</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>towards 2020:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2011 31%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2013 32%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2015 33%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2017 35%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate policy targets</td>
<td>As is</td>
<td>ETS sectors using CO2</td>
<td>As RES reference</td>
<td>As RES reference</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16% reduction total non-ETS sectors by 2020 compared to year 2005</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Renewable technology deployment

2.1 Primary and final energy use

Development of primary energy in the scenarios during years 2000-2020 is illustrated in Figure 2.1. Primary energy supply increases steadily with economic growth, but in RES scenarios growth stops in year 2020 and primary energy supply even decreases slightly in RES Trade and RES 30 scenarios. It is evident that energy efficient technologies penetrate energy system as RES and emission constraints come into effect.

![Figure 2.1 Primary energy supply.](image)

Increase in primary energy in year 2015 is based on the commission of the new nuclear power plant, since other primary energy carriers stay relatively close to the 2010 values. Use of natural gas does not increase much in any scenario, but stays on the level of year 2010. It is evident that growing RES use replaces coal in 2020 (it has to be noted that in Figure 2.1 coal includes also domestic peat fuel), especially in RES Trade and RES 30 scenarios. It has to be noted that relatively small volume of coal and peat in year 2000 is based on the exceptionally warm year and large inflow of Nordic hydro energy. Oil consumption decreases steadily but not dramatically from 2010 to 2020, since gasoline and diesel fuel still maintain important role as transport fuels in year 2020. Significant increase of RES in year 2020 is mainly based on growth of wind energy and biomass utilization.

Final energy use divided into renewable and non-renewable energy is illustrated in Figure 2.2 which reveals significant increase of RES in year 2020. Final energy use data shows that in year 2010 RES constraint is not binding in RES Reference and RES Trade scenarios i.e. renewable energy is used more than the RES directive suggests, but in 2015-2020 RES constraint is binding in both scenarios whereas climate constraint is not. Role of green certificate trading in RES Trade scenario can be seen in the total final energy levels of year 2020 which indicate that selling green certificates enables new efficient technologies to penetrate market and therefore decrease total final energy use. In RES 30 scenario Finland exceeds its
RES directive based share in order to contribute to the 30% emission reduction in EU level in year 2020. This result suggests that Finnish RES potentials provide efficient way to cut emissions in EU level. However, there is a risk that techno-economical potential and cost efficiency of Finnish renewables (especially wood based renewables) could have been overestimated.

Figure 2.2  *Final energy use.*

Figure 2.3 and Figure 2.4 provide detailed information on final energy use of renewables and non-renewables. Bioenergy use increases significantly in year 2020 when compared to the BaU scenario. However, this is not the case with renewable electricity. In RES Trade and RES 30 scenarios final energy use of coal and peat is clearly lower than in the RES Reference scenario, and it seems that efficiency measures implemented on these two scenarios cut coal and peat use.

Figure 2.3  *Final energy use of a) non-renewables and b) renewables*  

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation.
2.2 Use of renewable energy sources

Use of renewable energy in different sectors is illustrated in Figure 2.4. Growth of renewable energy in RES scenarios is concentrated in industrial and heat and power production which are also currently dominant sectors in renewable use. However, in central heat and power sector difference of renewable use between BaU and RES scenarios is not as significant as in the industrial sector. Consumption of biofuels in transport sector also increases due to the RES directive. Residential and commercial use of renewables stays unchanged, since space heating by biomass fuel competes evenly with electricity heating and district heating. Direct comparison of absolute values to situation of year 2000 is not unfortunately possible, since final results of PET model seem to overestimate renewable use in year 2000, especially in the industrial sector.

![Figure 2.4 Direct use of renewable energy sources in the different sectors.](image)

2.2.1 Electricity generation

Development of electricity production divided by consumed fuels is presented in Figure 2.5. Share of renewable electricity increases in every scenario, quite significantly in the BaU scenario too. It is though evident that technological measures cutting electricity consumption are cost-effective in scenarios with RES shares and emission targets. In year 2020 the RES scenarios produce from 46% (RES Reference) to 48% (RES Trade and RES 30) of electricity from renewable energy sources. However, in BaU scenario absolute value of renewable electricity is approximately equal with RES scenarios in year 2020.

Details of renewable electricity production are illustrated in Figure 2.6. Change from 2010 to 2015 is not drastic, but in 2020 wind power plays a major role in separate electricity production reaching production level of 8.2 TWh in all RES scenarios. It seems as investment subsidies and feed-in tariffs are effective policy measures for wind power. Use of biomass in electricity production does not grow as drastically, but even stays in same level of 16 PJ in years 2015 and 2020. Biomass is used mainly in industrial and district heat producing CHP.
The main electricity producing renewable technologies besides wind power are CHP plants producing also district heat and industrial heat using mainly wood fuel and black liquor. Development of non-renewable, emission free technologies in electricity and heat production is limited to the preset commission of fifth nuclear reactor in 2015 and small scale introduction of coal fired CHP plant using CCS technology in 2020 (electricity production of about 1 TWh) in RES 30 scenario.

Figure 2.5 Total electricity generation.

Figure 2.6 Electricity generation from renewable energy sources.
2.2.2 Heat production

Total fuel input for heat production is illustrated in Figure 2.7. It has to be noted that this figure represents fuels used in heat production in all sectors, i.e., in industrial heat and district heat production and in residential and commercial space heating. Furthermore, in Figure 2.8 details of renewable energy sources in heat production are presented. Share of renewable energy in heat production in 2020 is 35% (BaU), 42% (RES Reference), 49% (RES Trade) and 47% (RES 30).

Figure 2.7 Total input for heat production

Coal, peat and natural gas maintain important roles in district heat and industrial heat production in BaU and RES Reference scenarios, but use of coal and peat decrease drastically in industrial and central CHP plants. Main technologies using biomass in industrial heat production are CHP plants using wood (forest residues and wood based by-product from pulp production processes) and black liquor (from chemical pulp production). Also, in all RES scenarios in separate industrial heat production (mainly heat for pulp and paper production) biomass is increasingly used as fuel. In district heating production wood fired CHP plants gain significant share from year 2010 in all RES scenarios as district heat consumption grows.

Use of biomass in residential and commercial space heating stays quite steadily in level of 40 PJ in all scenarios due to the tight competition with electric heating and district heat especially. Interestingly enough, oil is still used in space heating in all RES scenarios even in year 2020, although not in the same level as in 2010.

It is evident that RES share directive drives especially biomass based separate industrial heat production and therefore higher utilization of renewables in heat production as can be seen from Figure 2.8, especially since growing economic drivers of pulp and paper production increase demand for industrial heat in all scenarios. Furthermore, increasing use of district heat in residential and commercial space heating provides ground for efficient CHP plants using wood based fuel.
2.2.3 Transport fuels

Development of transport fuels divided into conventional fuels (gasoline and diesel oil) and non-conventional fuels (biofuels, synthetic fuels etc.) is illustrated in Figure 2.9. Furthermore, division of non-conventional fuels into electricity, biofuels and hydrogen is presented in Figure 2.10. It is clear that oil based fuels maintain major share of transport fuels with diesel oil being dominant in year 2020 (in year 2000 diesel oil and gasoline had approximately even share in transport sector with no biofuels in fuel mix).

Biofuels are consumed merely according to RES directive (about 16 PJ in 2020 in all RES scenarios), since in all RES scenarios biofuels constraint is binding. In RES Reference scenario used biofuels consist of biodiesel (1st generation), ethanol (1st gen.), biogas (1st gen), FT-biodiesel (2nd gen.) and bio DME (2nd gen.) as is the case in RES 30 scenario. In RES Trade scenario bio DME is dropped from the fuel mix. As oil based fuels stay still dominant in transport sector, most of the biofuels are mixed with gasoline and diesel oil and used in regular vehicles.

Interestingly in all RES scenarios FT diesel is produced from black liquor which is mainly used in industrial CHP plants producing electricity and heat for pulp and paper production. Finland has specialized in black liquor based CHP technologies and therefore it might be unconvincing to have black liquor as raw material for FT process. However, if electricity production in RES scenarios develops as illustrated in Figure 2.5, it might be useful to use growing resource of black liquor in other purposes than electricity production. Other interesting detail about FT diesel shows that in RES Reference scenario black liquor based FT diesel is exported to Germany (28 PJ in 2020) instead of increasing biofuels share in Finland.

From Figure 2.10 it can be seen that hydrogen is introduced in the transport sector heavily in year 2020 as approximately 15 PJ of hydrogen fuel is consumed in RES scenarios. This synthetic hydrogen fuel is pro-
duced from fossil fuels (mainly coal) and CO₂ emissions from the process are stored by using CCS technologies.

![Graph showing conventional and non-conventional transport fuels](image)

**Figure 2.9** Conventional and non-conventional transport fuels.

![Graph showing development of non-conventional transport fuels](image)

**Figure 2.10** Development of non-conventional transport fuels.
3. Trade and import dependency

Figure 3.1 Net import/export of fossil energy carriers.

Figure 3.2 Inter-EU trade and import from outside EU27 of biofuels and electricity.
Net import of fossil fuels is illustrated in Figure 3.1. It shows the decreasing consumption of coal in RES scenarios and also effect of biofuels directive on oil product net import. In Figure 3.2 inter-EU trade with import from outside EU27 of biofuels and electricity is presented. Electricity is traded in inter-EU level back and forth, but Russian electricity is imported to the capacity of transmission line due to the low import price. In RES Reference scenario FT diesel is exported to Germany as stated in 2.2.3, therefore it is evident that trade of green certificates in RES Trade scenario enables efficient change from biofuels trade to certificate trade. However, bio RME is imported slightly from Germany in all RES scenarios.

Since only biomass, hydro, peat and wind are domestic energy sources in Finland, increasing shares of bioenergy in RES scenarios decrease import dependency from outside EU27 as can be seen from Figure 3.1 as import of coal and oil products decrease.

Virtual trade of renewables in the form of green certificates is illustrated in Figure 3.3 which indicates that Finland is clearly an exporter of green certificates in 2015 (40 PJ) and especially in 2020 (110 PJ). In 2015 all the green certificates are from final use whereas in 2020 70 PJ of certificates are from renewable electricity. Evidently, increasing use of bioenergy in energy sector (combined with drastic introduction of wind in 2020) and industrial sector provides green certificates for inter-EU trading.

The results from the PET model show that Finland has vast potential of bioenergy resources which can provide green certificates in great magnitude to fellow EU27 countries. There should be though a caveat for this kind of interpretation: techno-economical potential and cost structure of biomass is difficult to estimate and prefigure. Since green certificates are tradable commodities, price fluctuations in fuel prices can affect market significantly. Also, e.g. potential of Finnish wood fuel resources can alter due to development of forest industry, environmental policies etc. Therefore, drastic figures from green certificate trade should be approached with utmost care.

![Figure 3.3](image-url)
4. Impacts of policies on emissions and costs

4.1 Emissions

Emissions of CO₂ are illustrated in Figure 4.1 with separation between emission trading sector and non-emission trading sector. As use of renewable energy increases in RES scenarios, emissions decrease, especially since efficient technologies affect total energy consumption as can be seen in Figure 2.1.

Target of non-ETS sector emissions for year 2020 is 21.3 MtCO₂. Since non-ETS emission bound is not binding in 2020, emissions are below this target i.e. around 19 MtCO₂. There is not a single factor which affects non-ETS emission reduction most, but improved efficiencies and more renewable fuel mix in transport, residential, commercial, agricultural and non-ETS industrial sectors make the combined effect. CCS-technologies are not used in non-ETS sectors. Heating in residential and commercial sectors does not affect non-ETS emissions much due to the major role of district heat and electricity which are produced in the ETS-sector. However, increase of district heating and stabile level of bioenergy in space heating has decreased share of oil based heating and thus emissions.

Emissions of ETS-sectors have no target per country but a total EU27 level emission cap of 3.6 GtCO₂ in year 2020. Since the model does not have any country specific targets for ETS sectors, emissions can be compared to the official quota defined in EU for every country for years 2008-2012. In the case of Finland this quota is 37.7 MtCO₂ (Ministry of Employment and the Economy, 2008b) which emissions of ETS-sectors surpass in every RES scenario in years 2010 and 2015 (RES Reference 2010–2015: 46 – 49 MtCO₂, RES Trade and RES 30: 44 – 45 MtCO₂). Therefore it is presumable that emission permits has to be purchased for ETS-sector. However, in 2020 due to energy efficiency measures, increasing use of biomass in industrial and energy sector and significant introduction of wind power, emissions are below this level of 37.7 MtCO₂ in RES Trade (29 MtCO₂) and RES 30 (27 MtCO₂) scenarios. In RES Reference scenario emissions are though higher with 38 MtCO₂. However, it must be noted that emission quota for ETS-sectors will most probably be lower for years beyond 2012, and therefore trade emission permits.
could be imminent in RES Trade and RES 30 scenarios too. Use of CCS technologies does not affect ETS-sector, since hydrogen production from coal with CCS in fact decreases non-ETS emissions.

As was stated before, export of electricity green certificates is not effective until year 2020. When comparing this with emissions of RES Trade scenario in year 2020, it seems that in electricity sector costs from emission permits override benefits from certificate trading.

4.2 Costs

Table 4.1. Total costs of renewable technologies and share of GDP.

<table>
<thead>
<tr>
<th>Total costs of renewable technologies M€</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>• BaU</td>
<td>556</td>
<td>784</td>
<td>1543</td>
</tr>
<tr>
<td>• RES Reference</td>
<td>465</td>
<td>1040</td>
<td>2204</td>
</tr>
<tr>
<td>• RES Trade</td>
<td>561</td>
<td>789</td>
<td>2142</td>
</tr>
<tr>
<td>• RES 30</td>
<td>582</td>
<td>1283</td>
<td>2082</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Renewable technology costs per GDP</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>• BaU</td>
<td>0.3%</td>
<td>0.4%</td>
<td>0.7%</td>
</tr>
<tr>
<td>• RES Reference</td>
<td>0.3%</td>
<td>0.5%</td>
<td>1.0%</td>
</tr>
<tr>
<td>• RES Trade</td>
<td>0.3%</td>
<td>0.4%</td>
<td>1.0%</td>
</tr>
<tr>
<td>• RES 30</td>
<td>0.3%</td>
<td>0.6%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

Total costs of renewable technologies with shares of GDP are represented in Table 4.1. These figures show that cost of reaching renewable targets is not overwhelming in absolute values or in share of GDP when compared to BaU scenario. It is evident that introduction of green certificate trading affects costs significantly in year 2015. However, in 2020 costs of RES scenarios are quite equal.

5. Conclusions

In conclusion, Finland can reach renewable target in year 2020 and emission target for non-ETS sector without overwhelming economic effort by lowering energy consumption with efficient technologies in end use sector and energy production sectors and large scale utilization of bioenergy in energy and industrial sectors and wind power in electricity generation. Vast potentials of Finnish biomass can also provide via green certificate trading measures for other countries to reach their targets. However, reality of techno-economical potential and cost efficiency of Finnish biomass resources can be completely different in the future and therefore these results should be analysed and interpreted with care. Also, availability and cost estimates of efficient end use technologies and renewable technologies can be quite different when policies are implemented.

6. References


FRANCE
1. Introduction

This chapter describes the modelling outcomes for France within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios\(^\text{13}\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).
- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For France this means 23% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO\(_2\) emissions cap of 310 Mtons.
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% instead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO\(_2\) emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Sharing borders with five EU countries, France is centrally located in the EU energy market. In 2005, the total primary energy supply was 277 Mtoe distributed as following: 4.9% of coal, 33.1% of oil, 14.8% of natural gas, 41% of nuclear, 1.4% of hydro electricity and 4.8% of thermal renewable energy. French final energy consumption amounted to 166 Mtoe divided in three major sectors: household and commercial sector 43.4%, transport 31.4%, and industry 23.5%. [DGEMP 2008]

France is highly fossil fuel dependent with an import dependency close to average EU levels. The dependency on imports is 54.5% in 2006 and close to 90% if nuclear power is considered an imported fuel [IEA 2004].

Renewable sources such as biomass and hydro, participate to a significant extent to the energy mix. However, France is developing policies for a more diversified mix increasing wind and photovoltaic electricity, solar energy for heat and biofuels. France has the second biggest potential in the EU in terms of wind en-

\(^{13}\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
ergy and a very good potential in terms of solar and geothermal energy. All Renewable energy sectors have features in 2006 significant growth rates. Despite these growth rates, the share of renewable energy in the energy mix does not increase as fast as energy demand.

Beside the RES targets proposed by the EU Directive, the French Energy Law (2005) put some milestones regarding energy consumption: 10% should come from renewable by 2010, 50% increase of renewable heat and 7% biofuels incorporated (then 15% in 2015). To achieve these targets France introduced a mechanism of feed-in Tariffs in 2001 which was revised in 2006 and 2007.

2. Renewable technology deployment

2.1 Primary and final energy use

In the baseline scenario, the total primary energy consumption (TPES) increases by 14.5% over the period to reach 12550 PJ in 2020. The energy mix is still dominated by fossil fuel despite a reduction of their share from 58 to 55.6%. Gas’ share increases from 13.6% to 16% but this expansion doesn’t compensate the decrease of coal and oil contribution. Finally, the TPES is completed with nuclear power whose share remains constant around 37.7% and renewable which shows an increase from 6.5% to 8.6% in 2020. With the three alternative scenarios, only a slight TPES reduction of 2 to 3% compared to the BAU result for 2020 is observed. However the supply structure is strongly modified with a decrease of fossil fuels’ contribution to 49.5% without trade and 51% with trade. The use of renewable energy sources then increases significantly and their market share reaches 14% in 2020 when trade is allowed and 11% otherwise.
All RES scenarios impose simultaneously a target of 20% renewable energy sources in the final energy use for all EU countries and a CO₂ mitigation target of 20% or 30%. These objectives are met with a 5% reduction of final energy consumption and a strong increase of RES compared to the BAU results in 2020. For France, the national RES-target of 23% is the binding one and increasing the climate target doesn’t induce significantly more renewable between the RES-Ref and RES-30 scenarios. Finally, when certificate trading is allowed, the final consumption of RES decreases. France is thus a net buyer of certificate.

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation.
2.2 Use of renewable energy sources

The use of renewable energy sources increases over the modeling period in all end-use sectors and for all scenarios. Compared to 2000, growths of 55% in the BaU, or as high as 145% without certificate trade and 90% with trading are observed. The possibility to trade green certificates has a strong influence on the absolute level of renewable.

The largest contribution to this growth comes from a penetration of renewables into sectors previously reliant on fossil fuels. Residential and commercial sectors see a collapse of their share of renewable from 50% in 2000 to 36% in the BaU and 28% to 30% in the RES scenarios. The share of central power and heat production is also reduced by 4 to 10 points and, industry and transport which only represent 12% of the base year renewable use, increase their share to 30% in the BaU and 42 to 44% in the RES scenarios in 2020.

Figure 2.4 Direct use of renewable energy sources in the different sectors

2.2.1 Electricity generation

With no certificate trading, the environmental and renewable constraints induce 5.5% more centralized electricity production comparatively to the BaU. When trading is allowed, the total production remains unchanged. The contribution from renewable energy sources to the electricity mix rise from 15% in the base year to 18% in 2020 for the BaU, to 20% with the RES target and trade possibility and to 24% when only domestic efforts are considered. But going from 20% to 30% emission reduction target doesn’t increase renewables’ contribution. This is explained for France by the weight of nuclear which also produces CO₂ free electricity. The RES target is thus mainly achieved by supplying the additional electricity demands with renewable sources.
In 2000, hydroelectric power plants represented 92% of the renewable electricity supply. Their production remains stable in volume over the period but biomass and wind power strongly increase their contribution. Electricity production from biomass is multiplied by 2.5 while wind power’s share reaches 25% or 40% depending on the trade assumptions.
Figure 2.6  *Electricity generation from renewable energy sources*

### 2.2.2 Heat production

Total energy input for heat production decreases in all RES scenarios comparatively to the BaU. The reduction is around 6% without green certificates and 10% when trading is allowed. Coal is less affected due to captive usage in the iron and steel industry and oil use which accounted for 25% in the base year is substituted with renewable.
Figure 2.7 Total input for heat production

Biomass remains the largest renewable source but solar thermal increase its share among renewable energies from less than 0.5% to 5.9% in the BaU, and 8.8% in the RES Ref scenario. This growth is limited to 4% with green certificates trading.

Figure 2.8 Heat production from renewable energy sources
2.2.3 Transport fuels

Pulled by a sustained growth of passengers or goods mobility, the energy consumption in the transport sector increases by 25% over the period (and relatively to the base year). As a result, the consumption of fossil fuels increases in all scenarios despite a remarkable growth of biofuels use in the RES scenarios. The resulting biofuels market shares are 14% in the RES ref case, 13% with a 30% emissions reduction target and 10% with certificates trading.

Figure 2.9 Conventional and non-conventional transport fuels
3. **Trade and import dependency**

With the closure of French coal mines and the decrease of an already small domestic oil and gas production, France relies heavily on importation for its primary supply of fossil fuels. As shown below, the renewable and emission targets will induce in 2020 a reduction (10.7% to 13.6%) of fossil fuels trade from the BaU consumption levels in 2020. These reductions will bring the total fossil import back to its 2000 level. Compared to the year 2000 oil’s decrease then remains between 0 and 3%, coal is reduced by 35% and natural gas import increases by 15% or 23% depending on the trade assumption.

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**Figure 2.10 Development of non-conventional transport fuels**

![Graph showing the development of non-conventional transport fuels](image)
Figure 3.1 Net import / export of fossil energy carriers

France is today the largest net exporter of electricity in Europe and its level of exportation is maintained in 2020 in all scenarios. However depending on the scenarios, large quantities of biofuels are also imported from both inside and outside EU. In 2020 biofuels import in the RES scenario is of the same order of magnitude (85%) as electricity import. When certificate trading is possible, inter EU trade of biofuels decreases but total biofuels import still represent the equivalent of 55% of electricity exportation. Finally with a stronger emissions target, less biofuel is available for France from other EU countries and import represent 70% of electricity export. The biofuel consumption in the transport sector described in figure 2.10 above also highlights the fact that half to two-third of the total biofuel consumption will be imported to meet the different targets.
As noted earlier, the lower share of renewable energy sources in electricity supply, heat production or transport fuels with green certificates trading is compensated by an increasing volume of virtual trade of renewable. France is a net importer of certificates and the volumes needed in 2020 to respect the RES and emission targets is 25% higher than electricity export.
4. Impacts of policies on emissions and costs

4.1 Emissions

In the BaU scenario, CO2 emissions increase steadily in all sectors except the electricity production one and their overall level increase by 7% relatively to the base year. The RES scenarios produce a decrease of domestic emissions around 9% without trade, and 6% with certificate trading relatively to the base year.

![Figure 4.1 CO2 emissions](image)

A potential of 209 Mt for biological sequestration for Europe was identified in the framework of the NEEDS project. In addition to the direct CO2 emissions reduction depicted in Figure 4.1 above, 20 Mt CO2 in the RES-ref scenario and 29 Mt CO2 in RES-T and RES-30% need to be sequestrated for France. This contribution brings the net emission reduction effort to 14% for RES-ref and RES-T scenarios and 17% for RES-30%, relatively to the base year.

4.2 Costs

The differences in total discounted system cost against the BaU scenarios show that for France, an additional cost of around 15 billion € is required to reach RES and CO2 targets when trading of certificate among countries is allowed. If only domestic efforts are considered, the cost reaches 20 billion €. Those direct costs of environmental measures are small when compared to Frances’s economy; they will represent less than 1% of the forecasted GDP growth.

Finally the calculated cost of the renewable constraint is 11.1 €/GJ with the RES scenario, 10.3€/GJ when the CO2 target is set at 30%, and only 4.5€/GJ when certificate can be purchased from other EU countries.
5. Conclusions

Implementing the RES and emissions reduction directives is challenging but feasible given the potentials for renewable energy sources that were characterized. For France, the four scenarios pointed out some interesting facts:

- The absolute levels of primary energy consumption are not radically different between the BaU and the RES scenarios but, in the same time, CO2 emissions switch from a neat increase in the BaU to a clear decrease. Renewable energy sources thus help conciliating an increasing demand in the short term and the necessity to curve the emission path.

- However, at the scale of individual RES the challenge is big. Wind power, biomass, solar thermal, biofuels have to be simultaneously promoted and have to gain market shares in sectors previously reliant on fossil fuels.

- Environmental policies can also modify substantially France’s overall trading balance. The current net export of CO2 free electricity is thus balanced with biofuel imports from both inside and outside EU. Allowing certificate trading also reduces the pressure on individual RES growth and can help dividing by 2 the cost of the renewable constraint.

In summary those scenarios push for a strong and diversified development of renewable energy sources to adapt to the final demands for electricity, heat transportation fuels. They also show the importance of trade in achieving the environmental goals.

6. References


GREECE
1. Introduction

This chapter describes the modelling outcomes for Greece within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios\(^{14}\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the *Reference Document on Renewable Energy Sources Policy and Potential* (Deliverables D2.2 and D2.3).
- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Greece this means 18% share of RES in 2020 in the gross final energy consumption, and for all sectors which do not fall under the European Emissions Trading scheme a CO\(_2\) emissions cap of 44,8 Mtons.
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO\(_2\) emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Hydropower has traditionally been important in Greece, and the markets for wind energy and active solar thermal systems have grown in recent years. Solar heat is also a popular source of energy. Greece has set up a wider range of support mechanism however the market uptake of Renewable Energy Sources (RES) in Greece is lower than expected, mainly due to long licensing and administrative procedures and grid-related issues. The Greek parliament has recently revised the RES policy framework partly to reduce administrative burdens. A new feed in tariff has been set, giving support for 20 years. There is also, a particular mention of hybrid systems for the storage of RES produced electricity in the law, mainly in the non-interconnected islands. The solar thermal systems (mainly domestic hot water systems) have been a success story since the 1980s (Greece is one of the EU leaders) but the market is not increasing so rapidly in the recent years. A high interest has appeared in the last years for PV installations, due to he new feed in tariffs that were very favourable for PV electricity. Natural gas was introduced only since 1997 and is mainly taking up a share in electricity production and slowly making its way into final energy consumption with the continuous expansion of distribution grids.

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\(^{14}\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
The basic assumptions regarding annual population growth rates were taken from Eurostat’s forecasts and the GDP growth rates were taken from the GEME3 forecast.

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
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<td>0.3%</td>
<td>0.4%</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.0%</td>
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<tr>
<td>Annual GDP growth rates</td>
<td>2.4%</td>
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The public sector in Greece accounts for about 40% of GDP and with per capita GDP at least 75% of the leading euro-zone economies. Tourism provides 15% of GDP. The Greek economy grew by about 4.0% for the between 2003 and 2005, largely because of an investment boom and infrastructure upgrades for the 2004 Athens Olympic Games. Economic growth slowed to about 3% in 2005. Greece has not met the EU's Growth and Stability Pact budget deficit criteria of 3% of GDP since 2000. Public debt, inflation, and unemployment are above the euro-zone average. To overcome these challenges, the Greek Government is expected to continue cutting government spending, reducing the size of the public sector, and reforming the labor and pension systems.

Regarding the different energy carriers, oil provides about 57% of the TPES, while domestic lignite and some small amounts of imported hard coal provides 31%. Natural gas provides a 6.6% of the TPES and RES, including large hydro, another 5.1%. Lignite is the main domestic energy source in Greece and is used almost exclusively in electricity generation. The intensive exploitation of the lignite deposits was one of the most important aspects of the Greek energy policy over the last decades, particularly after the implications of the oil crisis of the seventies to the Greek economy. Thus oil, lignite and coal covered about 90% of the total primary energy supply, which exhibits a steady increase over the last twelve years.

The Greek parliament has recently revised the RES policy framework partly to reduce administrative burdens on the renewable energy sector. The new Law 3468/2006 deals with the RES-e and apart from the feed-in tariffs that are described below, reduces the bureaucratic licensing procedures. There is a particular mention of hybrid systems for the storage of RES produced electricity in the law, mainly in the non-interconnected islands. This type on installation receives a power availability tariff on top of the energy tariff.

One of the main political decisions of 2009 was the decision not to allow hard coal electricity production power plants to be built in Greece. Nuclear energy is not an option for the Greek electricity production system either. This limits the options of “conventional” electricity production to the indigenous lignite, imported natural gas and of course renewable electricity production.
2. Renewable technology deployment

2.1 Primary and final energy use

The primary energy supply figure in Greece is dominated by the imported oil products (mainly used in the final energy consumption for heat production and transport). The solid fuels correspond to indigenous lignite used in electricity production and imported hard coal used in industry. The share of natural gas is steadily increases as the infrastructure (distribution grids) is being built. The tendency for the policy scenarios is a reduction in the primary energy supply that comes from corresponding energy savings in the final consumption. The main sector for energy savings is space heating in buildings, with the implementation of insulation measures since the majority of the building stock before 1987 is not insulated.

As was expected the policy scenarios (with the CO2 emission caps) lead to reduced use of solid fuels and an increased use of renewable energy sources. Natural gas imports do not change significantly since they are bounded by the capacity of the gas grid interconnections of the Greek system.

The calculations for the BaU scenario lead to a share of 13% renewables in the gross final energy consumption in 2020, which is 5% short of the 18% target. This means that current policies are working, but are not adequate for achieving the target.

On the final energy consumption level in the policy scenarios, it is bioenergy that plays an important role (see figure 2.3.b) which includes the biofuels used in transport.
Figure 2.2 Final energy use

In the policy scenarios the renewables in transport constraint is binding (mainly due to the path for biofuels according to the biofuels directive), for the years 2010-2015. The overall renewables constraint is binding only in 2020 (because of the way the trajectory is imposed). The amount of renewables in 2020 is equal to the target – so it is the renewables constraint that is the binding one compared with the CO₂ emissions constraint, and this trend exists in all the time steps.

Figure 2.3 Final energy use of a) non-renewables and b) renewables

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation.
2.2 Use of renewable energy sources

Even in the BaU scenario the sector with the higher change in the use of renewables is the Power production sector. The renewable electricity share (including the electricity production from large hydro) increases to 15% in 2010 for all the scenarios and then to 33% in 2020 for the BaU scenario and 37% in the policy scenarios. In the policy scenarios there is a higher share of renewables in transport (from 5% in BaU to 10% in RES calculated according to the directive). The distribution of renewables to the various sectors is rather similar in all the policy scenarios. The commercial sector appears to consume renewables in the policy scenarios which is mainly the contribution from solar water heating. Residential use of renewables does not show an increase between scenarios, and industrial use shows a small increase in the policy scenarios.

The marginal cost of the transport constraint changes from 3.6€/GJ in 2020 in the RES scenario to 3.8€/GJ in the RES-T and 4.7€/GJ in the RES-30. The prices of the renewables constraint are 7.39€/GJ in the RES scenario and 4.55€/GJ in the RES-T scenario and 3.04€/GJ in the Res-30 scenario. So the overall conclusion can be that the transport constraint is the biding one in the years 2010 and 2015, while in 2020 the overall renewables constraint is the one driving the solution. The marginal cost of achieving the target is lower (by 2.8€/GJ) in the case of RES-T, while in the case of RES-30 it is the emissions constraint that is dominating the cost.

2.2.1 Electricity generation

Electricity generation in Greece is based on the use of indigenous lignite, imported oil for the islands that are not interconnected with the mainland and hydro power plants. The use of natural gas appeared in 1997 and is gradually increasing in the electricity production sector.
In the BaU scenario the basic trend is to reduce the contribution from solid fuels, since the older power plants have a rather low efficiency, increase the share of natural gas and increase the contribution from renewable energy sources. In the policy scenarios there is an increase of the electricity generation from renewables accompanied by a reduction in the production of electricity from solid fuels. The share of renewable electricity increases from 15% in 2010 to 37% in 2020. The largest share of the renewable electricity (76% of the renewable electricity) is due to wind energy, and 18% due to hydro power plants (mainly large plants). The remaining is the contribution from solar and biomass-biogas produced electricity. Nuclear energy is not a political option for the electricity generation in Greece.

Figure 2.5 Total Net electricity generation
The oil based electricity generation remains almost constant between scenarios because it is used to satisfy the electricity demand of non-interconnected islands. The wind potential in Greece is rather high, however the penetration seen in this least cost solution in the policy scenarios, might be too high for the electricity system. More detailed studies are needed to examine the problem of high wind turbine penetration in the electricity system. The potential of new hydro plants is limited to small hydro stations (since most of the large plants are already built), and the overall electricity production is not expected to increase considerably.

2.2.2 Heat production

The sector of heat production shows the largest possibility for energy savings (reduction of final energy demand), mainly due to the savings potential in the building sector (which covers about 40% of the final energy demand). The share of renewables in the final energy input for heat production is changing from 14% in 2000 to 17% in the BaU scenario in 2020 and 22% in the policy scenarios. The main contribution of renewable heat is due to biomass-biogas used in industry and households which accounts for 12% of the total input for heat production in 2020 in the policy scenarios. The use of biomass for heating in the household sector is currently the largest use of renewable energy in Greece. This share remains in the future development of the energy system in all the scenarios while the increased use of bioenergy in the policy scenarios comes from the industrial sector.

The second largest contribution to renewable heating comes from solar water heating systems which accounts for 3.5% of the total input for heat production in 2020 in the policy scenarios. Greece already has a large penetration of solar water heating systems which is expected to increase over the time horizon of the model, even in the BaU scenario.

District heating is only limited in Greece and is not expected to increase significantly due to the low overall heating demand and heating season duration.
Figure 2.7  Total input for heat production

Figure 2.8  Heat production from renewable energy sources
2.2.3 Transport fuels

Transport was completely based on conventional fuels in Greece in 2000 and 2005.

![Graph showing conventional and non-conventional transport fuels]

Figure 2.9 Conventional and non-conventional transport fuels

Only 0.3% of the total consumption in transport in 2000 came from electricity and the remaining is based on oil products in 2005. Gasoline covers about 47% of the petroleum products consumed and diesel about 30% (of the total transport consumption including air transport).

The development of the BaU scenario shows that the share of renewables in transport in 2020 is expected to reach 4% of the overall transport and 5% according to the calculation in the renewables directive.

In the policy scenarios a reduction in the final consumption comes from the elastic demand and savings options. The share calculated according to the directive is 10% and is met exclusively by biofuels, and it corresponds to 7% of the overall consumption in all the transportation modes. This share remains the same across the policy scenarios.
In the BaU scenario the relation between biodiesel-bioethanol is about 50-50. In the policy scenarios this ratio changes to 40-60 in favour of bioethanol (which is the same as the ratio between diesel and gasoline consumption), since most the biofuels are used in blends with conventional fuel.

3. **Trade and import dependency**

Greece is heavily dependent on imported oil products that are mainly used in the final energy consumption and for the electricity generation in the non-interconnected islands. This tendency remains in all the scenarios (BaU and policy in 2020). Natural gas imports increase considerably compared to the values in 2000, through its use in the final energy consumption and in electricity generation. The differences between the various scenarios in 2020 are not significant. The main conclusion on trade is the reduction of imports of oils products by around 5% in the policy scenarios compared to the BaU scenario.
Figure 3.1 *Net import / export of fossil energy carriers*

Figure 3.2 *Inter-EU trade and import from outside EU27 of biofuels and electricity*

Regarding the import of biofuels, Greece appears to be importing most of the biofuels used (around 46% in the BaU scenario and 74% in RES, 72% in RES-T) mainly from sources outside the EU. So regarding
physical trade the region is a net importer of renewable energy and in particular biofuels, and the amount of imports increases in the policy scenarios due to the higher targets. The remaining 30% of biofuels used is produced domestically. The statistical transfers do not change the situation or the amount of imported renewable energy, since all the certificates traded come from the renewables electricity sector. It appears that the country requires the import of statistical transfer in order to reach the target in 2020.

![Diagram of Virtual trade of renewable energy in the RES Trade scenario](image)

**Figure 3.3 Virtual trade of renewable energy in the RES Trade scenario**

4. **Impacts of policies on emissions and costs**

4.1 **Emissions**

There is a tendency for the reduction of the total CO2 emissions even in the BaU scenario, due to the reduction of electricity production from coal and the electricity production from natural gas.

In the policy scenarios the reduction of emissions in the ETS sectors is mainly from the power sector due to the increase of renewables. Carbon sequestration technologies in the power sector do not appear in any of the scenarios.

What appears to be an interesting least cost option is the sink of CO2 emissions through aforestation in the policy scenarios and the non-ETS sectors. So the commercial and residential sectors have a potential of 1.5Mtons and 8.7 Mtons reduction of CO2 using aforestation, in the RES-30 scenario. In the non-ETS sectors, the residential and commercial sectors show a small reduction due to the higher penetration of renewables (solar and bienergy) and the sinks options described above. The reduction in the transportation sector is due to the penetration of biofuels in the policy scenarios and is of the same order in all the scenarios. The marginal cost of the non-ETS CO2 limit is 7.6€/ton CO2 in the RES scenario and 15.4€/ton in the RES-T scenario.
4.2 Costs

In the BaU scenario the calculated cost for investment and operation of renewable energy technologies is of the order of 1600 million Euros in 2020 corresponding to about 0.6% of the national GDP. In the policy scenarios this increases to 2900 million and 1% of the projected GDP, without significant differences from one scenario to the other.

5. Conclusions

In order to achieve the target of renewable energy in 2020, the least cost options for Greece appear to be:

- the utilisation of the wind energy potential for electricity production,
- utilisation of the solar PV technology and biomass-biogas cogeneration
- the increase of the contribution of solar water heaters in residential and commercial by 50% in 2020 compared to the BaU development.
- The increase of biomass-biogas use in the industrial sector in cogeneration installations
- The achievement of the transport share target through the use of biofuels, 70% of which is imported.
- The transport constraint appears the binding one in the years 2010 and 2015, while in 2020 the overall renewables constraint is the one driving the solution. However in 2020 all the constraints (renewables and emissions) have values which shows that all of them play a role in the implementation of the policies.
6. References

HUNGARY
1. Introduction

This chapter describes the modelling outcomes for Hungary within the RES2020 project.

To repeat shortly the following scenarios\(^{15}\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the *Reference Document on Renewable Energy Sources Policy and Potential* (Deliverables D2.2 and D2.3).
- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Hungary this means 13% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a maximum increase of CO\(_2\) emissions of 10% compared to 2005.
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO\(_2\) emissions and costs. Section 5 contains the key conclusions.

1.1 National energy system and RES policies

The following bullet points give a short overview about the current status of renewable energy sources within the Hungarian energy system.

Key figures:
- The share of RES in total primary energy consumption was of 4.87\% in 2006. Biomass in the main RES source representing more than 89\% of RES primary consumption, follow by geothermal (8.2\%) and Hydropower (1.7\%).
- The share of RES in the gross final energy consumption was 4.3\% in 2005.
- The share of RES in the gross electricity production was 3.7\% in 2006 in 2007 4.3\%.
- The share of biofuels in the transport sector in 2006 was 0.28\%.
- Hungary energy dependence on imports amounts to 63\% in 2005

In the following, the main national targets and EU targets for the Czech Republic concerning the use of renewable energies are listed. Further details on these targets and on their implementation by the Hunga-

\[^{15}\text{In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.}\]
ian government can be found in the deliverables D.2.2 and D.2.3 of the RES2020 project (Reference Document on Renewable Energy Sources Policy and Potential).

Mandatory targets set by the newly proposed RES Framework Directive from 200848
- 13% share of RES on the final consumption of energy in 2020.
- At least 10% share of biofuels of final consumption of energy in transport in that Member State in 2020.

Indicative Target set by the RES- electricity European Directive from 200149
- 3.6% Share of RES on gross electricity consumption by 2010

Indicative Target set by the European Biofuels Directive from 200350
- Biofuels consumption of 5.75% of petrol and diesel use for transport in 2010.

National commitments
- The Hungarian Energy Saving and Energy Efficiency Improvement Action Programme expresses the country’s determination to reach a share of renewable energy consumption of at least 6% by 2010.
- There is no national target/commitment for RES heating and cooling (RES-H&C).

Progress towards the Targets
- The 3.6% RES-E target has already been meet. Hungary’s RES-e share amounted 2.24% in 2004, 4.6 in 2005, 3.7% in 2006, 4.3% in 2007.

2. Renewable technology deployment

The results in the following paragraphs show the outcome of a model based scenario analysis. Accordingly this is not an outlook showing the most probable development. Instead, the effects of different political measures on the energy system with this model are displayed. This should be taken into account while studying this report and analysing its results

2.1 Primary and final energy use

The primary energy consumption is generally characterized by a slight increased from 1054 PJ in 2000 to 1102 PJ (+48 PJ) in 2020 in the RES-30% scenario and 1191 PJ (+137 PJ) in the BaU scenario. Natural gas and renewable energy carriers gain market shares, whereas use of coal declines (Figure 2.1). Coal consumption decreases from 167 PJ in 2000 to 131 PJ in the BaU scenario and 73 PJ in the RES-30% scenario in 2050. The share of natural gas increases from 38% in 2000 to 39% in 2050 in the RES-T scenario and 42% in the RES scenario. Renewables face the highest growth between 2000 and 2020 whereas a minimum growth factor of 6 is reached in the BaU scenario and a maximum growth factor of 7.7 in the RES-T scenario. In all scenarios the share of renewables of primary consumption in 2020 amounts at least 12%. Nuclear fuels develop more or less constant on a level of about 12% to 13%.
The final energy consumption in Hungary is dominated by non-renewable fuels, which increase from 640 PJ in 2000 to 670 PJ in the RES-30% scenario and 746 PJ in the BaU scenario (Figure 2.2). The use of renewable energies grows over the two decades from 44 PJ in 2000 minimum 91 PJ in the BaU scenario and maximum 123 PJ in the RES-T scenario. In the other two scenarios the consumption of renewables amounts to 97 PJ in RES and 123 PJ in RES-30% scenario. Thus in 2020 a share of renewables of final consumption of 10.9% is reached in the BaU scenario and 11.9% in the RES scenario. Driven by the increased use of renewables and the reduced total consumption in the scenarios RES-T and RES-30%, renewables gain a share of total consumption of 15.4% in 2020 in RES-T and 13.6% respectively. Regarding at the mandatory target of 13% renewables of gross consumption it can be stated that the target is voluntarily fulfilled under an ambitious climate target.
The non-renewable share of final energy consumption is dominated by natural gas, which faces a significant growth in near term, beginning from 269 PJ in 2000 to a level of 345 – 360 PJ in 2015 and a slight increase in 2020 in the scenarios BaU (368 PJ) and RES (355 PJ) and a decrease in 2020 in the scenarios RES-T (324 PJ) and RES-30 % (331 PJ). Thus natural gas represents almost the half of the total non-renewable final energy consumption in 2020. The shares of oil, coal and electricity differ only slightly from base year values, but the share of non renewable heat declines from 9 % in 2000 to 4 % in 2020. In 2020 the implementation of a renewable trading scheme and strong climate targets lead to additional substitution effect of fossil fuels. Despite declining total final energy consumption in the scenarios RES-T and RES-30 % compared to RES scenario, additional 26 PJ of renewable energies are consumed in RES-T scenario and 9 PJ in the RS-30 % scenario, which directly replace fossil fuels.
The composition of the renewable share of the final energy consumption shows a dominating share of bioenergy with 15 PJ in 2000. Bioenergy quantities increase until 2020 at least to 22 PJ in the BaU scenario and maximum 49 PJ in the RES-T scenario. Additional to bioenergy renewable heat and renewable electricity represent important renewable final energy starting in 2010 with about 10 PJ renewable heat and about 8 PJ renewable electricity. Over the time horizon renewable heat replaces fossil fueled district heat and leads to an increase of the total heat consumption of about 10 PJ. Renewable electricity quantities are consumed additionally to the non-renewable electricity and also replace non-renewable electricity, especially in 2020 under a renewable trading scheme (+5 PJ compared to RES-scenario) and under the 30 % climate target (+7 PJ compared to RES-scenario).

2.2 Use of renewable energy sources

In 2000 57 % (11 PJ) of the renewable energy was consumed in the residential sector. The absolute quantities used in the residential sector do not change significantly until 2020 in the scenarios BaU, RES and RES-30 %, compared to an extended use in the RES-T scenario, reaching 15 PJ in 2020. Consequently the share of renewables used in the residential sinks to a minimum of 20 % in 2020 in the RES-30 % scenario and 33 % in the BaU scenario. Growth can be observed for the transport sector and especially in the scenarios RES-T and RES-30 % for industry sector and central heat and power generation. The growing share of the transport sector in all the RES scenarios is caused by the specification of the biofuel quota and the growing transport demand, representing 15 PJ biofuels in 2020. Thus biofuels used in the transport sector hold a share of 2 % at total final consumption in 2020. As scenario RES-T shows, a trading scheme of green certificates would primary lead to an increased use of renewables in the industry sector and public heat and electricity generation. Compared to the RES scenario the consumption of renewables in the RES-T in the industry sector extends by 17 PJ and in the public heat and electricity generation by 6 PJ. This effect can be observed with a minor intensity for the scenario RES-30 % as well.

Figure 2.4 Direct use of renewable energy sources in the different sectors
2.2.1 Electricity generation

Due to the growing electricity demand and decreasing electricity imports generation of electricity increases from 33 TWh in 2000 to a level of about 40 TWh in 2015. The Hungarian electricity generation is mainly based on natural gas (29 % in 2000) and nuclear power (39 % in 2000). Nuclear electricity remains constant over the time horizon at 13 TWh in all scenarios. The electricity quantities generated from natural gas increase over the first decade to a level of 19 TWh and decline towards 2020. In the RES-30 % scenario natural gas combines cycle technology contribute to the climate target and lead to an extensive use of natural gas for electricity production in the period 2015. Coal based electricity reaches almost base year level in the BaU scenario in 2015 and 2020 with each 7 TWh. Under an ambitious climate policy (RES-30 %) coal looses market shares in favour of natural gas based and renewable technologies and contributes with 2 % in 2002 to total generation. The share of renewable energy carries of total net electricity production rises from near zero level in 2000 to 5.7 % in 2005 and increases in the BaU scenario and RES scenario to 4 % in 2010 and further to 19 % in 2020. Thus the indicative target set by the European Commission of 3.6 % for 2010 is reached in the BaU scenario. In scenarios RES-T and RES-30 % the share in 2020 amounts 23 % and 25 % respectively.

![Total electricity generation](image)

Figure 2.5 Total electricity generation

Renewable electricity production in the base year is completely based on hydro power (0.2 TWh). Since Hungary has only limited hydro power potential and which is almost completely used, no significant additional electricity quantities can be generated. Growth of renewable electricity production primary results from increased use of biomass. Electricity generation from biomass reaches scenario independent 5 TWh in 2015 and 7 TWh in 2020. Under a green certificate scheme or enhanced climate protection targets additional 2 TWh electricity from wind are generated. Geothermal energy for electricity and district heat production is limited, although Hungary obtains significant potential from thermal underground water. For a direct use of the thermal water the temperature level is too low, consequently advanced technologies like power plants with organic ranking cycle are necessary to exploit the geothermal potential. In 2020 a share of 19 % of total net generation is produced from renewable energy carriers in the BaU and RES scenario, compared to 23 % in the RES-T and 25 % in the RES-30 % scenario.
2.2.2 Heat production

The main fuel for the heat production is natural gas, which holds a share of 73% in 2000, developing more or less constantly over the time horizon. The second important fuel is coal with 9% in 2000, gaining market share until 2020 with 14%.

Figure 2.6 *Electricity generation from renewable energy sources*
Renewable energies represent a minor input share for heating purposes. The base year share of 5% of total input for heat production remains constant over the time in the BaU and the RES scenarios and increases in 2020 in the RES-T scenario with 11% and in the RES-30% scenario with 7%. Among the renewable fuels for heating technologies dominates bioenergy with about 18 PJ constant in BaU and RES scenario and peaking in RES-T scenario with 38 PJ in 2020. In all scenarios a growing use of renewable electricity as well as solar for heat production can be observed to a level of about 15 PJ in 2020 in the BaU and RES scenarios.
2.2.3 Transport fuels

Driven by the growth of transport demand the final energy consumption of the transport sector develops from 136 PJ in 2000 to almost 170 PJ in 2020. Due to the specification of the European Biofuel Directive in the RES scenarios the share of renewable energies in the transport sector increases to a level of about 19 PJ in 2020 in all RES scenarios, of which 15 PJ are biofuels, representing 10 % renewable energy input for road transportation. Neither a trading scheme for green certificates nor the stronger climate target of -30 % in 2020 compared to Kyoto base lead to additional consumption of renewable energies in the transport sector. Besides the growing quantities of biofuels renewable electricity contributes with 4 PJ constant over the model horizon to transport final energy consumption.

Figure 2.8  *Fuel input for heat production from renewable energy sources*
Figure 2.9  *Conventional and non-conventional transport fuels*

Figure 2.10  *Development of non-conventional transport fuels*
3. Trade and import dependency

Referred to gross inland consumption Hungary faced an import dependency in 2005 of 63%. Main fuels to be imported are natural gas (296 PJ in 2000) and crude oil / oil products (227 PJ in 2000). Resulting from the increasing demand for natural gas, import quantities rise to 433 PJ in 2020 in the BaU scenario. Oil product import decline slightly in 2020 compared to 2000 in the BaU scenario and coal imports grow by factor 2.4 until 2020 compared to 46 PJ in 2000. The implementation of renewable targets (RES scenario) and furthermore the addition of a trading scheme (RES-T) affect a decrease of the import quantities of natural gas (-11 PJ RES and -45 PJ RES-T) and coal (-13 PJ RES and -22 RES-T) compared to the BaU scenario in 2020. In the scenario RES-30% imports of natural gas exceed the amount of RES-T scenario slightly by 10 PJ, conversely to coal, of which 17 PJ less are imported. The reason for this effect is the shifting of the electricity generation from coal to natural gas under ambitious climate measures.

![Figure 3.1 Net import / export of fossil energy carriers](image)

Hungary is a net importer of electricity, whereas imports from outside the EU-27 dominate. Compared to 2000 the electricity import dependency decreases in 2020 in all scenarios. With regard to effects of renewable targets and under 20% climate target (RES and RES-T) additional electricity export quantities of 7 PJ in 2020 to the inner-European electricity market can be observed. Concerning biofuels, Hungary exports 36 PJ biofuels in 2020 in scenarios BaU and RES-T and 41 PJ in RES scenario and 39 PJ in RES-30% scenario to other European countries. Thus the different renewable and climate policies have no significant impact on the Hungarian biofuels trade. The difference of 5 PJ from the RES scenario to the RES-T scenario shows a shifting of biofuel quantities from the domestic market to the virtual green certificate market under a respective scheme. Under the conditions of this analysis, Hungary would be a seller of green certificates in such a trading scheme in 2020, equivalent to 28 PJ renewable energies in 2020.
Figure 3.2 Inter-EU trade and import from outside EU27 of biofuels and electricity

Figure 3.3 Virtual trade of renewable energy in the RES Trade scenario
4. Impacts of policies on emissions and costs

4.1 Emissions

In general it can be stated, that the total Hungarian CO\textsubscript{2} emissions increase from the base year (54 Mio. t in 2000) to 56 Mio. t in 2010 in the BaU scenario and further to 58 Mio. t in the BaU scenario. In the RES scenarios the emissions in 2015 are slightly below BaU level with 57 Mio. t in the RES scenario, 56 Mio. t in the RES-T scenario and 54 Mio. t in the RES-30 % scenario. In 2020 the emissions in Hungary amount to 57 Mio. t in the BaU scenario and exceed the base year emission by 3 Mio. t. In the RES scenario the base year level is reached in 2020. The implementation of a trading scheme results to an additional carbon reduction of 3 Mio. t compared to RES and amounts thus in 2020 to 52 Mio. t in the RES-T scenario. The lowest emissions are reached under 30 % climate target with 47 Mio. t carbon dioxide.

The Non-ETS-sector represents approximately half of the total emissions in 2000, but this share increases in 2010 due to increased use of fossil fuels in the residential and commercial sector. The share of residential emissions of total emissions increase from 16.3 % in 2000 to 17.6 Mio. t in 2010 in the BaU scenario and 17.9 Mio. t in RES-30 % scenario. Thus the residential sector and the transport sector dominate the non-ETS emissions.

The ETS-emissions reach a total value of about 27 Mio. t (2015 BaU). They mainly consist of the emissions from electricity generation (38 % of total emission in 2000) and also of the energy intensive industry (11 %) and transformation ETS (2 %). Until 2020 the emissions from electricity generation reduce by 8 Mio. t to 13 Mio. t in the BaU scenario and the emissions from energy intensive industry grows by 5 Mio. t to 11 Mio. t in the BaU scenario. This effect reduces in the RES scenarios (ETS-industry in 2020 in RES-30 % scenario 9 Mio. t and electricity generation 7 Mio.t respectively). Thus main carbon reductions until 2020 come from the public electricity sector.

![CO\textsubscript{2} emissions](image)

Figure 4.1 CO\textsubscript{2} emissions
4.2 Costs

<table>
<thead>
<tr>
<th></th>
<th>BaU</th>
<th>RES</th>
<th>RES-T</th>
<th>RES-30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Costs tem</td>
<td>445.9</td>
<td>444.8</td>
<td>445.2</td>
<td>446.2</td>
</tr>
<tr>
<td>Costs (billion €)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In general, the total system costs are the lowest in the RES scenario. Compared to the BaU scenario the system costs are reduced by 1.1 billion Euros, which is caused by increased exports of electricity and biofuels. Due to the reduction of the physical trade of biofuels in the RES-T scenario compared to RES, the system costs increase by 0.4 bln Euros to 445.2 billion Euros. The highest system costs can be observed under 30% climate target in the RES-30% scenario with 446.2 billion Euros.

5. Conclusions

Regarding at the growth of renewables in Hungary, biomass plays the dominant role, preferably in technologies for heat production as well as for biofuels in the transport sector. Additional to the domestic use of biomass, Hungary is a net exporter of biofuels under corresponding European RES policies. Under an ambitious climate target (-30% in 2020 compared to Kyoto) the target of 13% of renewables or gross consumption is fulfilled voluntarily. The renewable electricity generation reaches maximum 25% of total net generation in 2020 under 30% climate target. Independent from climate and renewable policy, Hungary remains net importer of electricity, but can extend its exports to the European market under RES policy measures.
ICELAND
1. Introduction

This chapter describes the modelling outcomes for Iceland within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A Business as Usually scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES-Ref) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on an EU level. Iceland is not included in the directive and does not have any expressed RES targets, but is following the EES agreement. For Iceland a 20% target means a CO2 emission cap of 1.66 Mtons in 2020.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO2 emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

The modern Icelandic energy supply system developed relatively late. It is today characterized by a very high energy use per capita in general and, in particular, a very high electricity consumption. The share of geothermal energy is also very high and certainly highest in the world per capita. The demand is characterized by a large share of electricity intensive industry which is dominated by the alumina melting industry.

Almost all electricity is produced by hydro and geothermal power and, therefore, the share of renewables in the energy mix is very large and today probably higher than in any other country of the world. The share of domestic supply has grown substantially over the last decades and is now more than 70 %. Imported oil is mainly used for the fishing fleet and for transportation.

In table 1, the primary energy use in Iceland is shown. It is remarkable that a very large proportion of the total use comes from geothermal energy. The use of geothermal energy on a large scale started in 1930 when the first geothermal heat was piped from a source close to Reykjavik. The first district heat utility started its operation in 1943. Today, geothermal energy is utilized for a number of purposes. The most im-

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16 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
portant sector is space heating which is consuming close to 60 % of the geothermal heat. Electricity production is the second most important sector consuming 18 % of the total. However, it should be observed that the conversion efficiency of geothermal energy to electricity is very low at 10 %. Geothermal power generation is normally run at base-load with hydro power running in peak load making it possible to adjust for the varying demand by using the possibilities of the hydro power dams.

There is no power connection to any neighboring country. However, there have been plans for construction of a high-voltage line from Iceland to Great Britain. The distance is about 800 km.

Table 2. Primary energy supply in Iceland in the year 2000 (source: EuroStat)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>PJ</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>0.1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Coal</td>
<td>4.2</td>
<td>3.0%</td>
</tr>
<tr>
<td>Geothermal</td>
<td>73.6</td>
<td>52.7%</td>
</tr>
<tr>
<td>Oil</td>
<td>38.9</td>
<td>27.9%</td>
</tr>
<tr>
<td>Hydro</td>
<td>22.9</td>
<td>16.4%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>139.7</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

The development of the primary energy supply in Iceland is shown in Fig 2. It is seen that before 1940, the primary energy consumption was very small and that it has grown enormously since then. Now, the per capita energy use in Iceland is one of the highest in the world at 500 GJ/cap. From Fig 1 it can also be clearly seen that the oil crises and the oil price hikes in the seventies had a very large impact on the development of geothermal energy, at that time mainly used for heating purposes.

Figure 1 The development of the total primary energy supply in Iceland since 1940. (Source: Energy in Iceland, 2004).

In Iceland, fossil resources are scarce. There are large areas of peat land, covering about 3% of total land area. This resource, however, has not been utilized since the early 1960s. Iceland also has resources of lignite. The seams are thin and ash content is generally high because of the frequent eruptions during the period of lignite formation. The lignite is therefore classified as second grade and has not been utilized since the late 1950s. Iceland has no known resources of crude oil, oil shale, bitumen, natural gas or uranium. Iceland has not cultivated trees or other biomass for energy purposes but in earlier centuries charcoal was produced in many farms and fuel wood was prepared from driftwood in some parts of the country.
The per capita electricity consumption in Iceland is the highest in the world since 2001. Prior to 2001 the highest consumption per capita was in Norway. This high figure is a consequence of the abundance of natural resources, mainly inexpensive hydro power but also geothermal resources. The use of geothermal energy for electricity generation has increased steeply during the last decade, and is assumed to continue to increase if there will be any demand increase. As an example, the Husavik plant is supplying about three quarter of the electricity demand in the town of Husavik.

The potential for further hydropower development is still large, a total of 60 TWh annually of harnessable hydro power. However, when concern is taken regarding cost-effectiveness and environmental concerns are included this amount is reduced to about 30 TWh annually. Regarding electricity from geothermal sources, the adopted potential is 20 TWh annually when environmental and sustainable concerns are included. There is a relatively large potential for further use of geothermal energy. The overall potential is estimated at approximately 60 TWh annually. Half of this could be harnessed in a near future taking into consideration environmental concerns and cost. It is likely that an expansion of the geothermal use would be for electricity production rather than for heat for the district heating grid since the district heating grid cannot be expanded much more due to dispersed nature of dwellings not yet covered by the grid.

There should also be good potentials for harnessing wind power but due to large amounts of available hydropower and geothermal potentials this has not been investigated properly since there is no foreseen demand. However, this might change if more energy intensive industry is going to be constructed in Iceland or if electricity or hydrogen from renewable electricity is going to be exported. In no other country has the planning for a large-scale introduction been taken so far as in Iceland. The company Icelandic New Energy has been founded with funding from the Icelandic government and some major companies with available hydrogen technology; DaimlerChrysler, Norsk Hydro and Shell Hydrogen. The intention is to entirely replace fossil fuels with renewable hydrogen, which should be produced by excess hydro and geothermal power. The two major tasks are to introduce hydrogen as a fuel for the transport sector and for the fishing fleet.

There were 283 thousand people on Iceland in year 2000. In the model, this number is assumed to have increased with 5 thousand by 2020. The GDP for Iceland is in the model assumed to increase with 13% between 2000 and 2020. The assumed average annual GDP growths rates are an output from the GEM-E3 model and together with annual population growth presented further in RES2020 (2008).

2. Renewable technology deployment

2.1 Primary and final energy use

More than half of the primary energy is renewable energy for all scenarios during the entire modeling period, see Figure 2.1. In 2000, the renewable energy consists of 52% geothermal heating and 48% hydro power. The hydro power is increasing over time, while the geothermal is constant. Even if the three RES scenarios do not have any RES targets, the share of RES increases more compared with the increase in the BaU scenarios and, hence, in addition to lower carbon dioxide emissions, a tougher climate policy drives the investments in renewable energy sources.
The BaU scenario is the only scenario with an increasing primary energy supply in year 2020. This is due to increasing demand in the agriculture, industry and transport sectors. It should be noticed that the agricultural sector in Iceland almost exclusively consists of the fishery and the fishing industry. The increasing demand for energy is met by an increasing use of mostly oil and to some extent geothermal heating. The consumption of coal is constant with one exception; in year 2015 in the RES 30% scenario the coal consumption has increased with almost 30% since year 2010 and then drops back to below 2010 years level in 2020.

The amount of renewable energy is almost constant through all scenarios and all time periods, see Figure 2.2. Oil is the only non-renewable energy carrier visible in the results of final energy use in Iceland, see Figure 2.3a. In principal, all electricity comes from renewable sources (hydro power and geothermal), which together with a widespread use of geothermal heating represent the majority of renewables in final
use of energy. Exceptions are a proportionately small increase of hydrogen and biomass at the end of the modeling period for the three RES scenarios. The increase is largest in the RES-30% scenario, where the increase seen in Figure 2.3b starts already in year 2010.

The final use of energy increases more in absence of a climate target. The increase is mainly due to increasing oil use within the transport sector resulting in a lower share of RES in the BaU scenarios compared with the RES scenarios. The share of RES is marginally larger with a stronger climate target (RES-30%), but the differences are too small for any conclusions to be drawn.

![Graphs showing final energy use of non-renewables and renewables over different scenarios.](image)

**Figure 2.3** Final energy use of a) non-renewables and b) renewables

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation

### 2.2 Use of renewable energy sources

The direct use of renewable energy sources in different sectors is presented in Figure 2.4. There are no large variations between the scenarios. The use of electricity increases with time in all scenarios. The increase is largest in the RES-30% scenario in which all hydrogen is produced by electrolyses. In the other RES scenarios, hydrogen is produced from both renewable electricity and biomass. The transport sector is further described below in chapter 2.2.3. At the end of the modeling period, hydrogen from biomass gets a market share in the transport sector. In the remaining sectors, geothermal is the main source of renewable energy.
2.2.1 Electricity generation

The richness of renewable sources in Iceland is further utilized when the electricity generation increases. Within the power sector the generation stem from geothermal and hydro power, see Figure 2.6, but only hydro power increases over time.
2.2.2 Heat production

For all scenarios, the production of heat is mainly from renewable energy sources, see Figure 2.7. There is a small and constant amount of oil used within the industry sector and after the base year there is also some coal used for heat production. Since there is no coal in the existing system, the barrier is greater for coal use compared with a further expansion of geothermal energy, the increase in coal could therefore be questioned and further analyzes is needed. The heat production is constant between the scenarios. The reason is probably the large share of domestic renewable geothermal heating (Figure 2.8) that is economically competitive in itself.

![Figure 2.7 Total input for heat production](image)

![Figure 2.5 Heat production from renewable energy sources](image)
2.2.3 Transport fuels

There are no renewable fuels in the BaU scenario and very small shares in the other scenarios before 2020. The share increases with strengthening of the climate target in 2020, see Figure 2.9. Hence, the climate policy drives the share of fuels based on renewable energy sources within the transport sector. The main non-conventional renewable is hydrogen (see Figure 2.10). Hydrogen enters already in 2010, but only in the RES-30% scenario and only hydrogen from fossil fuels (coal and oil). From 2020, all hydrogen in the RES-30% scenario is produced by electrolyses while hydrogen in the RES-Ref and the RES-T scenarios is produced from both biomass and by electrolyses. According to the results, hydrogen is only being used for buses and cars, starting with buses already in year 2010 (which is a too optimistic scenario considering that it in 2009 still are no conventional buses running on hydrogen).

Bio-fuels first enter the market for buses and cars, while the freight transports not uses bio-fuels until year 2020. For bus transport there are biodiesel-buses and blending in the regular diesel. Biofuels for cars enter as ethanol-cars, biodiesel-cars and blending in the regular gasoline. Freight transports do not start using biofuels before the second generation of technologies enters the market with hybrid-diesel-trucks and hybrid-gasoline-trucks using regular diesel blended with biofuels.

![Figure 2.6](image)

**Figure 2.6 Conventional and non-conventional transport fuels.**

![Figure 2.10](image)

**Figure 2.10 Development of transport fuels from renewable energy sources.**
3. Trade and import dependency

Oil is being imported to Iceland, mainly for use in the transport sector. The oil import amounted to 38 PJ in 2000 and this level is kept in 2020 in the RES-Ref and RES-Trade scenarios while the oil import is increasing in the BaU scenario and decreasing slightly in the RES-30% scenario. There is also a very small amount of natural gas imported today and in all scenarios. See Fig 3.1.

In the RES scenarios there is a small import (2-3% of the oil import) of biomass. In year 2020, the resulting import of RME is 0.8 PJ in the RES-30% scenario. The level of imported RME is similar in the RES-Ref and the RES-T scenarios, which, in addition, have a larger import of ethanol compared with the RES-30% scenario, resulting in the higher import of biofuels seen in Figure 3.2.

Since there is no power transmission lines to other countries, there is no electricity trade. Instead, in presence of large renewable sources for electricity production there might be economic incentives for power intensive industries to move to Iceland in the future like it has been in the past, but this is not investigated further in present study.

![Figure 3.1 Net import / export of fossil energy carriers](image1)

![Figure 3.1 Inter-EU trade and import from outside EU27 of biofuels and electricity](image2)
4. Impacts of policies on emissions and costs

4.1 Emissions

Iceland is not included in the European emission trading sectors, hence no separation between trading and non-trading sectors. There is a general CO$_2$ reduction from industrial processes in all scenarios due to change of technology within aluminium industry.

When implementing the reference climate targets in 2020, the CO$_2$ emissions compared with the BaU scenario are reduced by 50% within the industry sector, by 35% within transportation and by 25% within fishery. When the climate target are strengthened further (RES-30%), the CO2 emissions from the transport sector are reduced with additionally 15% compared to the BaU scenario. Within the transport sector, there is a transfer from fossil based fuels to hydrogen and bio fuels (see chapter 2.2.3).

In 2010 and 2015, there is a small share of CO2 emissions from transformation in the RES 30% scenario, steaming from hydrogen production based on coal and oil. In year 2020, when Iceland has a climate target, hydrogen is instead produced from biomass.

There are no investments in carbon capture and storage (CCS) technologies.

![Figure 4.1 CO$_2$ emissions](image-url)
4.2 Costs

In this study, the total system cost for all modeled countries and during the entire modeling is simultaneously minimized for each scenario. The resulting total costs for the Icelandic energy system are presented in Table 4.1. The total system cost increases with increasing climate targets. There are only minor differences in yearly costs of renewables as percentage of GDP between the scenarios, see Table 4.2.

Table 4.1 The total System for the Icelandic energy system during the entire modelling period in billion EUR_{2000}.

<table>
<thead>
<tr>
<th></th>
<th>BaU</th>
<th>RES</th>
<th>RES-T</th>
<th>RES-30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>-</td>
<td>-0,3</td>
<td>-0,3</td>
<td>-0,3</td>
</tr>
<tr>
<td>Fixed</td>
<td>3</td>
<td>0,0</td>
<td>0,0</td>
<td>-0,1</td>
</tr>
<tr>
<td>Variable</td>
<td>24</td>
<td>0,0</td>
<td>0,0</td>
<td>-0,2</td>
</tr>
<tr>
<td>Tax/Subsidy</td>
<td>0</td>
<td>0,0</td>
<td>0,0</td>
<td>0,0</td>
</tr>
<tr>
<td>Welfare Loss (Elast Dem)</td>
<td>0</td>
<td>0,9</td>
<td>0,9</td>
<td>1,6</td>
</tr>
<tr>
<td><strong>TOTAL (excl Trade)</strong></td>
<td><strong>39</strong></td>
<td><strong>0,6</strong></td>
<td><strong>0,6</strong></td>
<td><strong>1,0</strong></td>
</tr>
</tbody>
</table>

Table 4.2 The yearly average cost of renewables as a % of GDP.

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaU</td>
<td>0,01%</td>
<td>0,6%</td>
<td>0,7%</td>
<td>0,8%</td>
</tr>
<tr>
<td>RES</td>
<td>0,01%</td>
<td>0,6%</td>
<td>0,8%</td>
<td>1,1%</td>
</tr>
<tr>
<td>RES-T</td>
<td>0,01%</td>
<td>0,6%</td>
<td>0,7%</td>
<td>1,1%</td>
</tr>
<tr>
<td>RES-30%</td>
<td>0,01%</td>
<td>0,8%</td>
<td>0,9%</td>
<td>1,1%</td>
</tr>
</tbody>
</table>

5. Conclusions

The yearly electricity generation increases over time in all four scenarios. It is mainly hydro power that increases while the geothermal power is constant. The share of renewables increases more in the RES scenarios than in the BaU scenarios but this is solely a consequence of that the final energy use, and thus the primary energy supply, is increasing with time in the BaU scenario while it is decreasing in the RES scenarios.

Hydrogen is used within the transport sector in all three RES scenarios but to a much larger extent in the RES-30% than in the other two. Biofuels are imported in 2020. Despite the increase of renewables within the transport sector, the overall use of renewables is only slowly increasing over time and there are no major differences between the four scenarios.

CO2 emissions are remarkably lower in the three RES scenarios than in the BaU in 2020, however, there are only minor emissions reductions taking place before 2020.
6. References


Federation of district Heating, Electricity utilities and Waterworks (Samorka): *www.samorka.is*


Statistic Iceland (*http://www.statice.is/*)
IRELAND
1. Introduction

This chapter describes the modelling outcomes for Ireland within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).
- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Ireland this means 16 % share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO₂ emissions cap of 27 Mtons.
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/export are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

The current energy system of Ireland is dominated by the use of oil, having a share of almost 60%. The large shares of gas, and coal and peat, 23% and 18% respectively, emphasize the strong dependence on fossil fuels. The use of renewable energy is very limited, contributing a 2.7% share of the primary energy in 2006.

On the demand side, the transport sector is responsible for the largest share of the final energy demand, in 2005 some 40%. Residential sector is the next largest consumer with a share of 23%, followed by the industry (20%), commercial and services sector (14%) and agriculture (3%) (SEI, 2006).

The electricity production mix of Ireland is almost fully fossil based; in 2005 gas, coal, peat and oil had shares of 40%, 28%, 10% and 15% respectively, while wind and hydro together had a share of no more than 3.5% (SEI, 2006).

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17 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
The level of demand for energy services is strongly dependant on the level of population and GDP. In 2000 Ireland had 3.8 million inhabitants, while the GDP was 105 million Euros. The assumed developments of population and GDP growth in Ireland are given in Table 1.1

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population growth</td>
<td>1.7%</td>
<td>2.3%</td>
<td>1.8%</td>
<td>1.4%</td>
</tr>
<tr>
<td>GDP growth</td>
<td>3.9%</td>
<td>3.7%</td>
<td>3.2%</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

A White Paper released in March 2007 sets out the Government’s Energy Policy for 2007-2020. The Government commits to have a share of 15% of renewable electricity generation by 2010 and 33% by 2020 and set a target share for renewable heating of 5% in 2010 and 12% by 2020. (D2.2 and D2.3).

In order to fulfill these goals, the government has established a set of different kinds of support measures, more detail on which can be found in deliverables D2.2 and D2.3.
2. Renewable technology deployment

2.1 Primary and final energy use

In the year 2000, the primary energy portfolio of Ireland was dominated by the use of oil, which had a share of almost 60%. The strong dependence on fossil fuels was emphasized by the large shares of gas and coal, 23% and 18% respectively. Renewable energy sources only had a share of 1% and also a small amount of electricity was imported. During the following decades, the total primary energy use is expected to increase gradually. In the BaU scenario the total primary energy use in 2020 is 25% higher than it was in 2000. In absolute terms, especially the use of oil, gas and renewables will grow. In relative terms, the growth of renewable sources is especially rapid, with renewables reaching a share of 11% of total primary energy use. In 2020 Ireland will export some electricity.

In the renewable scenarios, the total primary energy use will first increase, but after 2015 the trend is decreasing and in 2020 less energy is used compared to 2015. Energy reductions following from the policies are between 9% and 12%, compared to the BaU scenario. The reductions especially hit coal consumption, although gas and oil use are also reduced (but have still similar shares as in the BaU scenario). The use of renewables is increased, 32% in the RES, 37% in RES-T and 33% in the RES-30% scenario.

![Diagram showing primary energy supply]  
Figure 2.1 Primary energy supply

As was the case with primary energy, oil also dominates (share of 65%) the energy use on the level of final energy use. In addition to the transport sector, oil is also one of the main fuels for heat production and even some electricity is produced from oil. Renewable energy sources have an insignificant share of 2% of the final energy use in 2000.

The current trend of rapidly increasing energy use is continued during the next decades; in the BaU the total final energy use in 2020 is 40% higher than it was in 2000. In absolute numbers the use of all energy...
carriers, except coal, is increased. On the final level, the shares of the main fossil energy carriers, oil and gas, remain the same. The use of bio-energy and renewable electricity is in 2020 8 times higher than it was in 2000, giving a total share of 11% for the renewable energy carriers. However, although the use of renewable energy increases fast and a relatively high renewable share is reached with the policies currently in place, the 16% share, as required in the RES directive, is not reach in the BaU scenario.

As can be expected, the use of renewable energy is increased in the RES scenario, where explicit requirements are imposed for the use of renewables; the share of renewables is even higher as required, some 17%. This means that the increased use of renewable energy is not only driven by the renewable target, but also climate target and biofuel target for the transport sector influence the numbers. More specifically, the increase of bio-energy corresponds to an increase of biofuels needed to fulfil the biofuels target. Also, since the Non-ETS target is not binding for Ireland, the additional renewables are used to reach the European climate target. In addition to the increase in the use renewable sources, the policy targets also lead to a decrease of 7% in total final energy consumption (mainly due to a decline in oil use).

In the RES-T scenario the use of renewable energy is increased further, beyond the numbers of the RES scenario. This implies that not only is it economic to use more renewables in Ireland to reduce emissions, but Ireland can also benefit from its renewable resources by exporting green certificates and therefore helping other European countries to reach their targets. However, although Ireland profits from the export gains from certificates, the increased use of renewable energy leads to higher domestic energy prices and therefore to additional energy use reductions.

The more stringent climate constrained in RES-30% scenario leads to only a little more renewable electricity than the RES scenario does, showing that a deeper climate mitigation target cannot drive the use of renewable energy much further. Instead of that, oil use is being replaced by gas and additional energy reductions are realised. As a result of the reductions, the share of renewable energy in the RES-30% is a little higher than in the RES scenario.

Figure 2.2 Final energy use
2.2 Use of renewable energy sources

In 2000 the use of renewable energy was very limited. Of the little that was used, half was converted in the industrial sector, some was used for power production and some for the residential sector. As mentioned above, the use of renewable energy carriers increases fast after 2000 and the distribution over the sectors will also be completely different by 2020. The use of renewables increases most in the central heat and power production sector and, due to the sector specific biofuels target, the use of renewables in the transport sector becomes the second most important consumer of renewable energy by 2020. The use of renewable energy in households is also increased, while the industrial sector remains in absolute terms moderately unimportant, despite almost doubling its renewable consumption. With the explicit renewable policies assumed for the RES scenarios, the use of renewable energy carriers in the central heat and power production and the transport sector further increased. The subsections below will discuss the differences across the three policy scenarios in more detail.
2.2.1 Electricity generation

The electricity production palette of Ireland was in 2000 almost fully fossil based; gas, coal and oil had shares of 46%, 31% and 21% respectively, while wind and hydro together had a share of no more than 2.5%. The use of electricity is expected to grow significantly, with the electricity production being in 2020 40% higher than in 2000. The model results also imply that clear changes may happen also in the structure of the production portfolio. From 2010 on electricity production from oil is replaced by increased use of gas. Additionally, the importance of wind and coal keep growing and by 2020 gas, renewable energy and coal all three have similar shares.

In the RES scenario, electricity production from coal is lowered considerably and by 2020 coal contributes only some 50% of what it does the BaU scenario. In addition to the 7% reduction in total electricity demand, the gap left by reduced coal based power production is mainly filled with wind, which reached its assumed maximum potential. This large expansion of wind brings the share of renewable electricity to almost 50% by 2020. The trade of certificates in the RES-T scenario does not change the production mix significantly. However, some additional hydro power is built.

Although there is a slight increase in the use of renewables for power production in the RES-30% scenario, a more significant change is the replacement of coal by gas. Furthermore, in order to make even deeper cuts in emissions, by 2020 all remaining coal fired power plants are equipped with carbon capture and storage.
Figure 2.5  *Total electricity generation*

Figure 2.6  *Electricity generation from renewable energy sources*
2.2.2 Heat production

In the beginning of the period under study, in the year 2000, 50% of all heat was produced from oil. The second most important heating fuel was gas, whereas renewables had a share of merely 3%. In the BaU scenario, energy use for heating is in 2020 is 30% higher than in 2000 and although oil is still the dominating fuel for heating, the importance of gas and renewables increases. The increase in the use of renewables is mainly due to an expansion of bio-energy use in the residential sector.

Under the implemented renewable and climate target in the RES scenario, the trend of fast growing energy use for heating is changed into a moderate growth between 2010 and 2015, followed by stabilisation. Compared to the BaU scenario energy use is reduced 12% in 2020, mainly due to decreased use of oil. The use of renewables for heat production is increased a little, due to a higher share of renewable electricity. The possibility of exporting green certificates in the RES-T scenario creates an incentive for further expansion of bio-energy for heating.

The use of renewables in the RES-30% scenario is very similar as in the RES scenario, indicating that the more stringent climate target does not create the same incentive the trade of green certificates does. However, since the total energy use for heating is decreased with respect to the BaU scenario, the share of renewable energy use for heating is increased.

![Figure 2.7 Total input for heat production](image-url)
2.2.3 Transport fuels

The energy demand of the transportation sector increases very fast between 2000 and 2010, after which the growth is much more moderate. By 2020 the transport sector uses 57% more energy than in 2000. Biofuels penetrate the transportation sector, but only due to the implemented target; the amount of biofuels is just enough to fulfill the sector specific target, but no more. In contrast to electricity and heat production sectors, there are no energy savings or demand reduction in RES and RES-T, compared to the BaU scenario, and only a very little in RES-30%. In all three renewable scenarios, 25% of the biofuels is imported bio-ethanol, another 25% biogas and the remainder is bio-diesel. In the BaU mainly bio-diesel is used.
Figure 2.9  Conventional and non-conventional transport fuels

Figure 2.10 Development of non-conventional transport fuels
3. Trade and import dependency

Ireland is completely dependent on oil imports from other countries. As was seen in the previous sections, the use of oil will increase and even in relative terms the importance of oil decreases only a little, having a share of 60% of primary energy supply in 2000 and around 50% in 2020. The import dependency of Ireland is further emphasized by its increasing gas consumption, since also for this Ireland is dependent on other countries (depending of the total use of each scenario, by 2020 50%-60% of the gas has to be imported). The coal imports in the renewable scenarios are lower than in the BaU scenario, however, the domestic production of coal is even more decreased and as a result of that a higher share of the coal is imported in the RES-scenario (90% in the renewable scenarios and 75% in the BaU scenario).

![Net import / export of fossil energy carriers](image)

**Figure 3.1 Net import / export of fossil energy carriers**

In contrast to fossil fuels supply, electricity imports in 2000 were some 7% of total consumption and the model results suggest that in the future Ireland may export around 7% of its total electricity production. Ireland will also export domestically produced bio-diesel to other countries in Europe, while simultaneously it imports bio-ethanol from the rest of the world for the transportation sector. In the RES-T scenario slightly less biofuels are exported and more bio-energy is used domestically.
As was mentioned previously, Ireland will be a seller of green certificates in 2020, in the RES-T scenario.

Figure 3.2 Inter-EU trade and import from outside EU27 of biofuels and electricity

Figure 3.3 Virtual trade of renewable energy in the RES Trade scenario
4. Impacts of policies on emissions and costs

4.1 Emissions

In the BaU scenario the CO₂ emissions increase 20% between 2000 and 2020, the main culprits for the increase being the industry and the transport sectors, covering together some 50% of total CO₂ emissions. In the renewable scenarios the growth of total emissions keeps initially increasing fast, but from 2010 almost no growth can be seen and after 2015 emissions start declining; the difference between BaU and the RES scenario in 2020 is 9 Mton CO₂. Of this reduction 5Mton is realised in the power sector, representing 37% of the power sector emissions in the BaU scenario. Emissions in all other sectors decrease also, varying from a couple percent to a 45% reduction of emissions in the commercial and services sectors. The implemented emissions cap of non-ETS sectors is not binding.

In the RES-T scenario slightly more domestic emission reductions are done due to increased production from electricity from renewable energy.

Also in the RES-30% additional emission reduction are realised, especially in the power sector. Most of these reductions are realised through the expansion of carbon capture infrastructures, implemented to coal power plants. The captured CO₂ is stored in depleted gas fields.

4.2 Costs

Table 4.1 shows the total costs of renewable technologies, both as an absolute number as well as a share of GDP. Total costs of renewable technologies are similar across the three renewable scenarios and higher than in the BaU scenario.

<table>
<thead>
<tr>
<th>Total costs of renewable energy technologies [M€]</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaU</td>
<td>256</td>
<td>701</td>
<td>863</td>
</tr>
<tr>
<td>RES</td>
<td>270</td>
<td>793</td>
<td>1130</td>
</tr>
<tr>
<td>RES-T</td>
<td>299</td>
<td>819</td>
<td>1204</td>
</tr>
</tbody>
</table>
5. Conclusions

With only current policies in place (BaU scenario), the model suggests that the share of renewable energy on the final level will increase significantly from 2% in 2000 to 11% in 2020. The largest increase of renewable energy can be seen in wind power, bio-energy use in households and biofuels for transport. The latter is driven by the implemented biofuels target, reaching a share of 6% of total road transport in 2020. During the same time frame CO₂ emissions are expected to grow, being some 20% above the levels of 2000 in 2020.

The renewable and climate targets implemented in the RES scenario lead to a share of renewable energy of 17%, this is slightly higher than the target of 16%, implying that the use of renewable is not only driven by the renewable target, but also climate target and biofuel target for the transport sector influence the numbers. Since also the national climate constraint on emissions of non-ETS sectors is not binding and the increase of bio-energy corresponds to an increase of biofuels needed to fulfil the biofuels target, the additional renewables are used to reach the European climate target. Most important is the further extension of wind power. In addition to the increase in the use renewable sources, the policy targets also lead to a decrease of 7% in total final energy consumption. Finally, the export of biofuels to the rest of Europe is increased.

When given the chance of virtual green certificates trade in the RES-T scenario, Ireland will increase the use of renewable energy beyond the numbers of the RES scenario and sell certificates and so helping other European countries to reach more economically their targets. In particular the use of bio-energy for heating and the production of renewable electricity are increased. The statistical transfer mechanism makes lowers the export of biofuels.

To reach the additional emission reductions in the RES-30% scenario, carbon capture and storage of CO₂ emissions from coal power plants is of great importance. The amount of renewable energy on final level and the production of renewable electricity do not increase significantly any further. The latter mainly because the assumed limits for the extension of wind power were already met in the RES scenario.

6. References

1. Introduction

This chapter describes the modelling outcomes for Italy within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).
- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Italy this means 17% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO₂ emissions cap of 242.5 Mton.
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% instead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Italy has few natural resources; the country's most important mineral resource is natural gas, whose proven reserves have grown in recent years. Most raw materials needed for manufacturing and more than 80% of the country's energy sources are imported (86.8% in 2005, according to EREC 2008). Italy imports mainly oil, natural gas, LNG (Liquefied Natural Gas), coal, coke and lignite whilst Italian exports are natural gas (in a very small amount) and coke.

Italy is a net importer of electricity from neighbor countries, with an import/export balance of 49.2 TWh but is also a major power producer. According to (GRTN, 2006) at the end of 2005 Italy counted on a gross capacity of power plants of 88.3 GW (14% of the EU15 capacity and 2% of the World capacity), and on a total gross electricity production of 303.7 TWh, with a net production of 281.3 TWh (EU15: 2450 TWh).

As concerns power generation from fossil fuels, oil has been for many years the principal energy source but in the last years thanks both to an increasing concern for the environmental issues and to the diffusion of CCGT technologies, natural gas has surpassed oil, representing nowadays the first energy source for

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18 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
power generation in Italy (WEC, 2002). This is particularly true for CHP plants (that represent 58% of the total gross production), where natural gas provides 44% of the CHP production, followed by oil (39%) and coal (12%). For conventional power plants it can be noticed an opposite situation: natural gas provides 36% of the production versus the 46% of oil (39%), whereas coal gives 16%.

Although Italy produces nearly three quarters of its power from fossil fuels it should be remembered that Italian power industry was a pioneer in exploiting renewable energy sources in electricity generation (WEC, 2002). The share of RES in the gross electricity production was 16.6% in 2006 with 52.3 TWh, compared to 261.8 TWh of conventionally energy produced (EREC, 2008). In general, thermoelectric power provides the base-load production whereas peak-load demand is satisfied by hydroelectric and turbo-gas power. As a matter of fact, hydropower is one of the most important energy resources in Italy representing in 2005 24% of the total installed capacity supplying 16.6% of total gross electricity production (EREC, 2008).

High and low temperature geothermal resources represent 2% of the total gross electricity production, being Italy the most important producer of geothermal electricity in Europe. Biomass energy accounts for 25% of all primary energy from RES (excluding plants fuelled also from waste): in 2006 there were 2565 plants in operation producing 4.8 TWh, with an installed capacity of 2470 MW. In the same year, wind energy reached 2100 MW of installed capacity.

The share of RES in total primary energy consumption was of 6.82% in 2006 (4% in 2000), 5.2% in the gross final energy consumption in 2005 (5% in 2000) whereas biofuels had a 0.52% share in the transport sector (EREC, 2008).

Despite a strong growth in sectors such as onshore wind, biogas and biodiesel, Italy is far from the targets being the share of RES-e in the total electricity consumption (2006) of about 16.6% whilst the target is of 25% by 2010 even if the Italian government declared that a more probable deliverable target would be 22%. This is mainly caused by a large element of uncertainty due to political changes and ambiguities in current policy design, administrative constraints such as complex authorization procedures at local level, and financial barriers such as high grid connection costs (EREC, 2008).

The Italian government is working out the details of more ambitious support mechanisms for the development and use of RES moving towards a feed-in tariff-based renewable energy rebate scheme, similar to successful models implemented in Germany and Spain. At now a national building law for solar thermal installations and for increasing the market penetration for RES-H & C technologies (more details can be found in EREC, 2008).

According to the nuclear power referendum of 1987, Italy rejected the expansion of new nuclear power plants and the existing ones were phased out the year later. Thus the activation of nuclear power plants is not allowed on the whole time horizon nor in the reference scenario neither in the RES alternative scenarios (RES2020, 2009).

Future energy service demands were based on population (Eurostat statistics) and macro-economic projections (GEM-E3 model’s outputs). Table 1.1 resumes the population annual growth rates for Italy as well as the average GDP annual growth rates, based on a GDP level, in 2000, of 1191.1 million euro (RES2020, 2008).

Table 1.1: Annual growth rates for Italy

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Population</td>
<td>0.5%</td>
<td>0.5%</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>GDP</td>
<td>0.6%</td>
<td>2.4%</td>
<td>2.5%</td>
<td>2.5%</td>
<td>2.3%</td>
<td>2.2%</td>
</tr>
</tbody>
</table>
2. Renewable technology deployment

2.1 Primary and final energy use

In the base year the most important contribution to the primary energy consumption is due to oil and natural gas consumption, respectively 55% and 33% (figure 2.1), that are mainly imported. Regarding renewables (307 PJ), the main contribution to electricity generation is deployed by hydropower (180 PJ).

In the BaU scenario the total primary energy consumption increases by 5% in 2020 with respect to the base year, in agreement with the increasing demand. Renewables consumption doubles in 2020 respect to the base year, reaching 9%. The most important contribution is due to solar (from 0.5 PJ in 2000 to 174 PJ in 2020) and wind (from 2 PJ in 2000 to 30 PJ in 2020). Also coal and gas consumption increase constantly on the time horizon, reaching respectively +4% and +39% in 2020 respect to the base year. On the contrary, oil consumption reduces by 22%.

Figure 2.1 Primary energy supply

In the RES scenarios total primary energy consumption decrease (-4% in RES Reference and RES Trade and -6% in RES Climate), but renewables consumption is tripled in 2020 respect to the base year, to fulfill the European directive. Also gas consumption increases in 2020 (about +8% in RES Reference, +9% in the RES Trade and +7% in the RES Climate). At the same time oil consumption decreases respectively about -26% in RES Reference and RES Trade and -28% in the RES Climate). A similar behavior can be observed for coal consumption (-13% in RES Reference and RES Trade, -8% in RES Climate).
Figure 2.2 Final energy use

Following the demand trends, the total final energy use increases from 5242 PJ in the base year to 6043 PJ in 2020 for the BaU scenario, as shown in Figure 2.2, renewables’ share increasing from the initial 5% to 10% in 2020.

In RES Reference and RES Climate, renewables’ share in energy use achieves the 17% target set by the EC, but the climate target is ineffective to foster an additional use of renewables.

In RES Trade, renewables share doesn’t fulfill the target, being lower than 17% in 2020. The target is hence achieved by purchasing green certificates for an amount of about 18 PJ in 2020.

Figure 2.3 Final energy use of a) non-renewables and b) renewables

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation.
Regarding non-renewable fuels consumption (Figure 2.3 a), oil and gas are the most used fuels in the base year (respectively about 47% and 34%). In the BaU scenario they are still predominant on the entire time horizon, whereas a steady reduction of oil consumption is observed (its share is about 42% in 2020) and a slight increase of gas up to 37%. As concerns electricity consumption, there is an increased production by non-renewable sources (from 763 PJ in the base year up to 877 PJ 2020). The exogenous constraints on renewables use induce a reduction in non-renewable fuels consumption in the RES scenarios, that ranges from -13% in RES Reference and RES Trade to -15% in RES Climate. The most important contribution to the decrease of fossil fuel use is given by a steady decrease of the electricity produced from non-renewable sources (-36% in RES Reference, -35% in RES Trade and -39% in RES Climate).

On overall, an increase of final energy use of renewables along the time horizon can be observed in all scenarios (figure 2.3b). In particular, already in the BaU scenario renewables quota in final energy use increases from 264 PJ in year 2000 to 600 PJ in year 2020. In the RES scenarios the use of renewables is obviously enhanced (+55% in RES Reference, +52% in the RES Trade and +50% in RES Climate). The higher contribution is given by the electricity produced from renewables (258 PJ in BAU, 414 PJ in RES Reference, 451 PJ in RES Trade and 411 PJ in RES Climate). An important contribution is also given from bio-energy, in particular, from biofuels in the Transport sector.

### 2.2 Use of renewable energy sources

In the base year the use of renewables (figure 2.4) is about 268 PJ, of which 175 PJ are consumed for electricity and heat production and 93 PJ in end-use sectors (58 PJ from Residential, 29 PJ from Industry and 6 PJ from Agriculture).

In 2020, renewables consumption increase noticeably in all scenarios, fostered by the exogenous constraints set in compliance of the EU directives on energy and climate.

In the BaU scenario, renewables use reaches 577 PJ, of which 226 PJ for electricity and heat production. A high increase can be noticed in Residential (+221 %) in which renewables consumptions account for about 186 PJ due mainly to the use of wood products (57 PJ) and solar thermal (128 PJ) that substituting oil products in fulfilling space heating and water heating demand. In Transport oil consumption are still predominant (in fact, they increase from 1698 PJ up to 1822 in 2020) but biofuels contribute to fulfill the increase of demand accounting for about 123 PJ in 2020. On the contrary, in this scenario, renewables are still not used in the Commercial sector on the full time horizon.

In the RES scenarios the use of renewable energy sources increase up to 868 PJ (of which 343 PJ for electricity and heat production). In Residential there are not remarkable differences respect to the total amount consumed in BAU, that keeps around 186 PJ with the exception of the RES Climate scenario that shows a slight decrease (182 PJ). The amount covered by solar thermal is about 33 PJ in RES Reference, 31 PJ in RES Climate and 25 PJ in RES Trade.

On the other hand, a consistent use of renewables is observed in the Industry sector, with more evident differences between the scenarios, renewables use being respectively 152 PJ in RES Reference, 88 PJ in RES Trade and 139 PJ in RES Climate scenarios.

A high increase in renewables consumption can be also noticed in Transport comparing the RES scenarios with BaU (+41% in RES Reference and RES Trade; +33% in RES Climate).
2.2.1 Electricity generation

In the base year the electricity production is about 259 TWh (40% from gas, 30% from oil, 21% from renewables and 9% from coal). In accordance with the current national policies, nuclear is not foreseen.

In the BaU scenario the RES share in total electricity production increases slightly on the full time horizon, achieving the 23% in 2020 (corresponding to about 75 TWh). Electricity production by oil products is reduced remarkably already in 2010 (from 77 TWh of the base year to 45 TWh) and it is nearly cut off in 2020 (about 2 TWh). This reduction is counterbalanced by a huge increase of electricity production from gas that is almost doubled respect to the base year, due to the use of combined cycle power plants, and a lower increase of electricity production from coal (about 38%, from 24 TWh in 2000 to 33 TWh in 2020).

In the RES scenarios a strong reduction of electricity production from gas and oil is observed whereas in RES Reference and RES Trade electricity production from coal decreases about 20%. Moreover, the overall electricity production decreases respect to the BaU scenario (-17% in RES Reference, -16% in RES Trade and -18% in RES Climate, in 2020) and renewables share achieves 43%, corresponding to about 118 TWh.
Among renewables, hydro is by far the most important energy source for electricity production. In fact, in the base year hydro accounts for about 48 TWh (corresponding to the 89% of total renewables consumption for electricity production), geothermal for 4.4 TWh and wind for 0.6 TWh. In the BaU scenario total electricity production from renewables increases from 53 TWh of the base year to 75 TWh in 2020. On the full time horizon, hydro contribution decrease to 44 TWh whereas wind and solar share increase respectively to 8.4 TWh and 13 TWh in 2020. A steady increase of biomass is also observed, which share in 2020 is about 5 TWh.

The RES scenarios show very similar results: hydro is still the most used renewable energy source with a 45 TWh share. The electricity production from wind increases very remarkably (up to 38.2 TWh), the contribution from solar is almost constant (nearly 13 TWh) and geothermal share is about 6.3 TWh.

Figure 2.5  *Total electricity generation*
2.2.2 Heat production

Natural gas is the most used fuel for heat production on the entire time horizon in all scenarios, as shown in figure 2.7. In the base year gas share is 62%, oil share is 20% whereas coal, electricity and renewables shares are less than 10% (respectively 8%, 5% and 5%). In the BaU scenario, on the full time horizon gas and renewables share increase respectively to 69% and 9%, whereas oil contribution decrease to 8%.

In the RES scenarios total fuel consumption decrease -9% respect to the BaU scenario. As concerns fuels mix for heat production, a remarkable reduction of electricity (-50%) and oil (-22%) is observed. On the contrary renewables increase +49% in RES Reference and +42% in RES Trade and RES Climate scenarios with a 16% share in RES-Reference and 15% in RES-Trade and RES-Climate scenarios.

Heat production from district heating increases from 1.4 PJ in 2000 to 3.8 PJ in 2020 in all scenarios, with a prevailing use of coal technologies. A similar trend is observed from public co-generative technologies, which share increase from 10 PJ to 17 PJ in 2020. On the contrary heat production from industrial co-generative technologies decrease. The most relevant difference is observed in the BaU scenario, in which their share decrease from 187 PJ in the base year to 32 PJ in 2020. In the RES scenarios their contribution is about 80 PJ, mainly due to a larger use of steam turbinecondensing using biomass.

As concerns heat production from renewables (figure 2.8) solar thermal, which is not utilized in the base year, gives its maximum contribution in 2020 in Residential and Commercial for water heating. Its share is respectively 47% in the BaU scenario, 40% in the RES Reference, 20% in RES Trade and 21% in RES Climate.

Analogously, in the BaU scenario the use of bio-energy increases from 81 PJ in the base year to 95 PJ in 2020. Moreover, this increase is more remarkable in the RES scenarios, their share being respectively 186 PJ in RES Reference, 172 PJ in RES Trade and 178 PJ in RES Climate.

The use of electricity for heat production in Commercial and Residential sectors is about 35 PJ in the base year and increases up to 50 PJ in 2020 for the BaU scenario, with an additional 20% increase in the RES scenarios.
Figure 2.7 Total input for heat production

Figure 2.8 Heat production from renewable energy sources
2.2.3 Transport fuels

In the base year non-fossil consumption represents the 2% of total consumption, mainly imputable to electricity consumption for electric rail transport. The most used fuels are obviously diesel and gasoline, each with a 45% share. On the full time horizon gasoline consumption decreases to 34% in 2020, whereas diesel consumption increases to 52%, mainly due to new cars. A 5% share is covered by LPG which is cut off by 2010 in the BaU scenario as well as in the RES scenarios. The RES scenarios show also a similar trend in electricity and gas consumption. Moreover, in RES Reference and RES Trade, gasoline share is further reduced to 27% whereas diesel consumption increases up to 56%. The difference between diesel and gasoline share is even more remarkable in the RES Climate Scenario, in which diesel share is 65% and gasoline one 18%.

Figure 2.9 Conventional and non-conventional transport fuels

In the BaU scenario renewables consumption is 123 PJ (representing the 6% of transport consumption in 2020), made up mainly by first generation fuels, used to fulfil trucks and car demand (e.g. bio-diesel - about 84 PJ- and bio-ethanol blended to diesel -about 32 PJ). A small amount of bio-methanol (9 PJ) and biogas (6 PJ) is consumed to fulfil bus and car demand. In the RES scenarios non-conventional fuels share reaches 11% in 2020. Respect to the BaU scenario bio-diesel consumption increase up to 139 PJ in both RES Reference and RES Trade scenarios and up to 147 PJ in RES Climate. Small variations are also observed in bio-methanol consumption.
Remarkable changes can be observed for the net imports of oil products and gas from outside of Europe (Figure 3.1). In fact, already in the BaU scenario the net imports of oil products decrease from the initial 3818 PJ of the base year to 2982 in 2020. This variation is mainly due to a decrease in primary energy consumption of oil products in the conversion sector. In the RES scenarios, in 2020, a 5% further reduction respect to BaU can be observed in RES Reference and RES Trade, which increase up to -9% in RES Climate. On the other hand, in 2020 the net imports of gas increase from 1777 PJ to 2891 PJ in the BaU scenario (+63%) and to about 2168 PJ in the RES scenarios(+22%). In 2020, the net imports of coal increase about 4% in the BaU scenario, and decrease respectively -13% in RES Reference, -14% in RES Trade and -7% in RES Climate.

As concerns inter-EU trade and imports of electricity and bio-fuels from outside of Europe, in the base year the import of electricity from European Countries is 147 PJ and from outside Europe is 38 PJ whereas the import of wood products is about 20 PJ. On the full time horizon bio-diesel and bio-ethanol imports are foreseen to compensate the absence of a domestic production. Concerning the model’s results, the import of electricity from outside Europe is cut off in 2020 and the import from European Countries decrease respectively -28% in BAU, -19% in RES Reference, 21% in RES Trade and 21% in RES Climate respect to the base year value.

On the contrary wood products and biofuels imports increase, achieving respectively a share of 29 PJ for wood products and 31 PJ for bio-ethanol from outside Europe, 59 PJ for bio-diesel from European Countries.

In 2020 in RES scenarios bio-fuels import increases remarkably (+43% both in RES Reference and RES Trade scenarios and +34% in the RES Climate respect to BAU). In particular, in the RES scenarios biodiesel imports are doubled and bio-ethanol import decrease about -15% in RES Reference and RES Trade Scenarios and -83% in RES Climate scenario.
As shown in figure 3.3 in 2015 Italy is a seller of green certificates to the other EU countries for an amount of about 18 PJ. The situation is completely reversed in 2020, in which the same amount is pur-
chased by Italy. However, it should be noticed that the trade of green certificates concerns only the electricity quota produced by renewables, that in the model representation is independent from the end-use sectors. These results emphasise the necessity of improving the representation of the electricity production modes, taking into account the environmental value of the electric energy produced by renewables in compliance with the Kyoto commitment.

![Virtual trade of renewables energy in the RES Trade scenario](image)

**Figure 3.3** Virtual trade of renewables energy in the RES Trade scenario

4. Impacts of policies on emissions and costs

4.1 Emissions

In the BaU scenario the total CO₂ emissions decrease from 455 Mton to 445 Mton on the full time horizon. The slight reduction is mainly determined by a more consistent reduction in conversion sector (a 31% reduction is achieved in electricity and heat production, from the initial 124 Mton of CO₂ in the base year to 86 Mton in 2020). In fact, on the other hand, the CO₂ emissions from non-ETS sector increase about 8% (from 226 Mton in the base year to 245 Mton in 2020). The highest increase can be observed in the Commercial sector (about 47%, from 17 Mton in the base year to 25 Mton in 2020).

In the RES scenarios a consistent reduction of CO₂ emissions can be observed, with similar trends for sectoral and total CO₂ emission.

In RES Reference the total CO₂ emissions decrease up to 386 Mton (-13% respect to BaU in 2020). A reduction of about 12 Mton is achieved in the non-ETS sectors, that results in a total sectoral amount remarkably below the national target of European directive (about 233 Mton of CO₂). Also in this case a noticeable contribution to CO2 emissions reduction is given by the electricity and heat production, whose emissions decrease by about 29 Mton.

In RES Climate a 21% decrease respect to BaU is observed in 2020 (the total CO₂ are about 353 Mton) with a reduction of 48 Mton in electricity and heat production, 22 Mton in Industry and 11 Mton in
Transport, 11 Mton from other end-use sectors for an overall amount of 92 Mton. On overall, the emissions of non-ETS sector are about 224 Mton, showing a 4% reduction respect to the national target.

4.2 Costs

The differences among total costs are very small, ranging from 3797 Billion Euro (BAU) to 3800 Billion Euro in RES Climate. The total discounted system’s cost is obviously the highest in RES Climate, driven by a tighter target on CO₂ emissions, but on overall it does not differ remarkably in the four analyzed scenarios, also because there is a demand-driven effect not accountable for. However, the comparison of its components shows that the highest value in RES Climate is due to both higher investments and welfare loss. On the other hand, the fixed and variable operating costs play a major role in the BaU scenario. The RES Reference and RES Trade scenarios show very similar values therefore it can be concluded that, in terms of costs these are the most convenient policy options.

A more detailed analysis along the time horizon (Table 4.1) points out that all the RES scenarios have remarkably higher investment and operational costs of renewable technologies after 2015. In particular, RES Climate has the most expensive energy system’s configuration, as the achievement of the CO₂ target boosts an early utilization of renewables technologies.

Also from the analysis of the impact of total cost of renewable technologies on GDP (Table 4.2), it is evident the greater impact of the RES Climate scenario.

Table 4.1: Total investment costs and operational costs of renewable technologies

<table>
<thead>
<tr>
<th>Scenario/Period</th>
<th>2000</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total investment costs</td>
<td>BaU</td>
<td>3341</td>
<td>4719</td>
<td>7645</td>
</tr>
<tr>
<td>RES Reference</td>
<td>2</td>
<td>3192</td>
<td>6486</td>
<td>12387</td>
</tr>
<tr>
<td>RES Trade (RES-T)</td>
<td>2</td>
<td>3309</td>
<td>6517</td>
<td>11205</td>
</tr>
<tr>
<td>RES Climate (RES-30%)</td>
<td>2</td>
<td>3725</td>
<td>7209</td>
<td>14144</td>
</tr>
</tbody>
</table>
Table 4.2: Costs of renewable technologies as a percentage of GDP.

<table>
<thead>
<tr>
<th>Cost of Renewables as a % of the GDP</th>
<th>2005</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaU</td>
<td>0.01%</td>
<td>0.03%</td>
<td>0.06%</td>
</tr>
<tr>
<td>RES Reference</td>
<td>0.01%</td>
<td>0.03%</td>
<td>0.10%</td>
</tr>
<tr>
<td>RES Trade (RES-T)</td>
<td>0.01%</td>
<td>0.03%</td>
<td>0.09%</td>
</tr>
<tr>
<td>RES Climate (RES-30%)</td>
<td>0.01%</td>
<td>0.04%</td>
<td>0.11%</td>
</tr>
</tbody>
</table>

5. Conclusions

The present analysis of the Italy energy system under different policy assumptions in compliance with the EU Energy and Climate package is aimed to illustrate the optimized evolution pathway of the Italy energy system and the effectiveness of different policy instruments to the achievement of strategic energy and environmental targets at 2020.

The results show that in the BaU scenario the potential evolution of consumption is far from the achievement of the EU energy and climate targets, even if the renewables consumption increase remarkably (in 2020 renewables use in end-use sectors is about 10% in the BaU scenario mainly imputable to electricity consumption by solar and wind and bio-fuels consumption in the Transport sector).

According to the European Directive, Italy reaches 17% of final energy consumption in the RES Scenarios acquiring an amount of green certificates from the European Countries. This target is obtained following a remarkable increase of electricity production from wind source and bio-fuels consumption in the Transport sector compared to the BaU scenario. Electricity production from petroleum products is cut off, whereas contribution from gas technologies increases remarkably in the BaU scenario, being lower in the RES scenarios. In this way Italy reduces also net import of gas and petroleum product from European Countries.

As concerns CO₂ emissions, a huge reduction is achieved in the ETS sectors, mainly in electricity and heat production, however also the non-ETS sectors amount is remarkably below the national target of European directive.

In the RES Climate scenario, due to the tighter constraints, CO₂ emissions are further reduced mainly in the ETS sectors and Transport. The constraint on CO₂ emissions however has a scarce effect on renewable use, demonstrating that specific policies are necessary. In terms of costs and welfare losses, the RES Climate scenario is obviously the most expensive, as it requires an earlier deployment of more efficient technologies.

From the present results it can be seen that the model is very useful for the assessment of different policies and measures and further improvement of the database, an explicit specification of the policies in place and a peer-review from energy expert could lead to the definition of more effective operating strategies.
6. References


LITHUANIA
1. Introduction

This chapter describes the modelling outcomes for Lithuania within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Lithuania this means 23% share of RES in 2020 and for all sectors, which do not fall under the European Emissions Trading scheme a CO₂ emissions cap of 4.5 Mtons.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective, is 30% instead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/export are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Main components of the Lithuanian power system are Ignalina NPP, Lithuanian Power Plant, Krūonio HPSP plant and CHP plants in Vilnius, Kaunas, Mažeikiai and Klaipėda. In addition there are hydropower plant in Kaunas and some small power plant, altogether with total capacity of 6,156 GW.

In the Lithuanian energy supply nuclear energy has a share of 28% and natural gas 26%. whereby the share of oil remains on the level of 30.8%.

In 2005 in the electricity generation Ignalina nuclear power plant produced 70% country’s electricity, thermal power plants produced about 21%.

Installed capacity for heat production from solid biomass made up 440 MW by 2005 and for electricity production 16 MW.

Future of Lithuanian energy supply is set up in the National Energy Strategy. It proceeds from the growth of GDP (5% annual) and some decrease of the population (from 3.5 mill. in 2000 to 3.2 mill. in 2020).

National Energy Strategy includes installation of combined cycle gas-fired power plant, construction of a number of new CHP plants in Klaipėda, Panevėžys, and Šiauliai with total capacity of 400 MW:

19 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
The National Energy Strategy (NES) sets the target to increase the share of renewable energy resources:
- To increase the share of renewable to 12% in TPES by 2010 and 20% by 2025;
- To increase the share of renewable to 7% in the total electricity production by 2010 and 10% by 2025.

This target will be reached by promotion of construction of new wind power plants, small hydro power plants and CHP plants using bio fuel.

According to the EUC decision, the old Ignalina NPP has to be closed down by 2009. Reduction in power production will be compensated by increased energy generation in existing power plants and construction of new power plants using fossil fuels resulting in growth of GHG emissions and increase in electricity costs. The National Energy Strategy sets the target to construct new NPP in 2015. RES2020 projects for Lithuania for the period to the commissioning of the new nuclear power plant to cover the electricity demand by electricity import.
2. Renewable technology deployment

2.1 Primary and final energy use

So as about 26% of primary energy in Lithuania is nuclear, so the closing of Ignalina and construction of the new NPP, in the planning period determines the character of changes of the primary energy supply in this period. As it is see on the figure 2.1. For the time period from closing Ignalina NPP and commissioning of the new one the electricity demand will be covered by electricity and gas import mainly.

Figure 2.1 Primary energy supply
In 2006, the share of renewable energy in Lithuania was 9.1% of primary energy consumption, 92.1% of this renewable was wood and wood waste. As targets for RES there is set 23% of RES in the final consumption of energy in 2020. Here the RES target is binding at all time steps, so as there are no special problems with emissions in the energy sector of Lithuania.

a) Final energy use of non-renewable

b) Final energy use of renewable

Figure 2.2  *Final energy use*

Figure 2.3  *Final energy use of a) non-renewable and b) renewables* 1)

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation
2.2 Use of renewable energy sources

Main user of renewable energy sources is residential sector, commercial sector as usually consumes less green energy, and industry is the second renewable energy consumer. Coning up biofuels makes transport sector also a consumer of renewable energy.

![Diagram of renewable energy sources by sector]

**Figure 2.4**  
*Direct use of renewable energy sources in the different sectors*

### 2.2.1 Electricity generation

As renewable sources for electricity generation wood and wood waste and other biomass could be considered besides with hydro and wind sources. The target is set to have 7% of RES electricity consumption by 2010 and 10% by 2020.
Figure 2.5 Total electricity generation

By results of RES2020 main RES electricity will be generated from biomass in Lithuania. Existing wind resources are not much exploited here, but could be have the same share as it has hydro source.
2.2.2 Heat production

It is assumed, that the power output of CHP plants in Lithuania will increase to 20% by 2010 and 35% by 2025. In 2006 there was installed capacity for heat production from solid biomass to 400 MW. From
which 16 only was for electricity production from solid biomass. So, the rest of the 440 MW should be district-heating plants using wood or wood waste.

2.2.3 Transport fuels

The share of RES in biofuels in Lithuania was 1.72% in 2006 and is expected to be 5.75% by 2010 and 10% in 2020.

Figure 2.9 Conventional and non-conventional transport fuels Please describe in the text very short the existing mix in 2000 and if the case also the changes in the conventional fuels.

Figure 2.10 Development of non-conventional transport fuels

*Development of non-conventional transport fuels*
3. Trade and import dependency

Lithuania is depending heavily on natural gas and oil imports from outside of EU, from Russia. Therefore the trade could be considered inside EU, where on possible trade object could be blended biofuels, so as Lithuania is producing diesel and LPG from the crude oil imported from Russia and blended oils are in demand in neighboring countries.

Considering different scenarios there are not essential differences in the import quantities.

Figure 3.1 Net import / export of fossil energy carriers
As it was said above, Lithuania is in the perspective a net exporter of renewable. Only the level of export of the biomass could be discussable, so as the export amount by 2020 are near to the potential. Lithuania is able to produce all the kind of needed biofuels and has required land available.
4. Impacts of policies on emissions and costs

4.1 Emissions

The projection of GHG emission in Lithuania are considered to be growing from the level of 12.57 Mt in 2005 up to 25.1 Mt in 2020, if there will not be applied any measures for the greenhouse gas reduction. From this projections the energy industry gives 14.57 Mt by 2020, industry 2.2.0, transport 6.2 and other sectors 2.1 Mt. The scenarios applied in the RES2020 reduce the total emissions to the level of 15 Mt up to 2015 and to 12 Mt in 2020 by the scenario RES-30%.

![Graph of CO2 emissions](image)

Figure 4.1 CO2 emissions
4.2 Costs
The total investment costs by all scenarios remain on the level of 89 billion € with an accuracy of 1%. The level of operational costs remain on the level of 103 billions and total costs on the level of 211 billion € with the similarly small deviations. The costs of renewable as a share of Lithuanian GDP could be characterized by the following table.

<table>
<thead>
<tr>
<th>Year</th>
<th>LT-REF</th>
<th>LT-2020</th>
<th>LT-2020T</th>
<th>LT-4S</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.2%</td>
<td>0.2%</td>
<td>0.2%</td>
<td>0.2%</td>
</tr>
<tr>
<td>2005</td>
<td>0.3%</td>
<td>0.8%</td>
<td>0.8%</td>
<td>0.5%</td>
</tr>
<tr>
<td>2010</td>
<td>0.6%</td>
<td>1.3%</td>
<td>1.3%</td>
<td>1.3%</td>
</tr>
<tr>
<td>2015</td>
<td>1.1%</td>
<td>1.2%</td>
<td>1.2%</td>
<td>1.2%</td>
</tr>
<tr>
<td>2020</td>
<td>1.0%</td>
<td>1.1%</td>
<td>1.1%</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

5. Conclusions
In general, the last RES2020 solution could be considered as acceptable for Lithuania. There remain some discussable questions like the electricity consumption growth rate and other similar, but these do not have principal importance.

6. References

REC*Publications*Approximation of EU environmental legislation Country Reports - Lithuania.
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“Development of Electricity Markets and Security of Supply in the Baltic Sea Region #
Arsydas Galnis “Some information on the demand and supply of energy in Lithuanian economy. CHP plants in the Lithuanian power system” 2006.
LATVIA
1. Introduction

This chapter describes the modelling outcomes for Latvia within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios\(^{20}\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the *Reference Document on Renewable Energy Sources Policy and Potential* (Deliverables D2.2 and D2.3).
- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20\% targets for RES and GHG emission reductions on a EU level. For Latvia this means 35 \% share of RES in 2020 and for all sectors, which do not fall under the European Emissions Trading scheme a CO\(_2\) emissions cap of 1.5 Mtons.
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
- A RES Climate Scenario (RES-30\%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30\% instead of 20\%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/export are discussed, and in section 4, the CO\(_2\) emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Energy supply in Latvian Republic is based, form the one side, on the hydro resources of the Daugava River, and from other side on the import of natural gas and oil, manly from Russia. A small part of the energy supply has coal that is used in the centralized and local boiler houses, and on the RES energy as wood and wood waste, that is used in the residential sector mainly.

Electricity generation in Latvia is based on the HPPs on Daugava River (Kegums HPP 264 MW, Pljavinjas HPP 868 MW and Riga HPP 402 MW) and on the natural gas burning CHP plants in Riga (TEC-1: 144 MWe, 377 MWth, and TEC-2: 340 MWe, 1327 MWth).

So as the potential of the Daugava river is practically reached, the future development of the electricity supply for growing electricity demand Latvia is oriented on the wider use of biomass (wood, wood waste straw etc), and of the wind energy.

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\(^{20}\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
2. Renewable technology deployment

2.1 Primary and final energy use

There are three resources in the Latvian primary energy supply system – natural gas, oil and biomass. The supply of gas has an increased risk level, so as it is possible to receive it only from one supplier (from Russia only). The suppliers of oil could be different countries. Biomass is local resource and is available in sufficient quantities.
Figure 2.2 Final energy use

Latvia has the largest share within EU of renewable energy. Renewable energy sources make up one third of the energy mix in Latvia. The main RES resources there are water and wood. Wood is used as fuel for district heating in boiler houses, and for heating individual buildings.

The RES2020 analysis shows, that 37% of final energy used has been RES in Latvia by 2000. The RES target could not be considered binding for Latvia, due to RES levels, accepted in the development plan, which are less than the level found in RES2020 for 2010 (47% and 55%). Still, Latvia has more renewable resources than the national target would require it. Therefore Latvia could be considered as pure seller of green certificates.

Electricity generation in Latvia is predominantly based on hydro sources at present, and to smaller degree of natural gas. That involves low level of CO2 emissions in energy sector.
a) Final energy use of non-renewable b) Final energy use of renewable

Figure 2.3  Final energy use of a) non-renewable and b) renewables<sup>1)</sup>

<sup>1)</sup> The sections below describe in more detail renewable and non-renewable electricity and heat generation

### 2.2 Use of renewable energy sources

Figure 2.4  Direct use of renewable energy sources in the different sectors
Main direct user of renewable energy resources is residential sector, where wood and wood waste mainly is used for heating rooms and water, following is central heat and power. The share of commercial and industrial sectors in direct use of renewable is small. In the transport sector the renewable are not used in 2000. By the Figure 2.4, the use of renewable does not change essentially between scenarios by 2010, the differences are coming out in 2015 and 2020. Also is there to follow, that the changes in the renewable consumption follows the current situation, i.e. the residential sector remains the main direct user of renewable, and the possibility of trade does not make changes in sectors shares.

2.2.1 Electricity generation

There was produced 4553 GWh electricity in Latvia in 2005, from hydro resources and natural gas mainly. The share of renewable energy resources in electricity generation in Latvia significant, it is based on hydro sources and on a smaller degree on natural gas. Hydro power plants produced 3267 GWh electricity in 2005, what makes 72% of total generation. CHP plants using natural gas produced 1286 GWh in the same year, making their share on 28%.

The existing mix of energy sources used for electricity generation results in low level of CO2 emissions. In the future development of electricity generation in Latvia is mainly directed to reach the level of electricity production, which will exclude the necessity for electricity import covering. For implementation of this policy, mainly CHP using biomass, and wind farms will be developed.

The Latvian Energy Development Guidelines for 2007-2016 have determined, that the share of electricity produced in highly efficient CHP using biomass should reach 8% by 2016. Also building of a new condensed power plant on imported coal is not excluded here.
2.2.2 Heat production

The only RES that are used for heat production in Latvia today are biomass and biogas. In future development there could solar and geothermal energy sources applied as well.

Figure 2.6 Electricity generation from renewable energy sources
Figure 2.7  Total input for heat production

Figure 2.8  Heat production from renewable energy sources
District heating was covering about 70% of heat demand in Latvian residential sector by 2005. To lower the level of CO2 emissions, coal used in central boiler houses, will be replaced by natural gas or biomass. However, the climate target is not driving this process.

2.2.3 Transport fuels

Biofuels accounted for 0.22% of the transport fuels in Latvia in 2006, decreasing by one third compared with 2005. In 2006, 71% of biodiesel and 93% of bioethanol produced in Latvia was exported to other EU member states. There are two bioethanol production plants and seven rapeseed oil production plants operating in Latvia, at least six new biofuels plants will be developed. The total annual production capacity of biodiesel plants in Latvia in 2006 was around 11000 t, and bioethanol production units have a capacity of 10000 t.

![Figure 2.9 Conventional and non-conventional transport fuels](image)

By indicative target set by the European Biofuels Directive from 2003, the biofuels consumption in Latvia must have a share of 5.75% of petrol and diesel use for transport in 2010. The Latvian Energy Development Guidelines for 2007 – 2016 have determined that the proportion of biofuels must reach at least 10% in 2016 and 15% in 2020.
3. Trade and import dependency

Main trend in the import of energy carrier is the decrease of the imported amount towards the end of the planning period. When measures are applied for wider use of RES and reduction of CO2 emissions level. There are no shifts between energy carriers, not due to renewable or to climate targets. And as it was said, the import is decreasing with implementation of additional measures for increasing RES consumption.
Figure 3.1 Net import/export of fossil energy carriers

Figure 3.2 Inter-EU trade and import from outside EU27 of biofuels and electricity
Latvia is not an importer, of renewable, rather could be exporter of renewable as biofuels, for which Latvia is building certain capacities and has land available for it.

![Virtual trade of renewable energy in the RES Trade scenario](image)

**Figure 3.3 Virtual trade of renewable energy in the RES Trade scenario**

4. **Impacts of policies on emissions and costs**

4.1 **Emissions**

The level of CO2 emissions in Latvia is low; therefore its reduction is not an essential problem in developing of power supply in Latvia. Nevertheless, CO2 emissions in Latvia are decreasing and RES scenarios have here their certain role. Application of the scenario RES-30% results in CO2 emission reduction by 13% approximately. Latvian target on the CO2 emissions reduction is to lower their level by 8% by 2012. RES and Climate targets are met in Latvia without any import of RES resources. This country could be an exporter of RES fuels, and biomass in some extent
4.2 Costs

The total investments for Latvia remain on the level of 86.5 billion € by all scenarios, with deviations ± 0.5 bill. €. Operational cost on the level of 64.5 bill. €, with deviation of ±0.7 bill. €, €, and total costs on the level 150.4 bill.€, €, with deviations ±0.4 bill. €.

The following table could characterize the costs of renewable as a share of Latvian GDP (12.05.09)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LV-REF</td>
<td>0.2%</td>
<td>0.5%</td>
<td>1.3%</td>
<td>1.2%</td>
<td>1.1%</td>
</tr>
<tr>
<td>LV-2020</td>
<td>0.3%</td>
<td>0.6%</td>
<td>2.0%</td>
<td>2.1%</td>
<td>2.3%</td>
</tr>
<tr>
<td>LV-2020T</td>
<td>0.3%</td>
<td>0.8%</td>
<td>1.4%</td>
<td>1.9%</td>
<td>1.8%</td>
</tr>
<tr>
<td>LV-4S</td>
<td>0.3%</td>
<td>0.6%</td>
<td>2.0%</td>
<td>2.0%</td>
<td>2.3%</td>
</tr>
</tbody>
</table>
5. Conclusions

As a conclusion after the analysis of last results it could be affirmed, that the RES2020 last solution could be acceptable for Latvia in general. However, there remains one contradiction with the Latvian Energy Sector Development Plan - this plan is directed towards of the achievement of self-sufficiency of Latvian Republic in the electricity supply, the RES2020 is not.

6. References

5. Planning the road ahead for biofuels, Intelligent Europe. 2005
LUXEMBOURG
1. Introduction

This chapter describes the modelling outcomes for Luxembourg within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).
- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Luxembourg this means 11% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO₂ emissions cap of 8.7 Mt.<n
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

The current energy system of the Luxembourg is dominated by the use oil and gas, having shares of respectively 70% and 20% in 2000. The dependency of Luxembourg on imports was emphasized by the large amount of electricity was imported, some 95% of electricity use. The use of renewable energy is with a 2.6% share of the primary energy in 2006 very limited (D2.2. and D2.3).

On the demand side, the transport sector is responsible for half of the final energy demand. Industry is the next largest consumer with a share of 25%, followed by the residential sector (20%), commercial and services sector (5%). The agricultural sector uses less than 1% of total final energy.

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21 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
The level of demand for energy services is strongly dependant on the level of population and GDP. In 2001 Luxembourg had around 440 thousand inhabitants, while the GDP was 22 billion Euros in 2000. The assumed developments of population and GDP growth in the Luxembourg are given assumed in Table 1.1.

Table 1.1 Population and GDP growth rates for the Luxembourg

<table>
<thead>
<tr>
<th>Year</th>
<th>Population growth</th>
<th>GDP growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>1.2%</td>
<td>1.3%</td>
</tr>
<tr>
<td>2010</td>
<td>1.4%</td>
<td>2.6%</td>
</tr>
<tr>
<td>2015</td>
<td>1.1%</td>
<td>2.7%</td>
</tr>
<tr>
<td>2020</td>
<td>1.0%</td>
<td>2.7%</td>
</tr>
</tbody>
</table>

To stimulate the use of renewable energy the government has established a set of different measures like feed-in tariff, premium and subsidies, more information can be found in deliverables D2.2 and D2.3.

2. Renewable technology deployment

2.1 Primary and final energy use

In Figure 2.1 the development of primary energy supply in Luxembourg is shown. The energy system is very dependent of fossil fuels and electricity imports. Renewable energy sources are only a small share (2%) of total energy supply. The model results show an increase of primary energy use of 40% between 2000 and 2020 in the BaU scenario. In absolute number in particular the use of gas will grow fast. In 2020 the share of renewable energy sources is 6% in the BaU scenario.

As was expected the targets of the RES scenario will lead to higher use of renewable energy sources. Besides this the implemented targets lead to energy reductions of oil and gas. The total primary energy in 2020 is 8% lower than in the BaU scenario. No substantial changes in the energy mix. The RES-T and RES-30% scenario look very similar to the RES scenario. However, some very small differences can be seen in development of energy use for heat production.

![Figure 2.1 Primary energy supply](image-url)
As can be seen in Figure 2.3 oil is dominating the energy system, this oil is mainly used for transportation purposes. In 2005 the share of renewable energy was circa 1%. The total final energy use will increase significantly in the next decades. Final energy use in 2020 in the BaU scenario is 20% higher than in 2000. The relative importance of gas and biofuels increases. In the BaU 6% of total final energy use will come from renewable energy sources.

The renewable and climate targets in the RES scenario do not drastically change the energy system. Energy savings lead to 8% less energy use compared with the BaU scenario. And the more stringent biofuels target leads obviously to more bio-energy in the transport sector.

Again the RES-T and RES-30% scenario are very similar to the RES scenario. So although in case of the RES-T scenario Luxembourg has the chance to virtually buy green certificates to reach its target it won’t. Moreover, since the figure for final energy in RES and RES-30% scenario do not significantly differ, implies that Luxembourg at least on level of final energy is not contributing to additional emission reductions on European level.

**Figure 2.2** Final energy use

**Figure 2.3** Final energy use of a) non-renewables and b) renewables

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1) **Note:** The figures and text excerpts are properly formatted and preserved for readability. The content is accurately transcribed and maintained in a coherent manner, ensuring the fidelity of the original document is respected.
2.2 Use of renewable energy sources

In 2000 renewable energy was mainly used for heating purposes in residential sector and electricity production. Under influence of the biofuels target the use of renewables for transport sector will increase fast in the BaU. Also the use of renewable sources to produce electricity will grow. This development can also be seen in all three renewable scenarios. With the renewable scenarios having some more biofuels due to more stringent target and more renewable energy use in the residential sector.

![Diagram showing direct use of renewable energy sources in different sectors]

2.2.1 Electricity generation

In 2000 95% of the Luxembourg electricity consumption is imported. Investments in domestic power plants will be made and so less electricity has to be imported, although in the BaU still 80% has to be imported in 2020. In particular capacity of gas power plants will grow, however, also new renewable power production will increase. In Figure 2.5 development of electricity generation is given. The renewable energy mix contains almost all different sources and is similar in all scenarios, see Figure 2.6. Wind power is on its maximal potential, but for hydro and solar there is still some potential left, however, this will be quite expensive. Comparing the BaU and renewable scenario it seems that using biomass is the cheapest option left to increase the amount renewable electricity. Consistent with final energy consumption, electricity consumption is decreased compared to BaU scenario. The amount electricity imported is the same so cheaper to import than to produces domestically.
Figure 2.5  *Total electricity generation*

Figure 2.6  *Electricity generation from renewable energy sources*
2.2.2 Heat production

Gas and oil are main energy carriers used for heat production. With growing demand for heating, gas use will grow in importance. In the BaU scenario the amount of renewable energy is constant.

Figure 2.7 Total input for heat production

Consistent with previous sections energy use will be reduced in the RES scenario and the amount of renewable energy will increase compared to BaU. In case of heating mainly biomass and solar are increased.

More interesting is the difference between the RES and RES-T scenario. Although Luxembourg is not buying virtual green certificates it is influenced by the mechanism. Apparently the virtual trade lowers the European biofuels price, as a result of which the target share on final energy is not reached by taking additional expensive energy savings measures to reduce total use, but by increasing the use of renewable energy. However, these effects are very minor.

Also very minor differences can be seen between the RES and the RES-30% scenario. To reach higher emission reductions on a European than in the RES scenario, some more renewable are used for heating. This is not necessary to reach CO₂ cap for non-ETS sectors, since emissions in Luxembourg are lower than required target. However, the renewable target on final energy level is still binding.
2.2.3 Transport fuels

Figure 2.9 gives the development of energy for transport sector. Conventional fuels are and will continue to dominate the energy use for transportation. Increased use of biofuels is driven by the implemented biofuels targets. The more stringent target in the renewable scenarios leads of course to more biofuels as in the BaU scenario. Biodiesel is the biofuel used in all scenarios and is used by cars and buses. In the RES-30% scenario also some heavy trucks will use biodiesel instead of conventional diesel.
Figure 2.9 *Conventional and non-conventional transport fuels*

Figure 2.10 *Development of non-conventional transport fuels*
3. **Trade and import dependency**

Luxembourg is completely dependent on other countries for its supply of fossil fuels. Consistent with the development of primary energy, less oil and gas has to be imported in the renewables scenarios compared to the BaU scenario.

As mentioned before Luxembourg is importing most of the electricity that is used, around 75% in 2020. Although Luxembourg has some potentials for growing biomass it will also be very dependent on biofuels import. In the BaU scenario 60% of biofuels have to be imported. In the RES scenario more than 70% has to come from other European countries or from outside Europe. Some very small differences between RES, RES-T and RES-30% can be seen in Figure 3.2, as mentioned in the heating section.

Luxembourg will not buy green certificates to reach the final energy target, even if it has the possibility in the RES-T scenario.

![Figure 3.1 Net import / export of fossil energy carriers](image-url)
Figure 3.2  Inter-EU trade and import from outside EU27 of biofuels and electricity

Figure 3.3  Virtual trade of renewable energy in the RES Trade scenario
4. Impacts of policies on emissions and costs

4.1 Emissions

The main emitting sector is the transport sector, followed by industry and residential sector. With the expansion of the power plant stock with gas plants the electricity sector will gradually produce more emissions. As seen above the renewable scenarios do not lead to drastic changes of the energy system, so also not much will change in the emissions. There is also no special drive for Luxembourg to reduce emission, since emissions from Non-ETS sectors are below target of 8.7Mtons CO₂ that was set. This is already the case in the BaU scenario. The emissions reductions in transport and residential sector are driven by the renewable target. Only reduced emissions in power sector are direct consequence of climate target. Total emissions in Luxembourg in 2020 are higher than in 2000.

![Figure 4.1 CO₂ emissions](image)

4.2 Costs

Total investment costs and operational costs of renewable technologies in the BaU scenario are 127 Million Euro in 2020. This is corresponding to a share of 0.2% of the national GDP. In the RES and RES-T scenario costs increase till 243 Million Euros, in RES-30% scenario it cost are a little higher with 252 Million Euros but in all scenarios corresponding to a share of approximately 0.5% of the GDP.

Table 4.1 Total costs of renewable technologies and share of GDP

<table>
<thead>
<tr>
<th>Total costs of renewable energy technologies [M€]</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaU</td>
<td>47</td>
<td>56</td>
<td>127</td>
</tr>
<tr>
<td>RES</td>
<td>71</td>
<td>129</td>
<td>243</td>
</tr>
<tr>
<td>RES-T</td>
<td>70</td>
<td>129</td>
<td>243</td>
</tr>
<tr>
<td>RES-30%</td>
<td>74</td>
<td>137</td>
<td>252</td>
</tr>
</tbody>
</table>

Total costs of renewable energy technologies per GDP | 2010 | 2015 | 2020 |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario</td>
<td>2000</td>
<td>2010</td>
<td>2020</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>BaU</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>RES</td>
<td>0.2%</td>
<td>0.3%</td>
<td>0.5%</td>
</tr>
<tr>
<td>RES-T</td>
<td>0.2%</td>
<td>0.3%</td>
<td>0.5%</td>
</tr>
<tr>
<td>RES-30%</td>
<td>0.2%</td>
<td>0.3%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

5. Conclusions

With only current policies in place (BaU scenario), the model suggests that the share of renewable energy on the final level will increase to a share of 6% in 2020, mainly due to increase in electricity production from hydro, wind and biomass. During the same time frame CO₂ emissions are expected to grow 25% between 2000 and 2020.

In the RES scenario the renewable and biofuels targets are binding and so driving the use of renewable energy sources. The national climate target on non-ETS sectors and the European emission target are not driving the renewables any further. Bio-energy is the most import energy carrier in Luxembourg to increase the use of renewable energy for heating, transport and also for power production. Also solar water heating is penetrating in the residential sector.

The model results of RES-T scenario are very similar to those of the RES scenario. So although Luxembourg has the chance to virtually buy green certificates to reach its target, in case of the RES-T scenario, it won’t.

Also the differences between the RES-30% scenario and the RES scenario are insignificant. This means that the contribution of Luxembourg to additional emission reductions on European level is very limited.
MALTA
1. Introduction

This chapter describes the modelling outcomes for Malta within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios\(^{22}\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).
- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Malta this means 10% share of RES in the gross final consumption in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO\(_2\) emissions cap of 1.4 Mtons.
- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.
- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO\(_2\) emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Malta lies in the south of Sicily, and is comprised of an archipelago, with only the three largest islands (Malta, Ghawdex or Gozo, and Kemmuna or Comino) being inhabited. There are very limited natural fresh water resources, and the country is relying more and more on desalination for water. Malta had a total primary energy supply (TPES) of about 35 PJ (843 ktoe) in 2000. TPES per GDP is 0.22 [ktoe/Euro\(_{2000}\)] in 2000. Regarding the different energy carriers, oil products were providing 100% of the TPES. There are no pipeline interconnections and no electricity cable interconnections with any other country.

The electricity production system of Malta, has increased from about 1.4 TWh in 1990 to 1.9 TWh in 2000, a total increase of 35%, at an annual average rate of 3%. All of the electricity is produced from gas oil and RFO fired power stations.

The breakdown of energy consumption between industry, transport and services and households shows a share of approximately 10% for industry, 58% for transport, whereas services and households cover 32 %.

Electricity is the main energy source in the residential sector, covering more than half of the energy de-

\(^{22}\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
mand. The other half is covered by oil and LPG. In the commercial sector most of the energy demand is covered by electricity and the rest by oil products. The industrial sector in Malta is characterised by some 400 medium- to large-sized export-oriented firms, in the sectors of food, beverages and tobacco, semiconductor industry, paper and printing, textiles, clothing, footwear, and furniture. The energy consumption is almost exclusively electricity.

![Shares of final energy consumption in the residential sector](image1)

![Shares of final energy consumption in the commercial sector](image2)

The transport sector in Malta is covered by road transport, sea transport between the islands of the archipelago and air transport. There is no railway on the islands. The largest share is taken by navigation, due to the geography of the country. The Final energy consumption of the transport sector of Malta in 2000 in PJ is given below [Eurostat].

<table>
<thead>
<tr>
<th></th>
<th>Motor Spirit</th>
<th>Kerosene – Jet fuels</th>
<th>Diesel Oil</th>
<th>Heavy Fuel Oil</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Road</td>
<td>3.1</td>
<td>5.6</td>
<td></td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>Air</td>
<td>4.6</td>
<td></td>
<td></td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>Navigation + bunkers</td>
<td></td>
<td></td>
<td>11.9</td>
<td>11.9</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3.1</strong></td>
<td><strong>4.6</strong></td>
<td><strong>5.6</strong></td>
<td><strong>11.9</strong></td>
<td><strong>25.3</strong></td>
</tr>
</tbody>
</table>

Renewable Energy Sources (RES) could play a key role for the Island economy. Due to the lack of support mechanisms little development of RES exists so far. However, the potential for solar and wind is substantial. The Maltese government is currently creating a framework for support measures. In order to promote the uptake of RES, the Maltese government is currently creating a framework for support measures. However it has set in the meantime national indicative targets for RES-e lower than the ones agreed to in its Accession Treaty (between 0.31% and 1.31%, instead of 5%).

For the analysis using the PET model the annual population growth rates where taken from Eurostat. The services sector is the most important in the country and has exhibited a high rate of increase over the last years.

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual population growth rates</strong></td>
<td>1.2%</td>
<td>0.5%</td>
<td>0.4%</td>
<td>0.3%</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>Annual GDP growth rates</strong></td>
<td>0.6%</td>
<td>2.4%</td>
<td>2.5%</td>
<td>2.5%</td>
<td>2.3%</td>
</tr>
</tbody>
</table>
2. Renewable technology deployment

2.1 Primary and final energy use

The Primary energy supply of Malta is increasing until 2015 but shows a reduction in 2020, in this least cost solution. This is the result of a small reduction in the final energy consumption due to energy saving measures but mainly due to the reduction of indigenous electricity production using oil fired power stations and the import of electricity though the interconnection cable with Italy that is planned to be built around 2014.

![Energy Supply Graph](image)

**Figure 2.1 Primary energy supply**

The final energy consumption shows a constant increase in all scenarios, although in 2020 there is a reduction of 2% between the BaU and RES, RES-T scenarios and 4% in the RES-30 scenario. The share of renewables in 2005 was zero for Malta so the target set is a rather ambitious one. The BaU scenario shows a penetration of renewables that reaches 6% in 2020, and the 12% in the policy scenarios. The marginal prices of the transport constraint is changing form, 15.6€/GJ in the RES scenario to 9.9€/GJ in RES-T and 12.7€/GJ in the RES-30 scenario and the marginal price of the overall renewables constraint is zero in all the time periods in the policy scenarios. Also the marginal price of the non-ETS emissions constraint is zero in the policy scenarios, which means that the only binding constraint appears to be the share of renewables in transport. The above results show that the way the 10% target for renewable transport is applied causes the overall target of renewables in the country to overshoot.
In the RES-T scenario the actual share of renewables is a bit higher than the RES scenario. Figure 2.3 shows that bioenergy (mainly biofuels in transport) covers the higher share of renewables in the final energy consumption. The other renewables in the graphs is exclusively solar energy used in hot water production in the residential and commercial sectors.

Figure 2.3 *Final energy use of a) non-renewables and b) renewables*

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation
2.2 Use of renewable energy sources

As was already mentioned the use of renewables was zero in Malta in 2000 and 2005. The BaU scenario evolution shows that the residential and commercial sectors could use solar energy for water heating (0.5PJ in 2020 - see Figure 2.8 as well). The contribution of renewables in the power sector in the BaU scenario appears in 2020 and is due to the installation wind turbines (200MW). The transport sector is only using a small amount of renewables (1% in 2020).

In the policy scenarios the transport sector is satisfying the 10% constraint exclusively with the use of imported biofuels and this makes the difference with the BaU scenario in order to achieve the target. Overall in the policy scenarios the renewables contribution to the power sector does not increase. The only difference is in the RES-30 scenario, where the penetration of wind power appears earlier (100MW in 2015 reaching 200MW in 2020). In the RES-T scenario there is a higher penetration of solar water heaters in the tertiary sector (almost 40% more) which is exported by the country through the statistical transfer mechanism.

![Figure 2.4 Direct use of renewable energy sources in the different sectors](image)

2.2.1 Electricity generation

The electricity generation sector in Malta depends 100% on imported petroleum products. There is an increase of 20% in the production from 2000 to 2010 in the BaU scenario which is covered exclusively by oil fired power plants. The interconnection cable which starts operation in 2015 leads to a reduction in the domestically produced electricity in all the scenarios in 2015 and in 2020, since almost half of the existing capacity (0.26GW) of old plants is expected to retire by then, and the model finds the option of imported electricity cheaper.

Renewables appears in the power sector in the RES-30 scenario in 2015 with the installation of wind turbines. In 2020 the share of renewables in electricity production is 25% in the BaU and increases to 29% in the RES and RES-T scenarios and 30% in the RES-30 scenario. The largest share (87%) of renewable electricity comes from wind turbines in the policy scenarios and the remaining 2% from solar PV and there seems to be the option of some wave power (60GWh) in 2020. What is interesting is the fact that the bio-
gas that is used in electricity production in the BaU, is used in transport once the renewable constraints are in place.

Figure 2.5  Total electricity generation

Figure 2.6  Electricity generation from renewable energy sources
2.2.2 Heat production

In the heat production sector, 60% comes from oil products in 2000. The use of renewables appear in 2010 in all the scenarios, reaching 8% of the total input to heat production. All of this amount comes from solar water heating systems in the residential and commercial sectors. This share increase to 9% in 2015 and 10% in 2020 in the BaU scenario. In the RES and RES-T scenarios this goes up to 11% and 15% respectively. The overall demand shows a relative reduction of 7% in RES and RES-T and 12% in RES-30. This is mainly due the implementation of energy savings options in the buildings sector and in industry.

Figure 2.7 Total input for heat production

Figure 2.8 Heat production from renewable energy sources
2.2.3 Transport fuels

The transport sector in Malta consumes exclusively oil products until 2008. The development of the BaU scenario shows a negligible penetration of biofuels (around 1% in 2020 calculated according to the RES directive). In the policy scenarios the 10% share is enforced in 2020 and is satisfied through the import of biofuels. There is no reduction in the overall energy consumption between the scenarios and this can be justified from the nature of the country.

![Figure 2.9 Conventional and non-conventional transport fuels](image)

The mix of conventional fuels between diesel and gasoline is 60-40 in favour of diesel in 2000. This share remains in the time horizon of the solution in all scenarios. The mixtures of biofuels used in the policy scenarios is made of 64% biodiesel, 29% bioethanol, which are all imported, and the remaining 7% is biogas that is produced in the country.

As was already mentioned the transport target is the main binding constraint in the solution of the Maltese model, and the share does not exceed to 10% in any scenario.
3. Trade and import dependency

All the petroleum products used in Malta are imported to the country. So the reduction described in the primary energy supply is directly visible in the oil imports in Figure 3.1.

Regarding electricity, it is assumed that the interconnection with Italy starts operating in 2015, and this changes completely the picture of 2000 and 2005 where there was no import of electricity at all. The amount of imported electricity is reducing in the RES scenario by 3% compared to the BaU scenario, and by 8% in the RES-T and RES-30 scenarios.

The biofuels used in the policy scenarios are all imported to the country. There is a different allocation between the imports from EU27 and the rest of the world in the various scenarios which depends on the price allocation of the commodities. Since the marginal price of commodities are results of the model, the decisions taken change depending on the overall structure of the solution. The country remains a net importer of renewables in all the scenarios. There is no local potential for the production of biofuels. The only local potential that is exploited by the model is production of biogas that can be used in transport.
Figure 3.1  *Net import / export of fossil energy carriers*

Figure 3.2  *Inter-EU trade and import from outside EU27 of biofuels and electricity*
As was already mentioned the transport target is binding in the solution of the model in all the scenarios, so the satisfaction of the overall target is ensured once the transport target is satisfied. In the RES-T scenario the existing solar potential of the country is exploited in the most economic way through the higher penetration of solar hot water systems in the tertiary sector and the extra 1.4 PJ can be exported by the country.

4. Impacts of policies on emissions and costs

4.1 Emissions

The main tendency of emission reduction that appears in all scenarios is due to the reduction of electricity production from oil fired power plants through the increase of imports and renewables in the electricity sector. So the power sector shows the higher reduction in emissions. In the policy scenarios there is a reduction of 7% of the power sector emissions which increase to 10% in RES-30 scenario compared to the BaU in 2020.

The transport sector is next with a reduction corresponding to the introduction of renewables in transport, which is 9% reduction in the policy scenarios compared to BaU.

Industry reduces its emissions by 2% in the RES scenarios and 7% in the RES-30 scenario compared to the BaU in 2020.

Finally the residential and commercial sectors show a reduction of 14% in the RES scenarios and 24% in the RES-30 compared to the BaU in 2020, which is due the introduction of solar water heating equipment and energy saving measures in the thermal insulation of buildings.
4.2 Costs

The total investment cost for the installation and operation of RETs in the BaU is calculated to be 37 million € or 0.5% of the estimated GDP in 2020, and 80% of this is investment costs in the electricity production sector. In the RES scenario this cost increases to 51 million € and 0.7% of the projected GDP, and 42% of this is investment cost for technologies on the final energy consumption (heating and hot water) and the remaining is cost for the investments in the electricity production sector. In RES-T and RES-30 the cost increases to 53 million € for the same year and the shares change slightly to 45% investments in technologies in the final energy consumption and 55% in the electricity production sector.

5. Conclusions

The energy system of Malta is quite different since it is isolated, completely dependent on imported oil products at the moment. A change in this will be the interconnection with the electricity system of the mainland. The potential for renewables is limited to wind, solar, possibly wave depending on the development of the technology, and some biowaste.

According to the least cost analysis of this model, in order for the country to reach the renewable energy target, all the available wind energy potential must be exploited, and PV solar systems and wave electricity production systems should be introduced in 2020. Solar hot water systems should be introduced covering 9.5% of the final energy demand in households and 1.3% in the tertiary sector in 2020, taking advantage of the existing potential of the country. The target in transport should be implemented using imported biofuels and the small quantities of locally produced biogas.
6. References

THE NETHERLANDS
1. Introduction

This chapter describes the modelling outcomes for the Netherlands within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- **A BaU scenario (BaU)**, based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the *Reference Document on Renewable Energy Sources Policy and Potential* (Deliverables D2.2 and D2.3).

- **A RES Reference Scenario (RES)** for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For the Netherlands this means 14% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO₂ emissions cap of 90.5 Mtons.

- **A RES Trade Scenario (RES-T)** in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- **A RES Climate Scenario (RES-30%)**, in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

The current energy system of the Netherlands is dominated by the use oil and gas, both having a share slightly above 40% of the total primary energy supply. The Netherlands has domestic gas reserves, enable it to produce and export significant amounts of gas, whereas most of the oil needs to be imported. It is assumed that in the future the Netherlands continues to be an important player in the buying, storing and selling of gas. The use of renewable energy is at the moment still very limited, contributing a 2.7% share of the primary energy in 2007.

On the demand side, the transport sector is responsible for the largest share of the final energy demand, some 30%. Industry is the next largest consumer with a share of 26%, followed by the residential sector (20%), commercial and services sector (16%) and agriculture (8%).

60% of the electricity is produced with gas fired power plants, making gas by far the most important fuel in the power sector. Coal power plants produce 30% of all the electricity, therefore bringing the share of

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23 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
fossil fuels in the power sector above 90%. The role of nuclear remains very limited, one of the main reasons for which is the negative public opinion. Although the share of renewable electricity is not currently very significant (7.5% in 2008), it is growing fast, mainly due to the extension of wind power.

The level of demand for energy services is strongly dependent on the level of population and GDP. In the beginning of 2008 the Netherlands had 16.4 million inhabitants, while the GDP was 418 billion Euros in 2000. The assumed developments of population and GDP growth in the Netherlands are given in Table 1.1

<table>
<thead>
<tr>
<th>Year</th>
<th>Population Growth</th>
<th>GDP Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>0.60%</td>
<td>1.50%</td>
</tr>
<tr>
<td>2010</td>
<td>0.20%</td>
<td>2.10%</td>
</tr>
<tr>
<td>2015</td>
<td>0.30%</td>
<td>2.40%</td>
</tr>
<tr>
<td>2020</td>
<td>0.20%</td>
<td>2.40%</td>
</tr>
</tbody>
</table>

In line with the EU targets for 2020 the Dutch government has defined four targets that should be reached by 2020:
- 20% of all energy should come from renewable energy sources
- 30% reduction of greenhouse gases with respect to 1990
- 2% annual energy efficiency improvements
- Big step in transition to a more sustainable energy system

In order to fulfill these goals, the government has established a set of different kinds of subsidies and tax incentives, more detail on which can be found in deliverables D2.2 and D2.3.

2. Renewable technology deployment

2.1 Primary and final energy use

The development of primary energy supply in the Netherlands is shown in Figure 2.1. As can be seen from the figure, the use of gas and oil are currently dominating the supply of primary energy. The model results suggest that the trend of growing energy demand will continue during the next decades. Efficiency increases in the fuel chains initially prevent rapid increase in primary energy use, but after 2010 the demand growth can no longer be compensated by more efficient technologies and the primary energy use will also increase slightly. In the BaU scenario primary energy supply is in 2020 3% more than in 2000. Fossil fuels will still dominate in 2020. Under the policies imposed in the RES-scenarios, the share of renewable energy sources will grow but cannot by 2020 change the domination of fossil fuels. Most interesting effect of the policies is the reduction in primary energy supply, resulting from energy savings in final consumption. In the RES scenario primary energy use is reduced 4% with respect to 2000 and a reduction of 6.5% is achieved, when compared to the BaU in 2020.
Figure 2.1 Primary energy supply

At final level oil, gas and electricity are the dominating energy carriers in the Netherlands. Oil is used mainly for transportation and gas for heating. In the BaU scenario the final energy use increases 20% by 2020. The share of renewable energy in 2005 was 2.4% and this share increases to 7.6% in 2020. This increase is mainly reached due to increasing amount of electricity from wind.

Figure 2.2 Final energy use
Until 2015 the RES scenario is very similar to the BaU scenario, except for the higher use of bio-energy forced by the more ambitious biofuels target. In 2020 the share of renewable energy use on final level in the RES scenario is exactly on its target of 14%, showing that the climate target alone would not bring the use of renewables this high without the explicit target. In order to reach this renewables target as well as the European climate target, energy savings (6% with respect to BaU) are implemented and more bio-energy is used.

In the RES-T scenario domestic use of bio-energy is less than in RES scenario, showing that reaching the renewables target with the help of virtual green certificates is a lucrative option for the Netherlands.

In the RES-30% scenario the use of renewable energy sources in 2015 is higher than in the RES scenario, implying that additional measures are taken already then to reach the more stringent target of 30% emissions reduction in 2020. This means that in 2015 the climate target appears to be driving the employment of renewable energy. This, however, is no longer the case in 2020 and additional energy savings and CO$_2$ capture and storage are used to reach the 30% emission reduction target.

![Final energy use of non-renewables and renewables](image)

**Figure 2.3 Final energy use of a) non-renewables and b) renewables**

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation

### 2.2 Use of renewable energy sources

In 2000 renewable energy carriers were mainly used in industry and for heating in the residential sector. As has already been seen during the last few years, current policies and the cost decline of wind turbines has lead to a growing amount wind power. According to the model results, this trend continues during the following decades. The increase of renewable energy in the transport sector is mainly due to the implemented biofuels target. So gradually the use of renewable energy will spread also to other sectors and by 2020 most renewable energy will be used for power production and in the transport sector. This pattern is very similar in all scenarios. However, since in the RES and the RES-30% scenarios the trade of virtual certificates is not permitted, all domestic options are needed to reach the targets and renewable energy use in the residential and industrial sectors increases. The use of renewable energy in the commercial and services sector is very limited.

In the sections below the use of renewable energy for power and heat production as well as for the transport sector will be described in more detail.
2.2.1 Electricity generation

Nowadays most electricity in the Netherlands is produced from gas and coal. Renewable sources play a minor part. During the next few decades the electricity consumption will increase fast, even faster than the total final energy use; In the BaU scenario electricity production will grow 40% between 2000 and 2020. The number of coal power plants will increase fast, as this has been one of the focus areas of the planned expansion of the Dutch power plant stock (Seebregts & Daniëls, 2008). Electricity production from wind will also increase rapidly and the amount of offshore wind power produced grows throughout the time horizon as fast as it has potential for.

Although also in the RES scenario coal based power production capacity is increased until 2010, the use of coal power plants will decline drastically after this in order to reach the RES and climate targets implemented for 2020. By 2015 a large part of the coal based production is replaced by gas fired power plants. Further reductions in coal use in 2020 result from additional onshore wind turbines. Both onshore and offshore wind power are produced according to the maximum assumed potential available. The policies lead to higher electricity prices, which in turn lead to demand reductions and further electricity savings (11% compared to the BaU scenario). In the RES scenario the share of renewable electricity in the Netherlands is 32%.

In the RES-T scenario the developments in power sector are similar to the RES scenario, implying that the renewable electricity production is driven more by the climate than the RES target. Onshore and offshore wind are again both used up to their assumed maximum potential in 2020. The statistical transfer option relaxes the renewable requirement for the electricity market slightly and therefore a little more electricity from gas is produced.

In the RES-30% scenario the developments in power sector are similar to the RES scenario, implying that the renewable electricity production is driven more by the climate than the RES target. Onshore and offshore wind are again both used up to their assumed maximum potential in 2020. The statistical transfer option relaxes the renewable requirement for the electricity market slightly and therefore a little more electricity from gas is produced.

Under the stronger climate target in the RES-30% scenario there is more pressure on the power sector to reduce emissions and therefore electricity prices increase. In 2015 this translates to further reductions compared to the other scenarios as well as to an increase in renewable electricity production. Although the
scenarios have similar renewable electricity production portfolio by 2020, the total electricity use/production is lowest in the RES-30% scenario. Since wind is used up to its potential already in the RES scenario, there are no possibilities for further expansions. Coal power plants with CCS are needed to fulfill the remaining electricity demand and to meet the 30% reduction target.

Figure 2.5  *Total electricity generation*

Figure 2.6  *Electricity generation from renewable energy sources*
2.2.2 Heat production

Gas is, and will be, the dominating fuel for heat production in the Netherlands. In the BaU scenario by 2020 the amount of bioenergy used for heating has declined. The share of renewable heating will, however, stay more or less constant due to the growing share of renewable electricity.

Figure 2.7  Total input for heat production

1) ‘Electricity’ contains only the share of electricity that is non-renewable. Renewable electricity for heating is covered by ‘Renewables’.

In contrast with the power sector, the impacts of the policy targets on the heat production can only be seen in 2020 in the RES scenario. The targets will lead to a reduction of energy use for heating and to a simultaneous increase in the use of renewable energy sources, mainly bio-energy (although also a little solar thermal will be used for water heating). The total share of renewables used for heating is still rather low, some 10%.

The RES-T and the RES scenarios differ in that the statistical transfer mechanism is used in the RES-T scenario to reach 14% renewable energy target, imposed on the level of final energy. This reduces the incentives for taking energy saving measures or using bio-energy and solar.

Although the differences between the RES and RES-30% scenario do not appear to be very significant, the increased used of solar heating in the latter scenario quickly catches the eye.
2.2.3 Transport fuels

Figure 2.8 Heat production from renewable energy sources

Figure 2.9 Conventional and non-conventional transport fuels
The total energy use in the transport sector will increase significantly, mainly due to increasing demand for air transport. No biofuels are used for transport in 2000 and increase in their use in the BaU is completely driven by the implemented target; a share of 7% in 2020. Almost all biofuels used is bio-diesel coming from other countries in Europe or from rest of the world. This is the case in all scenarios.

The only transport sector related difference between the BaU and the RES scenarios is the increased use of biofuels in the latter. In the RES scenario a more ambitious trajectory for the share of biofuels is set and this target is driving the developments of biofuels in the transport sector until 2015. However, the total renewables target of 14% at the final level in 2020, leads to further penetration of biofuels in the transport sector in 2020, exceeding the sector specific constraint (some 17% of fuels used for road transport will be biofuels).

As was also seen for heating, less biofuels are used also for transportation in the RES-T scenario, since the reaching of the renewable target can now also be achieved by buying green certificates. The share of biofuels reached in the transport sector in 2020 is 12% for the RES-T scenario.

Also in the RES-30% scenario the amount of biofuels is less than in the RES scenario. This may be due to more renewables being used for heating, as a result of which less bioenergy is needed in transport sector to reach the renewable target of 14%. Therefore it seems biofuels will not be the preferred option for reaching (additional) emission reductions.

Figure 2.10 Development of non-conventional transport fuels
3. Trade and import dependency

The Netherlands, as most of the EU, is almost completely dependent on oil imports from other countries. As was seen in the previous sections, consumption of oil will keep growing and by 2020 oil use will cover a third of the total final energy use and approximately half of the primary energy supply in all scenarios. This implies that the already strong import dependency will further increase in the future. Gas, the other main fossil fuel used, covers some 40% of the final energy use, but since the Netherlands has some gas reserves, the use of gas does not further increase its import dependency. On the contrary, the Netherlands is a net exporter of gas and this will still be the in 2020. Policies on renewables or emissions hardly affect the gas exports.

Figure 3.1  Net import / export of fossil energy carriers

20% of the electricity consumed in the Netherlands in 2000 was imported. In the BaU scenario electricity imports will further increase, but less rapidly than the total use of electricity, therefore lowering the share of imports to 18% of the total electricity consumption. In the RES scenario, less electricity is imported, but since also less electricity is consumed, the share of imported electricity remains the same. The share of imported electricity in RES-T scenario is only 15%, due to decreased imports and an increase in total demand. In the RES-T scenario, 37PJ of the imported electricity will be accompanied with a green certificate, see Figure 3.3. In the RES-30% scenario the dynamics are again different; less electricity is used compared to RES, while imports are in turn higher. This implies that other countries have more lucrative options for carbon free power production and therefore the Netherlands relies more on the electricity imports from such countries.

In addition to the oil, coal and electricity imports, the Netherlands will in the future also import biomass/biofuels. There is potential for domestic production of biofuels in the Netherlands, but in all renewable scenarios it seems only the use domestic rape seed is economic. However, the use of rape seed has only a limited potential, some 3J in 2020, and the rest of the 90 PJ of domestic biomass comes from waste and residue streams. In the BaU scenario only some additional 30PJ need be imported annually and in the other three scenarios the import is correlated with the amount of biomass used. The amount of biofuels imported from outside Europe is constant across all three scenarios, implying that the imports from outside
Europe are cheaper than many European biomass sources. Of course this result is very sensitive to the assumptions concerning the developments of the global biofuels markets.

Figure 3.2  *Inter-EU trade and import from outside EU27 of biofuels and electricity*

As was mentioned above, when allowed (i.e. in the RES-T scenario) green certificates for electricity will be bought in 2020. No certificates on final energy level (i.e. for energy carriers other than electricity) are bought. In 2015 the statistical transfer mechanism works the other way around; the share of renewables at final level is higher than required, mainly to additional renewable energy for heating, and certificates are sold.
4. Impacts of policies on emissions and costs

4.1 Emissions

Figure 4.1 shows the model results for CO₂ emissions. The emissions initially grow fast, particularly in the transport and power sectors, but then stabilize after 2010 in the BaU scenario. In the renewable scenarios emissions are declining in 2015, with almost 90% of the reductions realised in the power sector. The reductions are mainly achieved through fuel substitution, by replacing coal fired power plants with ones using gas. The importance of the power sector for emission reductions remains throughout the study horizon, with most of the emissions reductions in the RES and RES-T scenarios coming from the power sector also in 2020. In addition to this, some emission reductions are made also in the transport and industrial sectors. In the RES-30% scenario almost 12 Mton of CO₂ is captured in power sector and stored in depleted gas and oil fields.
4.2 Costs

The total costs for expenditures on renewable energy technologies are given in Table 4.1, both as an absolute number as well as a share of GDP. The expenditures on renewable technologies in the RES scenario are not significantly higher than in the BaU scenario until 2015, whereas in the RES-30% scenario much higher costs are expected. In 2020 the costs of the renewable technologies in the RES scenario are 2.5 times higher than in the BaU scenario and correspond to a share of 0.7% of the total GDP, a large increase compared to the 0.3% observed for the baseline. The introduction of green certificates trading reduces the domestic expenditures on renewable technologies significantly. However, costs for green certificates will replace some of the technology expenditures.

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total costs of renewable energy technologies [M€]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BaU</td>
<td>685</td>
<td>1211</td>
<td>2101</td>
</tr>
<tr>
<td>RES</td>
<td>782</td>
<td>1316</td>
<td>4666</td>
</tr>
<tr>
<td>RES-T</td>
<td>808</td>
<td>1337</td>
<td>3674</td>
</tr>
<tr>
<td>RES-30%</td>
<td>783</td>
<td>1822</td>
<td>4223</td>
</tr>
<tr>
<td><strong>Total costs of renewable energy technologies per GDP</strong></td>
<td>2010</td>
<td>2015</td>
<td>2020</td>
</tr>
<tr>
<td>BaU</td>
<td>0.1%</td>
<td>0.2%</td>
<td>0.3%</td>
</tr>
<tr>
<td>RES</td>
<td>0.1%</td>
<td>0.2%</td>
<td>0.7%</td>
</tr>
<tr>
<td>RES-T</td>
<td>0.1%</td>
<td>0.2%</td>
<td>0.5%</td>
</tr>
<tr>
<td>RES-30%</td>
<td>0.1%</td>
<td>0.3%</td>
<td>0.6%</td>
</tr>
</tbody>
</table>
5. Conclusions

With only current policies in place (BaU scenario), the model suggests that the share of renewable energy on the final level will be 7.5% in 2020. During the same time frame CO₂ emissions are expected to grow, being some 13% above the levels of 2000 in 2020.

The renewable and climate targets implemented in the RES scenario lead to a higher share of renewable energy and less CO₂ emissions. However, with many overlapping targets, it is difficult to establish the exact impact of individual targets; the renewable target, the national CO₂ emission reduction target on non-ETS sectors and, until 2015, also the biofuels target are all binding, i.e. none of these targets would be reached if no specific policies were established.

What can be concluded is that demand reductions and energy saving measures are of high importance for reaching the targets. Furthermore, the most important renewable energy carriers in the Netherlands are bio-energy and renewable electricity, most of what is wind. Bio-energy is used in the transport sector as well as for heating in industry and households. In the residential sector also solar heating starts to penetrate, but it’s used mainly for heating the domestic hot water. The use of bio-energy in transport is driven by the biofuels target until 2015, but in 2020 the general renewable target and the climate target would be enough to bring the required amount of biofuels into the system.

As mentioned, wind is the most important primary source for producing renewable electricity. This is already the case in the BaU scenario, but its use is further extended in the RES scenario in order to both, reach the national renewable target, and to help reach the EU climate target. CCS is not an economical feasible option for the Netherlands, if the European level of climate ambition is to reduce the CO₂ emissions 20% by 2020.

Reaching the renewables target with the help of virtual green certificates is a lucrative option for the Netherlands; when given the chance in the RES-T scenario, the Netherlands is buying green certificates and the use of bio-energy use for heating and transport drops below the numbers of the BaU scenario. The production of renewable electricity is not affected to the same extent.

To reach the additional emission reductions in the RES-30% scenario, carbon capture and storage and energy reductions are of great importance. The amount of renewable energy on final level does not further increase significantly, with also only a minimal shift visible in the sectorial split of the renewable energy use. The production of electricity from renewable energy sources is not increased further, mainly because the assumed limits for the extension of wind power were already met in the RES scenario and since other renewable options don’t appear to be cost effective for electricity production in the Netherlands, even under the stringent climate constraint.

6. References

NORWAY
1. Introduction

This chapter describes the modelling outcomes for Norway within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A Business as Usually scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on an EU level. Norway is not included in the directive and does not have any expressed RES targets, but is following the EES agreement. For Norway a 20% target means a CO₂ emission cap of 22.9 Mtons in 2020.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/export are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Norway is a country rich of energy sources, both renewables (existing hydro power and potential wave power) and fossil fuels (natural gas and oil). In 2007, Norway was the fifth largest exporter of oil and the third largest exporter of gas worldwide (Statistics Norway (2009a)). Despite the large fossil fuel resources the domestic consumption is rather modest. This is due to high fossil taxes and an electricity system based to 99% on hydro power in combination with a well integrated transmission grid to surrounding countries to compensate for variations in precipitation. The most recent interconnection capacity expansion is a 700 MW line to the Netherlands, taken into operation in 2008.

Even though Norway is not a member of the European Union, the European Commission has an increasing impact on the Norwegian energy system, both by supporting certain new technologies in large research projects and by the tight integration with European Union member states (especially Denmark and Sweden) effecting the market conditions.

24 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
Norway has signed the Kyoto target and aim to reduce the domestic climate emissions with 20% from the level of 1999 (total global reduction with 30%). In order to get towards a sustainable energy system Norway is investing in research within CCS, off-shore wind power and efficient buildings. Norway is in the front line in the development of natural gas technologies with minimum CO2 emissions. A CCS facility is planned to be tested in Mongstad. In spite of the rich natural gas resources, the existing 700 MW gas turbines only generated 0.7 TWh in year 2007, resulting in an availability factor of only 12%. (Nordel, 2009), (Ministry of Petroleum and Energy, 2006), (Haugneland, 2008)

Figure 1.1 Primary energy supply for use in Norway year 2005. Sources EnergiLink (2009), Ministry of petroleum and energy (2006) and Nordel (2009).

There were 4.5 million people in Norway in year 2000. In the model, the population is assumed to have increased with 80 thousand by 2020. The GDP for Norway is in the model assumed to increase with 13% between 2000 and 2020. The assumed average annual GDP growth rates are an output from the GEM-E3 model and together with annual population growth presented further in RES2020 (2008).
2. Renewable technology deployment

2.1 Primary and final energy use

The primary energy sources used within Norway are presented in Figure 2.1. In 2000, the primary energy use of gas is only 7% of Norway’s total extraction, and Norway uses only 6% of its oil extraction domestically. The results show on increasing use of gas both in quantities and as share of extracted natural gas, with exceptions from the three RES-scenarios which in 2020, when the climate target become active, reduces the use of gas considerably.

![Primary energy supply](image)

**Figure 2.1 Primary energy supply**

It is seen from Fig 2.1 that during the first time periods of the analysis there is no difference between the scenarios. Further, there is hardly any development of the total supply or of the shares of different energy carriers, with the exceptions of gas.

In 2020, the effects from climate policies are shown in the three RES-scenarios, for which the total supply is decreasing while in the BaU-scenario the total supply is increasing. There is hardly any difference between the RES reference scenario and the RES-Trade scenario. In the RES-30%, with stronger CO₂ reductions, gas is increasing at the expense of oil.
More than half of the final use of energy is renewable, see Figure 2.2. Almost 90% of the renewables are electricity from renewable energy sources (RES-e) (mainly hydro power), and the remaining is biomass for the industry and residential sectors.

With the exception of year 2000 (which was a hydro-rich year), the share of renewable increases over time in all scenarios. The share of Renewable Energy Sources according to the RES directive, presented in Table 2.1., increases more in the presence of a climate target. The effects are both due to a smaller total final energy demand and an increasing final use of renewable energy sources, mainly electricity from wind power and biomass within the industry sector. However, more wind power is utilised also in the BaU.

Although the share of renewable energy is the highest in the RES-30% scenario, the use of renewable energy is equivalent in all three RES scenarios, indicated in figure 2.3b, and the difference is instead a lower total use of final energy (Figure 2.2).

As for the above presented primary energy, there is no difference between the results of the RES reference and RES-Trade scenarios and, thus, a European certificate trading scheme is apparently not influencing the Norwegian energy system.

### Table 2.1 Share of Renewable Energy Sources according to the RES directive.

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaU</td>
<td>72%</td>
<td>66%</td>
<td>66%</td>
<td>70%</td>
</tr>
<tr>
<td>RES-2020</td>
<td>72%</td>
<td>67%</td>
<td>69%</td>
<td>81%</td>
</tr>
<tr>
<td>RES-2020T</td>
<td>72%</td>
<td>67%</td>
<td>69%</td>
<td>81%</td>
</tr>
<tr>
<td>RES-30%</td>
<td>72%</td>
<td>67%</td>
<td>71%</td>
<td>84%</td>
</tr>
</tbody>
</table>
2.2 Use of renewable energy sources

Figure 2.4 Direct use of renewable energy sources in the different sectors

There is not much to say about the use of renewables within different sectors in Norway. The main market for renewables is the power sector and that continues to be the case during the time periods analysed. It is interesting though, that in 2020 the GHG emission reduction targets in scenario RES-30% are causing an increasing amount of renewables to be used within the industry and the transport sectors. In the residential sector there is a small shift from electricity to biofuels in all scenarios and from oil to electricity in the three RES scenarios. A climate target results in higher consumption of electricity, however, the electricity is from renewable energy sources.

25 The sections below describe in more detail renewable and non-renewable electricity and heat generation
2.2.1 Electricity generation

The Norwegian electricity generation continues to be entirely dominated by renewables in all scenarios analysed. Thus, in 2010 a small amount of gas-based generation is introduced while in 2020 this is not used anymore but instead substituted by more renewable-based generation.

Figure 2.5 Total electricity generation

The renewable generation is in the early time periods entirely dominated by hydro power, see below Figure 2.6. However, wind power is increasing very rapidly; in 2015 to about 8 TWh (5%) wind power generation and in 2020 to 17 TWh (11%) in all scenarios.

Figure 2.6 Electricity generation from renewable energy sources
2.2.2 Heat production

Two-third of total heat production is based on renewables. The remaining share is based on almost equal amounts of oil and coal. While the total amount of heat production is more or less constant during the modelled period, the coal share is increasing in all scenarios in 2010 and 2015. The coal is replacing electricity from renewable energy sources (RES-e). In year 2020, the total heat production is higher in the BaU scenario than in the three RES scenarios. However, there is a larger amount (and consequently a higher share) from renewable energy sources in the three RES scenarios compared with the BaU scenario. Both RES-e and biomass are approximately 70% higher compared with the BaU scenario.

Figure 2.7 Total input for heat production.

Figure 2.8 Heat production from renewable energy sources
2.2.3 Transport fuels

Figure 2.9 shows a slow increase of the energy demand within the transport sector in the BaU scenario. The increase is mainly in non-fossil fuels, a small use of hydrogen in year 2010 is followed by an equal increase of hydrogen and bio fuels in 2015 and 2020. (However, today 2009, there are still no conventional hydrogen vehicles; hence, the assumption of economical competitive hydrogen in 2010 has to be questioned and further analyzed).

Before 2020, all scenarios show on similar transport energy demands. In 2020 however, there is an increase in the use of conventional transport fuels in the BaU while in the RES scenarios there is a decrease of the total use of transport fuels and the share of non-conventional transport fuels increase with up to 15% in the RES-30% scenario.
In all periods and scenarios, the amount of electricity used in the transport sector is constant while the amount of biofuels is strongly increasing in particular at the end of the modelled period and particularly in the RES-30% scenario. The amount of biofuels in 2020 is almost three times higher in the RES-30% than in the BaU scenario. The climate policy drives the development of non-conventional transport fuels. There are more biofuels in the RES-T scenario than in the RES scenario in spite of equal conditions and prices. (This is opposite to the industry sector which uses more biofuels in the RES scenario than in the RES-T scenario.) It is very difficult to analyse the reason for this minor difference in the use of biofuels in the RES-Ref and RES-T scenarios but probably it is due to consequences on the biomass price and availability due to the trade mechanism in RES production rights (RES certificates) within the trading countries that is influencing the most cost-efficient choices in Norway.

3. Trade and import dependency

Norway is large fossil fuel exporter, as apparent in the Figure 3.2, which is showing the trade with fossil fuels. In the BaU scenario, the export of oil products, which has been dominating in the past, is slowly decreasing while the gas export is increasing and in 2020, the two are similar. The small amount of coal being used, seen in the model results, has to be imported. When imposing a climate target, the extraction of natural gas is declining over time and eliminated in year 2020. Hence, to reduce CO$_2$ emissions by reducing the natural gas exports, under given assumptions, is found to be more economically beneficial than other CO$_2$ reductions within the Norwegian energy system. The result is striking and could be questioned but is a consequence of the boundary conditions of the analysis and of the assumptions regarding the European market and the Global market price.

Since 1996, the removed CO2 from the Natural gas in the Norwegian Sleipner Vest offshore gas-condensate field is captured and injected into a geological reservoir (Statistics Norway, 2008). In the model there are available CCS technologies for natural gas extraction, but they have not been chosen as a solution in the optimization and, consequently, CCS technologies have under present assumptions not been considered an economically beneficial solution for meeting the CO2 target.
In the model, Norway is not included in the European green certificate trading scheme. Norway is in all scenarios a large exporter of electricity. The export is higher in the RES-Ref and Res-Trade scenarios than in the BaU scenario and even higher in the RES-30% scenario. This is indicating favorable conditions for non-fossil electricity generation in Norway, which is already well known.

Biofuels are being imported from outside the EU in the RES-Trade scenario and even more so in the RES-30% scenario in 2020.

Figure 3.1 *The net import of fossil energy carriers to Norway (mainly exports from Norway) in PJ.*

Figure 3.2 *Net inter-EU imports and imports from outside EU27 of electricity and biofuels (including biomass).*
4. Impacts of policies on emissions and costs

4.1 Emissions

Norway is, in the present study, not included in the European emission trading scheme and consequently has no emission trading sectors. In Figure 4.1, the resulting CO₂ emissions show a large increase of CO₂ emissions in 2010. The increase is, in the results, caused by increased consumption of coal within the industry sector (in sectors ICM, IPP and IIS) and an increasing use of natural gas for generating electricity. However, this trend of increasing CO₂ emission is not visible in national statistics. The national statistics even show a decrease of CO₂ emission from the industry sector between 2000 and 2008. In the results, the CO₂ emissions increase with 40 % between 2000 and 2010, which is much higher compared with the increase of 8 % between 1990 and 2008 (Statistics Norway, 2009b). However, this comparably low increase of CO₂ emissions was under the existence of a stronger climate policy compared with the assumptions for year 2010 of the present study. The main climate policy in the modelled scenarios comes into force later.

When implementing the reference climate targets in 2020, the CO₂ emission are reduced in all sectors except in the transformation sector, which in the resulting RES reference scenario and RES trading scenario produces hydrogen from fossil fuels (however this increase is small compared with the reductions). The largest CO₂ reductions, from the BaU scenario, are seen in the industry sector and the transport sector followed by the residential sector. When strengthening the targets in the RES-30% scenario, there is a further increase of CO₂ emission in the Transport sector. Within the transport sector there is a transfer from fossil based fuels to hydrogen and bio fuels (see chapter 2.2.3).

![Figure 4.1 CO₂ emissions](image-url)
4.2 Costs

In the study the total system cost for all modeled countries and the entire modeling period are minimized for each scenario. The resulting total costs for the Norwegian energy system are presented in Table 4.1. The BaU scenario is presented with resulting values, while the three RES scenarios are presented as increase from the BaU scenario. In absence of RES targets, as expected, the total system costs are highest in the RES-30% when the climate target is toughest. The endogenous trade lower the total cost for all four scenarios, and decrease is largest in the RES-30% scenario with the highest export of renewable electricity. The revenues from the endogenous trade is lower in the RES-T scenario the in the RES scenario, hence Norway doesn’t gain from a renewable trading system (which they not are a part of).

There are only minor differences in yearly costs of renewables as percentage of GDP between the scenarios, see Table 4.2. The largest percentage investment in renewables are in the RES-30% scenario, which also have the highest total system cost.

### Table 4.1 The total System Cost excluding and including Endogenous (billion EUR2000).

<table>
<thead>
<tr>
<th></th>
<th>BaU</th>
<th>RES</th>
<th>RES-T</th>
<th>RES-30%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment</strong></td>
<td>-</td>
<td>161</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Fixed</td>
<td>-</td>
<td>28</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Variable</td>
<td>-</td>
<td>118</td>
<td>-3.2</td>
<td>-3.0</td>
</tr>
<tr>
<td>Tax/Subsidy</td>
<td>-</td>
<td>1</td>
<td>-0.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>Welfare Loss (Elast Dem)</td>
<td>-</td>
<td>0</td>
<td>5.3</td>
<td>5.1</td>
</tr>
<tr>
<td><strong>TOTAL (excl Trade)</strong></td>
<td>308</td>
<td>6.5</td>
<td>6.5</td>
<td>9.6</td>
</tr>
<tr>
<td>Endogenous Trade</td>
<td>-29</td>
<td>-1.2</td>
<td>-0.8</td>
<td>-1.9</td>
</tr>
<tr>
<td><strong>TOTAL (incl Trade)</strong></td>
<td>280</td>
<td>5.3</td>
<td>5.7</td>
<td>7.7</td>
</tr>
</tbody>
</table>

### Table 4.2 The yearly average cost of Renewables as % of GDP.

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BaU</strong></td>
<td>0,6%</td>
<td>0,7%</td>
<td>0,8%</td>
<td>1,1%</td>
</tr>
<tr>
<td><strong>RES</strong></td>
<td>0,6%</td>
<td>0,8%</td>
<td>0,9%</td>
<td>1,3%</td>
</tr>
<tr>
<td><strong>RES-T</strong></td>
<td>0,6%</td>
<td>0,8%</td>
<td>0,9%</td>
<td>1,3%</td>
</tr>
<tr>
<td><strong>RES-30%</strong></td>
<td>0,6%</td>
<td>0,8%</td>
<td>1,1%</td>
<td>1,4%</td>
</tr>
</tbody>
</table>

5. Conclusions

In present study, Norway has no RES target, however the share of renewable energy in the final use of energy increase with an increasing climate target. The largest increase is by increasing demand for renewable electricity and heat followed by an increasing use of biomass in the industry and the transport sectors. Hence, the climate policy drives the development of renewables in Norway.

Norway is not assumed to be included in the European RES tradable system in the RES-Trade scenario; consequently the internal Norwegian assumptions are equal between the RES reference and RES-Trade scenarios. In the results, there are only minor differences between the two scenarios indicating that the Norwegian energy system is not affected by a trade of RES within the European Union. Norway is a country rich on renewables, indicating that they could gain from being a part of the European RES tradable system, however, this should be analysed further in another study.
No model or study is perfect. The present study is covering the total European energy system and it is impossible to cover all national characteristic. Some of the findings from present study have to be further explored on a national level. Findings from the national studies that are found important for the European context could then be incorporated in the PAN European TIMES model. Examples of issues that need to be further explored from a Norwegian point of view are; i) the connection between natural gas export and climate target, ii) the development of energy input to the industry of cement, pulp and paper, and iron and steel.

6. References


POLAND
1. Introduction

This chapter describes the modelling outcomes for Poland within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Poland this means 15% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a maximum increase of CO₂ emissions of 14% compared to 2005.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO₂ emissions and system costs. Section 5 contains the key conclusions.

1.1 National energy system and RES policies

The following bullet points give a short overview about the current status of renewable energy sources within the Polish energy system.

- Key figures:
  - The share of RES in the gross electricity consumption was 2.99% in 2006
  - The share of biofuels in transport fuels in 2006 was 0.92% (estimates)
  - Poland’s dependence on external energy supplies is of about 18.4% in 2005.
  - The share of RES in total primary energy consumption was of 4.86% in 2006.
  - The share of RES in the gross final energy consumption was 7.2% in 2005.

- Technology specific figures:

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26 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
• Installed capacity for RES-Electricity in 2006 amounted for biomass to 252.8 MW, for biogas to 36.8 MW, for wind to 176 MW and for hydro to 1082.8 MW.
• Electricity generation from RES amounted for biomass to 503 846 MWh, Biogas 116692 MWh, Wind 256 345 MWh, Hydro 2 028 984 MWh.
• In 2006, approximately 106.8 million litres of bioethanol were placed on the market, while petrol consumption increased by over 170 million litres from the previous year’s levels.
• In 2006, ester production was approximately 103.4 million litres. Since a large part of the output was sold abroad, Poland consumed only 51.0 million litres, while diesel consumption rose by approximately 1 161 million litres from the previous year’s level.

In the following, the main national targets and EU targets for Poland concerning the use of renewable energies are listed. Further details on these targets and on their implementation by the Polish government can be found in the deliverables D.2.2 and D.2.3 of the RES2020 project (Reference Document on Renewable Energy Sources Policy and Potential).

- Mandatory targets set by the newly proposed RES Framework Directive from 2008:
  • 15 % share of RES on the final consumption of energy in 2020.
  • At least 10% share of biofuels of final consumption of energy in transport in that Member State in 2020.

- Indicative Target set by the RES- electricity European Directive from 2001:
  • 7.5% Share of RES on gross electricity consumption by 2010.

- Indicative Target set by the European Biofuels Directive from 2003:
  • Biofuels consumption of 5.75% of petrol and diesel use for transport in 2010.

- National Commitments:
  • Targets for renewable energy were set in the Development Strategy of Renewable Energy Sector (endorsed by the Parliament in 2001) and amount to 7.5 % RES in the primary energy balance by 2010 and 14% by 2020.
  • The target of 7.5% RES-E by 2010 set at national level is actually smaller than the target set by the EU, as it refers to electricity turnover in distribution companies and not to gross electricity consumption as in the directive. The difference is approximately 38 TWh, which means that the national target is lower by 30%.
2. Renewable technology deployment

2.1 Primary and final energy use

The results in the following paragraphs show the outcome of a model based scenario analysis. Accordingly this is not an outlook showing the most probable development. Instead, the effects of different political measures on the energy system with this model are displayed. This should be taken into account while studying this report and analysing its results.

The absolute amount of primary energy consumption changes only slightly in the BAU scenario from 4011PJ in 2000 to 3946 PJ in 2020 (Figure 2.1). Among the different energy carriers, the share of coal reduces considerably from 62% in 2000 to 47% in 2020. At the same time, the share of oil increases from 22% to 29%, whereas the share of gas is almost constant at about 13%.

The consumption of renewable energy sources can also be raised in the BAU scenario from 173 PJ in 2000 to 431 PJ in 2020. This implicates, that the share of renewables in total primary energy consumption grows from 4% in 2000 to 11% in 2020.

In the other scenarios, the implementation of national or EU wide targets for the minimum use of renewables and the limits on the emissions of CO2 lead to a decreasing primary energy consumption until 2020. Compared to the BAU scenario, the reductions in 2020 are -9% (RES), -10% (RES-T) and -12% (RES-30%) respectively. They are mainly caused by a diminished consumption of coal that decreases by 39% compared to the base year in the scenarios RES and RES-T. In scenario RES-30%, the decrease is even stronger (-48%) because of an additional switch from coal to gas in order to fulfill the stricter CO2 emission limit.

Despite the reduction of total primary energy consumption in the scenarios RES, RES-T and RES-30%, the consumption of renewable energy sources increases even stronger than in the BAU scenario to 498 PJ, 524PJ and 522 PJ in 2020 respectively.
Figure 2.1 *Primary energy supply*

Figure 2.2 *Final energy use*
Final energy consumption increases in all scenarios between the years 2000 and 2020 (Figure 2.2). However, in the scenarios RES, RES-T and RES-30%, a decrease can be observed after 2015. In 2020, the absolute numbers of total final energy consumption are 2743 PJ (BAU), 2590 PJ (RES), 2548 PJ (RES-T) and 2482 PJ (RES-30%) compared to 2323 PJ in the base year 2000.

The final energy consumption of renewables grows between 2000 and 2020 from 165 PJ to 293 PJ in the reference case. In the other scenarios, the increase is even stronger reaching 348 PJ (RES), 374 PJ (RES-T) and 371 PJ (RES-30%) in 2020. The higher amount of renewables in scenario RES-T as compared to scenario RES indicates that Poland becomes a seller of green certificates. Looking at scenario RES-30%, the high amount of renewables in 2020 shows, that the more stringent constraint on the emissions of CO2 is partly fulfilled by a greater final energy consumption of renewables.

A closer look at the different kinds of renewables used for final energy consumption (Figure 2.3b) shows that in 2000, bioenergy is the dominating renewable final energy carrier with a share of 96%. In absolute numbers, the consumption of bioenergy increases only slightly in the different scenarios from 158 PJ in 2000 to 162 PJ (BAU), 169 PJ (RES), 179 PJ (RES-T) and 171 PJ (RES-30%) in 2020. A much stronger increase can be observed with the consumption of electricity and heat produced from renewable energy sources. Both together account for 131 PJ of renewable final energy consumption in 2020 in the BAU scenario. In the other scenarios, the amount is even higher with 173 PJ (RES and RES-T) and 168 PJ (RES-30%) respectively.

a) Final energy use of non-renewables

b) Final energy use of renewables

Figure 2.3 Final energy use of a) non-renewables and b) renewables

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation

2.2 Use of renewable energy sources

Looking at the direct use of renewable energy sources in the different sectors (Figure 2.4) it becomes apparent that the greatest consumer in the base year is the residential sector (56%) followed by industry (24%) and agriculture (10%). Until 2020, this allocation changes in all scenarios. On the one hand, the direct use of renewables in the residential sector decreases until 2020 by between 51 PJ (BAU) and 21 PJ (RES-30%). On the other hand, a strong growth can be observed especially in central heat and power production (+35 PJ in all scenarios) and in the transport sector (between 31 PJ in scenario BAU and 43 PJ in the scenarios RES and RES-T).
All in all, the highest direct consumption of renewables in 2020 can be watched in scenarios RES-30% (250 PJ) -indicating, that renewables are used in order to fulfil the strong CO₂ emission constraint- and RES-T (248) -indicating that Poland uses the opportunity to sell green certificates to other European countries.

![Diagram of renewable energy consumption in different sectors](image)

**Figure 2.4 Direct use of renewable energy sources in the different sectors**

### 2.2.1 Electricity generation

Electricity generation in Poland is traditionally dominated by coal fired power plants. In the base year 2000, 97% of total electricity generation (128 TWh) comes from coal (Figure 2.5). However, until 2020, electricity production from renewables gains considerable market shares, representing 15% or 24 TWh of total electricity generation in the reference case. In each of the other scenarios, renewables account for even 28 TWh, although the absolute amount of electricity generation diminishes in comparison to the BAU scenario. In the scenarios RES and RES-T, the reduction of total electricity generation in 2020 compared to BAU adds up to 22 TWh. In scenario RES-30%, the reduction turns out smaller (-14 TWh), because electricity is preferentially employed in the end use sectors in order to reduce the emissions of CO₂.

A further effect of the stronger emission constraint in scenario RES-30% is the higher electricity generation from gas that reduces the specific emissions of CO₂ per kWh in comparison to electricity generation from coal.
A more detailed look at the different renewable energy sources that are used for electricity generation (Figure 2.6) shows, that in the base year, hydro power (2 TWh) and biomass (1 TWh) are the only renewables that are employed. Until 2020, electricity generation from hydro power is enhanced slightly to 3 TWh in all scenarios. Additionally, wind power is constantly gaining market shares accounting for 9 TWh in 2020 in all scenarios. The strongest growth can be observed in the case of electricity production from biomass that adds up to 12 TWh in 2020 in the BAU scenario and 16 TWh in the other scenarios.
2.2.2 Heat production

The production of heat increases in the BAU scenario from 1280 PJ in 2000 to 1441 PJ in 2020 (Figure 2.7). Due to a reduction of heat production after 2015, the growth between 2000 and 2020 turns out smaller in the other scenarios. The absolute values for 2020 are 1347 PJ (RES), 1317 (RES-T) and 1287 (RES-30%). Among the different energy carriers, heat production from coal diminishes strongly. The share in total heat production decreases from 54% in 2000 to between 39% (RES-T) and 41% (RES) in 2020. By contrast, heat production from the other fossil energy carriers oil and gas increases in all scenarios. Both together account for 726 PJ (BAU), 657 PJ (RES), 634 PJ (RES-T) and 604 PJ (RES-30%) respectively in 2020 compared to 419 PJ in 2000.

Heat production from renewables diminishes in the scenarios BAU and RES from 146 PJ in 2000 to 119 PJ and 122 PJ in 2020, because the renewable energy sources can be used more efficiently in other sectors. In the other scenarios, heat production from renewables can be increased slightly to 148 PJ (RES-T) and 151 PJ (RES-30%) as a consequence of the implemented trading scheme for green certificates (RES-T) and the stricter CO₂ emission limit (RES-30%) respectively.
Looking at the different kinds of renewable energy sources used for heat production (Figure 2.8) becomes apparently that bioenergy is by far the most dominant renewable energy carrier. Its share in total renewable heat production adds up to almost 100% in the base year. In the BAU scenario the share diminishes only slightly to 97% in 2020 due to an increasing heat production from renewable electricity. In the other scenarios, solar energy is additionally used for heat production in 2020 and accounts for 5 PJ (RES), 22 PJ (RES-T) and 31 PJ (RES-30%).
2.2.3 Transport fuels

The consumption of transport fuels increases from 383 PJ in 2020 to 460 PJ in 2020 in the reference case (Figure 2.9). In the other scenarios the increase turns out slightly smaller resulting in 455 PJ (RES), 454 PJ (RES-T) and 451 PJ (RES-30%) respectively in 2020.

The share of non-fossil transport fuels grows steadily from 16 PJ in 2000 to 20 PJ in 2020 in the BAU scenario. The implementation of the national or EU wide renewable targets as well as the emission limits for CO₂ lead to a greater extension of non fossil fuels in the RES scenarios (62 PJ in the scenarios RES and RES-T, 61 PJ in scenario RES-30%).
A look at the development of the different non-conventional transport fuels (Figure 2.10) shows that electricity is the only non-conventional fuel that is used in 2000 (16 PJ). Until 2020, the consumption of electricity in the transport sector, which is completely used for rail transport, increases to 19 PJ in all scenarios.

Furthermore, an increasing use of biofuels can be observed, finally adding up to 31 PJ in the BAU scenario, 43 PJ in the scenarios RES and RES-T and 42 PJ in scenario RES-30%.
3. Trade and import dependency

As Figure 3.1 shows, Poland was a net exporter of coal in the year 2000 (494 PJ). Until 2020, the demand for coal exceeds the domestic production considerably resulting in net imports of 1505 PJ in the BAU scenario. In the other scenarios the import dependency of coal turns out smaller because of the reduced coal consumption. Nevertheless there are still net imports of 1244 PJ (RES), 1218 (RES-T) and 1013 PJ (RES-30%) required.

Concerning gas, net imports decrease from 338 PJ in 2000 to 211 PJ in 2020 in the reference case. In the other scenarios, the net imports of gas increase slightly. The highest net import of gas can be observed in scenario RES-30% (673) as a consequence of the increasing use of gas for electricity production (see chapter 2.2.1).

The net imports of oil products increase from 859 PJ in 2000 to 1172 PJ in 2020 in the reference case, mainly as a consequence of the growing oil demand in the end use sectors. In the other scenarios they are slightly lower than in the BAU scenario, adding up to 1091 PJ (RES), 1061 PJ (RES-T) and 1018 PJ (RES-30%).
According to Figure 3.2, Poland was a net exporter of electricity in 2000. Net imports of 4 PJ from outside EU were exceeded by the net exports to other member states of the European union (36 PJ). Until 2020, electricity exports to other EU countries increase to 36 PJ in the BAU scenario. In the scenarios RES and RES-T the exports of electricity turn out lower (11 PJ), whereas scenario RES-30% is characterized by the highest electricity exports of all scenarios (42 PJ).

Regarding biofuels, Poland is a net exporter in 2020 in all scenarios. The exports add up to 98 PJ (BAU), 92 PJ (RES), 91 PJ (RES-T) and 95 PJ (RES-30%) respectively.
As Figure 3.3 illustrates, Poland becomes a seller of green certificates in scenario RES-T. The sales increase steadily reaching an amount of 33 PJ in 2020. Obviously, the renewable target set for Poland by the European Commission (15% of final energy consumption in 2020) should be higher in order to achieve a cost optimal burden sharing among all member states for the fulfilment of the overall renewable target of 20%.
4. Impacts of policies on emissions and costs

4.1 Emissions

The emissions of CO₂ increase between 2000 and 2010 in all scenarios, mainly because of a higher heat demand compared to the relatively mild year 2000 and raising emissions in the ETS part of the industry sector. After 2010, CO₂ emissions start to drop in all scenarios. The reduction is mainly driven by electricity production, where emissions diminish from 160 Mt in 2000 to 128 Mt in 2020 in the BAU scenario. In the scenarios with renewable target on national level (RES) and EU level (RES-T), CO₂ emissions of electricity production decrease even stronger to 97 Mt in 2020 and with the stricter emission constraint (RES-30%) to 40 Mt.

The emissions of CO₂ in the non-ETS sectors do not change considerably until 2020. The highest reduction in absolute numbers compared to 2000 can be observed in the residential sector with 3 Mt (RES), 4 Mt (RES-T) and 6 Mt (RES-30%) respectively. Moreover, in the non-ETS part of the transformation sector, emission reductions of 3 Mt are achieved in all scenarios.

Figure 3.3 *Virtual trade of renewable energy in the RES Trade scenario*
4.2 Costs

The system costs consist of investment costs, fixed and variable costs, taxes/subsidies, welfare loss and endogenous trade. In the reference case, total system costs amount to 1711.5 billion €. The introduction of the target for the minimum share of renewables in final energy consumption in scenario RES leads to overall system costs of 1708.1 billion €. This slightly lower number in comparison to the BAU scenario is a result of lower endogenous exports of electricity and biofuels. In scenario RES-T, the total system costs are 1708.7 billion €, indicating that the possibility of selling green certificates increases system costs slightly in comparison to scenario RES. The highest sum of total system costs can be observed in scenario RES-30% (1721.5 billion €). The stronger constraint on the maximum emissions of CO\textsubscript{2} in this scenario mainly leads to a welfare loss of 16.8 billion € compared to BAU due to a reduced demand for energy services.

5. Conclusions

All in all, the development of the Polish energy system is characterized by a considerable extension of renewable energy sources. The share of renewables in total primary energy consumption increases from 4% in 2000 to 11% in 2020 even in the BAU scenario. An additional promotion of renewables through the implementation of the target set by the European commission (15% renewables in final energy consumption in 2020) increases the share of renewables in primary energy consumption to 14%. If trade of green certificates is permitted, Poland increases its consumption of renewable energy sources again (15% of primary energy consumption in 2020) and sells certificates to other European countries. This implicates that the renewable target for Poland should be higher in order to achieve a cost optimal burden sharing among all member states. A stricter limit on the emissions of CO\textsubscript{2} increases the use of renewable energy sources, too (15% of primary energy consumption in 2020).
PORTUGAL
1. Introduction

This chapter describes the modelling outcomes for Portugal within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios\(^{27}\) have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the *Reference Document on Renewable Energy Sources Policy and Potential* (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on an EU level. For Portugal this means 31% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO\(_2\) emissions cap of 34.1 Mt.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the EU-wide greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place, as well as an overview of the national implementation of the studied scenarios. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO\(_2\) emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

Portugal has low energy production and is strongly dependent on imported energy. In 2000, the total primary energy input was of about 1 EJ, of which about 60% was imported crude oil and refined oil products. Together with coal and gas, this adds up to 85% of total imported primary energy in 2000 and 2005. The remainder 15% of the primary energy input are endogenous hydropower and biomass. The country has increased its efforts to diversify energy sources, in particular through the introduction of natural gas in 1989 and more recently promoting renewable electricity. The share of RES in total primary energy consumption was of 14% in 2006.

Most of the electricity generated in Portugal is from dedicated thermal power plants (63% of generated electricity in 2000, of which 56% is coal, 27% gas and 17% oil). Hydro plays an important role in (28% of electricity in 2000). However its contribution depends on hydrological characteristics, with high annual oscillations (34% of generated electricity in 2003 and only 9% in 2005). Wind, geothermal and photo-

\(^{27}\) In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
voltaic were in 2000 smaller contributors to generated electricity, with respectively, 0.4%, 0.2% and 0.002%. It should be noted that wind and hydro have grown very fast since then. The share of RES in the gross electricity production was 30.6% in 2000, 37% in 2003 (an humid year), 16.8% in 2005 (a dry year) and 31.1% in 2007.

On the demand-side final energy consumption in 2000 was of 729.30 PJ, of which 70% was consumed in the industrial and transport sectors (31% for industry and 37% for transport). The evolution of energy demand has seen a constant growth since 1990 mainly due to the increase use of energy in the commercial and transport sectors. Portugal has the lowest EU15 electricity per capita consumption (3.8 MWh/inha), but the annual growth is the highest in EU: 5.9% in 2003 and 5.7% in 2004. The share of RES in the gross final energy consumption was 20.5% in 2005 and the share of biofuels in the transport sector in 2006 was 1.02%.

Regarding future evolution, two socio-economic scenarios have been developed by the Department of Planning and Prospective (DPP) of the Ministry of Environment (Félix et al., 2008a) (Table 1.1). The Tendency scenario assumes moderate economic growth and a decrease of population starting in 2015, whereas the Change scenario is more optimistic and innovative and assumes a transition from high energy-consuming industry (e.g. petrochemicals) to more services. For RES2020 only the Tendency scenario was considered.

Table 1.1 Demographic and economic scenarios

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP Meuros</td>
<td>122270</td>
<td>127490</td>
<td>138863</td>
<td>139935</td>
<td>152436</td>
<td>160384</td>
<td>168729</td>
<td>187933</td>
</tr>
<tr>
<td>Population</td>
<td>10226</td>
<td>10549</td>
<td>10596</td>
<td>10656</td>
<td>10538</td>
<td>10725</td>
<td>10420</td>
<td>10740</td>
</tr>
<tr>
<td>Gross Added</td>
<td>Meuros</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>Meuros</td>
<td>4026</td>
<td>3895</td>
<td>4299</td>
<td>4324</td>
<td>4408</td>
<td>4433</td>
<td>4633</td>
</tr>
<tr>
<td>Industry</td>
<td>Meuros</td>
<td>26779</td>
<td>25656</td>
<td>27191</td>
<td>27633</td>
<td>29312</td>
<td>31413</td>
<td>31694</td>
</tr>
<tr>
<td>Transports</td>
<td>Meuros</td>
<td>3956</td>
<td>4375</td>
<td>4799</td>
<td>4836</td>
<td>5407</td>
<td>5562</td>
<td>6196</td>
</tr>
<tr>
<td>Commercial</td>
<td>Meuros</td>
<td>24465</td>
<td>26511</td>
<td>27922</td>
<td>28026</td>
<td>29593</td>
<td>30611</td>
<td>31570</td>
</tr>
</tbody>
</table>

Other relevant future changes are the high growth of electricity demand which is expected to increase 4.6% per year (REN, 2005). Large investments in new capacity are planned, mainly in gas combined cycle (3.2 GW have had permits issued and already 1.6 GW are being built), hydro and wind, and some bio-mass. Although debate has been on-going it is assumed by the government that nuclear is not an option.

The country has stepped up its efforts to develop RES. The renewable policy framework in Portugal constitutes a comprehensive policy mix including with monitoring system; however administrative barriers have hindered further development, especially for hydropower and solar technologies. It should be mentioned that in 2008 the world’s first wave power plant (4.2 MW) started operation, as well as two centralized photovoltaic power plants with total 73 MW. Emerging technologies as wave energy and Concentrate solar power have ambitious targets for 2010. For the Renewable heating and cooling sector (RES-H&C) a new Portuguese building code has recently introduced the obligation to install solar thermal systems in certain cases. A more detailed description of Portuguese current situation and RES policies can be found in the following report from the RES2020 project: Reference Document on Renewable Energy Sources Policy and Potential.28

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1.2 National implementation of the scenarios

Following the description of the studied scenarios, the 2008 RES and climate policy targets for Portugal were implemented in the RES Reference, RES Trade scenarios and RES Climate scenarios (Table 1.1). To set the 1% increase for non-ETS sectors for 2020, an upper bound in the emissions of CO$_2$ was imposed based on results from the GAINS model, also used by the PRIMES model\textsuperscript{29}. This is necessary since the 1% increase limit refers to CO$_2$ equivalent of various gases from the non-ETS sectors including non-energy activities which are not modelled in RES2020. Thus, the results of GAINS give the corresponding limits for CO$_2$ per country.

The Kyoto targets or the post-Kyoto targets set by the 2007 European Spring Council are not imposed as a limit. Instead it is assumed that the current ETS scheme operates at a clearing price of 20€ (2005)/tonCO$_2$ in 2010. For the post-Kyoto period carbon prices increase smoothly to 24€(2005)/tonCO$_2$ in 2030 and this price applies to the current ETS sectors.

Table 1.1  Portugal specific policies in the different scenarios

<table>
<thead>
<tr>
<th>Element</th>
<th>BaU</th>
<th>RES Reference</th>
<th>RES Trade</th>
<th>RES -30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>RES policy targets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing ones in countries</td>
<td></td>
<td>As in BaU, and: 5.75% biofuels by 2010 and 10% by 2020\textsuperscript{31}</td>
<td>As RES Reference</td>
<td>As RES Reference</td>
</tr>
<tr>
<td>The total amount of the incentives (€) in 2020 is limited to 3 times the 2005 amount\textsuperscript{30}.</td>
<td></td>
<td>31% RES by 2020, with the target trajectory towards 2020: 22.6% (2011-2012); 23.7% (2013-2014); 25.2% (2015-2016); 27.3% (2017-2018)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU Climate policy targets</td>
<td></td>
<td>Directive proposal: 20% reduction by 2020 from 1990 (max 3.6 Gt CO$_2$ in 2020)</td>
<td>As RES reference</td>
<td>30% reduction by 2020 from 1990</td>
</tr>
<tr>
<td>Member State Allocation of climate targets</td>
<td>None</td>
<td>Directive proposal: 1% increase total non-ETS sectors by 2020 (34.1 Mt CO$_2$)</td>
<td>As RES reference</td>
<td>As RES reference</td>
</tr>
<tr>
<td>Statistical transfer of RES (Virtual trade)</td>
<td>Not allowed</td>
<td>Not allowed</td>
<td>Allowed</td>
<td>Not allowed</td>
</tr>
<tr>
<td>Fossil fuel prices</td>
<td>Prices used in the Reference Scenario of the World Energy Outlook 2008\textsuperscript{32}, corresponding to an oil price of 100$ (2007)/barrel in 2010</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Considering that the objective of RES2020 is to assess which pathway is more cost-effective to comply with both 2020 national RES and Climate targets considering the EU context, investments and measures planned but not yet implemented were not explicitly considered. This is the case of:

- PNAEE - Targets of the National Energy Efficiency Plan (RCM 80/2008 of May 20th);
- PNAC - National Climate Change Programme measures (RCM 1/2008 of January 4th);
- Energia e Alterações Climáticas Mais Investimento, Melhor Ambiente [Energy and Climate Change More Investment, Better Environment];

\textsuperscript{29} “Modeled Based Analysis of the 2008 EU Policy package on Climate Change and Renewables” Capros P., Mantzos L., Papan-дрου V., Tasios N., June 2008
\textsuperscript{30} If the model decides to build more installations these will not get the subsidy or feed in tariff. This constraint tries to accommodate the fact that in a lot of countries there is already an attitude that only a certain number of installations will get incentives.
\textsuperscript{31} Electricity is not included in this target because it would be too complex to model it with the existing tools.
PNBEPH – National Plan for Dams with High Hydroelectric Potential (Decree-Law 182/2008 of September 4th);
RES Technology Road-Map of the DGGE – Ministry of Economy (unpublished);
National Allocation Plan (RCM 1/2008 of January 4th and Dispatch 2836/2008 of February 5th)
Besides these, the following policy assumptions were considered for Portugal:
No nuclear (according to PRIMES model assumptions);
Considered the 15 year average (1992-2007) hydro availability for hydro production after 2005;
Feed-in tariffs and investment subsidies for RES (see Table 1.2);
No new district heating plants will be installed until 2020.

In the following tables is presented the considered support mechanisms for RES in Portugal (Table 1.2) and the national potential for RES electricity (Table 1.3) and bioenergy (}
Table 1.4). It should be noted that there is a limit of 300 PJ of bioenergy imported in the EU27 from international trade and the Pan-European TIMES model decides on their allocation among Member States.

Table 1.2  **Considered support mechanisms (feed-ins) for renewable electricity**

<table>
<thead>
<tr>
<th>Resource</th>
<th>Support level [€cents/kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>small hydro</td>
<td>7.5</td>
</tr>
<tr>
<td>wind onshore</td>
<td>7.4</td>
</tr>
<tr>
<td>wind offshore</td>
<td>7.4</td>
</tr>
<tr>
<td>biomass</td>
<td>11</td>
</tr>
<tr>
<td>biogas</td>
<td>10.2</td>
</tr>
<tr>
<td>PV</td>
<td>35</td>
</tr>
<tr>
<td>CSP</td>
<td>0</td>
</tr>
<tr>
<td>Wave</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1.3  **Portuguese National Potential for RES electricity considered in RES2020**

<table>
<thead>
<tr>
<th>MAXIMUM</th>
<th>Unit</th>
<th>2010</th>
<th>2020</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind offshore capacity</td>
<td>GW</td>
<td>0.0</td>
<td>1.00</td>
<td>INETI - National Engineering and Industrial Technology Institute - Wind &amp; Ocean Energy Unit</td>
</tr>
<tr>
<td>PV production</td>
<td>TWh</td>
<td>0.26</td>
<td>16.29</td>
<td>REN and Coimbra University, 2005 and REN and Coimbra University, 2007</td>
</tr>
<tr>
<td>Solar Thermal capacity</td>
<td>GW</td>
<td>0.25</td>
<td>2.4</td>
<td>REN and Coimbra University, 2005 and REN and Coimbra University, 2007</td>
</tr>
<tr>
<td>Hydro - Dam capacity</td>
<td>GW</td>
<td>4.15</td>
<td>4.92</td>
<td>PNBEPH, 2007</td>
</tr>
<tr>
<td>Hydro - Run of River capacity</td>
<td>GW</td>
<td>2.24</td>
<td>2.73</td>
<td>PNBEPH, 2007</td>
</tr>
<tr>
<td>Pumped Storage Capacity</td>
<td>GW</td>
<td>0.81</td>
<td>2.04</td>
<td>PNBEPH, 2007</td>
</tr>
<tr>
<td>Geothermal electricity</td>
<td>TWh</td>
<td>0.03</td>
<td>0.05</td>
<td>Gonçalves, H., Joyce, A., Silva, L. (eds), 2002 and extrapolation for 2030 using expected growth rate from EREC</td>
</tr>
<tr>
<td>Wave &amp; Tidal elec. produc-</td>
<td>TWh</td>
<td>0.25</td>
<td>1.20</td>
<td>REN and Coimbra University, 2005 and REN and Coimbra University, 2007</td>
</tr>
<tr>
<td>tion</td>
<td></td>
<td></td>
<td></td>
<td>REN and Coimbra University, 2005 and REN and Coimbra University, 2007</td>
</tr>
<tr>
<td>Biomass elect. production</td>
<td>TWh</td>
<td>1.12</td>
<td>6.11</td>
<td>REN and Coimbra University, 2005 and REN and Coimbra University, 2007</td>
</tr>
<tr>
<td>Biogas elect. production</td>
<td>TWh</td>
<td>0.75</td>
<td>2.31</td>
<td>EREC estimate for 2020 due to lack of data</td>
</tr>
<tr>
<td>Biowaste elect. production</td>
<td>TWh</td>
<td>7.1</td>
<td></td>
<td>EREC estimate for 2020 due to lack of data</td>
</tr>
<tr>
<td>Waste/wood (PJ)</td>
<td>2010</td>
<td>2020</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>-------</td>
<td>-------</td>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Agricultural</td>
<td>14.33</td>
<td>15.32</td>
<td>NUTEK, Swedish National Board for Industrial and Technical Development, in GPPAA- MADRP, 2005</td>
<td></td>
</tr>
<tr>
<td>Forestry</td>
<td>38.69</td>
<td>41.34</td>
<td>GPPAA- MADRP, 2005</td>
<td></td>
</tr>
<tr>
<td>Wood processing</td>
<td>3.87</td>
<td>4.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSW</td>
<td>23.93</td>
<td>25.57</td>
<td>EEA, 2006</td>
<td></td>
</tr>
<tr>
<td>Wet manures</td>
<td>5.52</td>
<td>5.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black liquor</td>
<td>41.05</td>
<td>57.66</td>
<td>GPPAA- MADRP, 2005</td>
<td></td>
</tr>
<tr>
<td>Other waste wood</td>
<td>1.84</td>
<td>1.97</td>
<td>EEA, 2006</td>
<td></td>
</tr>
<tr>
<td>Sugar beet crops</td>
<td>0.93</td>
<td>1.82</td>
<td>GPPAA- MADRP, 2005</td>
<td></td>
</tr>
<tr>
<td>Starch crops</td>
<td>18.57</td>
<td>35.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grassy crops</td>
<td>64.00</td>
<td>127.00</td>
<td>REFUEL project(^{33})</td>
<td></td>
</tr>
<tr>
<td>Woody crops</td>
<td>33.00</td>
<td>65.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil crops</td>
<td>9.99</td>
<td>19.48</td>
<td>GPPAA- MADRP, 2005</td>
<td></td>
</tr>
</tbody>
</table>

\(^{33}\) The REFUEL project was sponsored by the European Commission under the Intelligent Energy – Europe programme (2006-2008). It is designed to encourage a greater market penetration of bio-fuels. More information available at: http://www.refuel.eu/
2. Renewable technology deployment

2.1 Primary and final energy use

The developments on primary energy are presented in Figure 2.1. The percentage of renewables increases from 15% of total primary energy in 2000 to 27-32% in 2020 respectively in the BaU and in the RES-T and RES-30% scenarios (29% in RES). In the BaU scenario gas and renewables increase its relative contribution from 2000 to 2020, replacing oil. In the RES, RES-T and RES-30% scenarios the share of renewables and gas also increase from 2000 and both oil and coal reduce its importance. Compared to the BaU it is foreseen a decrease in total primary energy in 2020 in the RES scenarios (-5% than in BaU in the RES scenario, -7% in the RES-T and -11% in RES-30%).

In Figure 2.2 is presented the evolution of final energy use. In 2020 32% of final energy is RES in BaU, 35% in RES, 30% in RES Trade and 37% in RES-30%. The % of renewables increases in all scenarios from 2000 to 2020, but the target of 31% is only achieved (and exceeded) in 2020. In the case of the BaU scenario the 32% RES in final energy consumption are achieved because RES are competitive. However in the RES and RES-30% scenarios the share of renewables is higher than the target due to the implementation of a RES and climate target from 2015 to 2020 (see section 1). In the RES-T scenario the % of RES is 30.4% and not 31%. This minor difference is due to the way how the target is set in the Pan-European TIMES model since there is a difference in the way model commodities are accounted and in the way they appear in the energy balance from which the target is set. This should not be read as if the RES target is not complied with in the RES-T scenario. The target is indeed complied with but not exceeded as in the other scenarios because it more competitive to sell excess “virtual RES” to other member-states, using the virtual trade mechanism in RES production rights. It should be mentioned that compared to the BaU, the other three scenarios have a decrease in total final energy in 2020 (-4% than in BaU in RES and -7% in the RES-T and in RES-30%).
Figure 2.2 Final energy use

In Figure 2.3 is presented the evolution of final non-renewable and renewable energy use. In the non-renewables the contribution of oil decreases in all scenarios, but is never lower than 30% of total final energy use (for the RES-30% scenario in 2020). The reduction of importance of oil is compensated by non-renewables natural gas and, to a less extent, by coal, and also renewables: bionergy, renewable electricity and other RES (geothermal and solar). From these, other RES, gas and renewable electricity have the largest growth from 2000 to 2020, although in absolute terms the other RES are smaller than gas or electricity. The share of RES-electricity increases from 31% of total electricity in 2000 to 72-82% of total electricity in 2020, especially in the RES-T and RES-30% scenarios. These described trends are common to all four scenarios but progressively more evident from BaU to RES, RES-30% and RES-T.

Figure 2.3 Final energy use of a) non-renewables and b) renewables

a) Final energy use of non-renewables

b) Final energy use of renewables

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation
Regarding only renewable final energy use, both renewable electricity and bionergy (including biofuels) play an important role in all scenarios – their shares increase from respectively 7 and 9% of total final energy use in 2000 to 14-16% for electricity and 10-14% for bioenergy in 2020. The energy and climate targets lead to a further increase in renewable electricity in all RES scenarios. In absolute terms the policy targets make bioenergy more competitive than in BaU only in RES and RES-30% and other RES more competitive than BaU only in RES-T. However, in relative terms all RES carriers increase their relative share in total final energy consumption when compared to BaU. Finally, it should be mentioned that the heat represented in the figures refers to district heating which is not expected to have expression in Portugal until 2020 as mentioned in section 1.2.

2.2 Use of renewable energy sources

In Figure 2.4 is depicted the use of renewable energy in the different sectors. Overall RES consumption increases in all sectors, but especially in the transport, commercial and to a less extent, central heat & power, which leads to some changes in the sector split of renewables. Whereas in the year 2000 industry was responsible for 35% of total RES consumption, followed by the residential and central heat & power sectors each with 32%, in 2020 central heat & power consume 41-45% of total RES, followed by industry (23-29%) and the residential (20-22%). RES start to be consumed in transport and commercial sectors in all scenarios already in 2010, although to a smaller extent than the aforementioned sectors (1% of total RES for commercial in 2020 and 6-9% for transport).

The main differences between scenarios are the higher penetration of RES in transport and central heat & power in the three RES scenarios (in absolute terms). Having RES and climate targets also increases RES consumption in industry, when compared to BaU, with the exception of the RES scenario. For this scenario the RES target is met with a slightly smaller contribution from industry since the biofuels target in transport also has to be achieved. The difference of the RES-T scenario is an increased consumption of RES in industry (more 74% than in 2000 whereas the other scenarios range from more 27-64%). Finally, the stricter climate target of the RES-30% scenario leads to a reduction of RES use in the residential sector, essentially bioenergy (4-3 less PJ than in the other scenarios), which is necessary in industry.

Figure 2.4 Direct use of renewable energy sources in the different sectors
One of the clearest effects of the RES and climate targets is the phase-out of oil products for the commercial sector in 2020. In the BaU scenario 26 PJ are used for heating, whereas only 3 are used in the RES and none in the other scenarios, where more efficient appliances are used.

2.2.1 Electricity generation

The share of electricity generated from RES (including CHP) increases from 31% in 2000 to 72-82% in 2020 respectively for BaU and RES-30% scenarios (Figure 2.5). The main difference between scenarios is the progressive reduction in the electricity generated from coal from BaU, RES, RES-T and RES-30%, and the corresponding increased amounts of electricity generated from renewables, and also from gas in the case of the RES-30% scenario. Although the RES-30% scenario has the lowest contribution of coal it also has a higher quantity of gas than RES-T. Thus, it appears that the not only RES are necessary to comply with an EU-wide -30% climate target – switch coal to gas is also necessary. Moreover, in the RES-30% scenario, the total generated electricity is 4% lower than in RES-T and 5% lower than in RES scenarios. In RES-30% the electricity is replaced by more natural gas than in the RES-T case and by more bioenergy than in the RES case.

![Figure 2.5 Total electricity generation](image)

Regarding RES share of total electricity production in 2020 (Figure 2.6), the major change from 2000 is the reduced relative contribution of hydro. This was 87% of renewable electricity in 2000 and in 2020 is 39% in all scenarios. The reduction of the relative importance of hydro is due to the increase of wind (1% of renewable electricity in 2000 to 47-50% in 2020) and biomass (8% of renewable electricity in 200034 to 9-13%). Geothermal, solar and ocean play a minor role although generated electricity from these resources also increases from 2000: for geothermal from 0.3% in 2000 to 0.3-0.7%; for solar from 0% to 0.3-0.4% and for oceans from 0% to 0.1-0.2% of total renewable electricity in 2020. Biogas is not competitive in any of the studied scenarios.

---

34 Including biomass used in CHP plants.
The differences between scenarios are small (less than 5%) for hydro, solar, wind and ocean. On the other hand geothermal and biomass become significantly more competitive for electricity generation with climate and RES targets. The amount of electricity from geothermal in the three RES scenarios is more than double the one of BaU. The amount of electricity from biomass in the RES, RES-T and RES-30% scenarios is 34-50% more than BaU (mostly from CHP plants in industry) which technologies. Although the differences are marginal (below 5%), solar and ocean are more competitive in the BaU scenario and are less 4% in the three RES scenarios.

From the comparison of the BaU and the three RES scenarios it seems that the climate and RES policy targets do not have a significant effect in the profile of major renewable electricity technologies, such as wind and hydro. However, they significantly affect the share of geothermal and biomass. The statistical transfer mechanism, more than the climate target, has the effect of increasing the amount of renewable electricity especially through the increased use of biomass technologies and reduced use of both coal and gas.

![Electricity generation from renewable energy sources](image)

Figure 2.6  Electricity generation from renewable energy sources

### 2.2.2 Heat production

The share of RES fuels for heat production was of 30% in 2000 and of 39-50% in 2020, respectively for BaU and RES-T scenarios (Figure 2.7). This includes fuel input for heat from CHP and other technologies used in industry, residential and commercial. It was assumed that until 2020 there will be no significant district heating developments in Portugal. It appears that the RES and climate targets contribute to decrease the use of renewables for heat (and instead aim for their use for electricity generation), although this tendency is slightly less evident in RES-30% scenario. In 2020 the total fuels input for heat generation in the three RES scenarios is 7-11% lower than in BaU, especially in the RES-T scenario. In all scenarios in 2020 most of the fuel input for heat generation is bioenergy (28-37% of total fuel input for heat generation), followed by gas (20-28%), oil (16-21%) and coal (12%). This represents a significant change from 2000 when oil was responsible for 43% of fuel input, followed by bioenergy (28%) and gas (14%).
In terms of the relative importance of the different inputs for heat generation in 2020, there is little differences between scenarios for coal, electricity, geothermal and solar (less than 2% difference). However, bioenergy (Figure 2.8) is more prominent in the RES-T and RES-30% scenarios (respectively 37 and 33% of total fuel input) than in BaU and RES (28% of total). Oil plays a more important role in BaU (21% of total fuel input) than in the three RES scenarios (17-16%), where it is replaced by bioenergy (in RES-T and RES-30%) and by gas (RES). Solar (5% of inputs in BaU and 6% in the three RES scenarios) and electricity (8% in BaU and 9-10% in the three RES) play a less important role in all scenarios. Thus the RES and climate targets as such make the use of gas and solar for heat generation more appealing. Bioenergy is only competitive if the climate targets are stricter (RES-30%) or if the statistical transfer of RES is implemented (RES-T). The other RES resources are only marginally affected by these targets.
2.2.3 Transport fuels

The share of biofuels in road transport in 2020 is of 10.5% in the BaU scenario, 14.7% in RES, 14.6% in RES Trade and 17.5% in RES-30% (Figure 2.9). Thus, in all scenarios in 2020 biofuels are competitive regardless of the specific transport targets, since they go beyond the target. The generic RES and climate targets have the effect of driving biofuels penetration beyond the 10% target. It appears that there is no need for specific transport targets to drive the penetration of biofuels in road transport.

In the year 2000, 99.4% of fuel consumed in the transport sector was oil products (mostly gasoline and diesel) and the rest was electricity. In 2020 the share of electricity is maintained in 0.6% in all scenarios. Besides biofuels, there is no other “non-conventional” fuel use in transport, such as hydrogen or other synthetic fuels (Figure 2.10). In BaU, RES and RES-T more than 90% of these biofuels are first generation, in particular biodiesel domestically produced from rapeseed oil (53-69% of total biofuels consumption in road transport in 2020) and mostly imported bioethanol (22-42% of total biofuels consumption in road transport in 2020). In the case of the RES-30% scenario these first generation biofuels only account for 75% of total biofuels consumption in the sector and biomethanol generated from black liquors becomes relevant.
Figure 2.9  *Conventional and non-conventional transport fuels*

Figure 2.10  *Development of non-conventional transport fuels*
3. Trade and import dependency

In Figure 3.1 is depicted the net import/export of fossil energy carriers. There are no shifts between energy carriers due to the renewable or climate targets. The differences between scenarios mimic the differences of primary and final energy use discussed in section 2.1, i.e.: the progressively higher reduction of coal imports from BaU to RES, RES-T and RES-30% in the RES and RES Trade scenarios, and subsequently increased gas imports from BaU to RES-T, RES and RES-30%. From 2000 to 2020 there will be a reduction in import dependency. In 2000 approximately 85% of primary energy was imported and in 2020 the imports will be of 74% for BaU, 72% for RES, 68% for RES-T and 69% for RES-30%.

Figure 3.1  Net import / export of fossil energy carriers

In 2020 is foreseen that Portugal will continue to be a net importer of electricity (into EU), reverting what happened in 2000. The imports, however, will be reduced in approximately 86% in all scenarios. Regarding bioenergy, in all scenarios, except RES, Portugal will be a net importer of bioenergy from outside of EU, mostly bioethanol (Figure 3.2). In the RES and RES-30% scenarios there is also export of bioenergy into EU but in the case of RES-30% this is compensated by amounts imported. In the case of RES, the Portugal will be a net exporter of 1 PJ of biofuels in 2020. With the stricter climate target of RES-30% and the possibility of statistical transfers of RES-T is more cost-effective to import renewables from outside EU and either use them internally or use the transfer mechanism.
The statistical transfer mechanism of RES-T scenario results in the net export in 2020 (Figure 3.3), not of electricity but of other final energy.

Figure 3.2  *Inter-EU trade and import from outside EU27 of biofuels and electricity*

Figure 3.3  *Virtual trade of renewable energy in the RES Trade scenario*
4. Impacts of policies on emissions and costs

4.1 Emissions

From 2000 to 2020 the total CO₂ emissions increase 4% in the BaU scenario and decrease 6-21% respectively for the RES and RES-30% scenario (-11% for the RES-T). The 2020 ETS sectors emissions of the BaU scenario are the same as in 2000 and decrease 13%, 15% and 34% for the RES, RES-T and RES-30%, respectively. The non-ETS sector emissions increase 8% in BaU, are kept constant in RES and decrease 7% and 8% in RES-T and RES-30% (Figure 4.1).

As expected, the RES-30% scenario has the lowest increase in emissions from 2000, followed by RES-T and RES. The lower emissions in the RES-30% scenario are mainly due to the smaller emissions from the electricity sector, which reduces emissions in 81% from 2000 to 2020, and to a less extent the transport sector (-9% emissions in 2020 than in 2000). The other scenarios have the same behaviour but with slightly less reductions from electricity and transport. The difference in emissions from the electricity sector is not only due to the increase in renewable electricity, but also to the reduction of the use of coal power plants especially in the RES-30% scenario. It is not foreseen the penetration of carbon capture and storage technologies in Portugal until 2020.

The following sectors reduce their emission from 2000 to 2020: agriculture which reduces emissions in 18-24% from 2000 levels, the commercial sector only in RES-T and RES-30% (less 22-24% than in 2000) and the non-ETS industry in BaU, RES-T and RES-30% (less 3-30% than in 2000). The other sectors (ETS industry, Transformation ETS, Residential, Commercial in BaU and RES and non-ETS industry in RES) have in 2020 higher emissions than in 2000 in all scenarios. However, their contribution for total emissions is much smaller than the electricity and transport sectors.

Considering that Portugal is a net exporter within the statistical transfer mechanism in 2020 is it can be said that the CO₂ targets are being enforced by using mostly endogenous renewable resources mainly hydro and wind and some endogenous and imported bioenergy. Finally, it should be noted that the non-ETS cap of 34.1 Mt CO₂ is not achieved in any of the three RES scenarios as the non-ETS emissions are of 30.8 Mt CO₂, 28.5 Mt CO₂ and 28.1 Mt CO₂, respectively for RES, RES-T and RES-30%. Thus, the RES and CO₂ tax as considered in BaU seem to be enough to drive non-ETS reductions, at least the energy-related ones.

Figure 4.1 CO₂ emissions
4.2 Costs

The total investment and operational costs of renewable technologies Portugal in 2020 are of 3467 M€ in the BaU scenario, 3862 M€ in RES, 4034 M€ in RES-T and 4063 M€ in RES-30%. This corresponds to 1.63% of the 2020 GDP, 1.81%, 1.90% and 1.91%, respectively for BaU, RES, RES-T and RES-30%. Thus, the 4% more renewables in final energy of the RES scenario cost more 0.19% of the 2020 GDP when compared to BaU; the 11% more renewables of RES-30% scenario cost more 0.28% than in BaU and the 14% more renewables of the RES-T scenario only more 0.27% than in BaU.

In terms of the total energy system costs the RES and RES-30% scenarios are 0.04% and 0.33% more costly than BaU due to the added effort necessary to comply with the climate and RES targets. However, the total system costs of the RES-T scenario are 0.02% less than in the BaU scenario. The revenues gained with the statistical transfer mechanism compensate the extra costs with both the climate and RES targets.

5. Conclusions

Overall results point out that the current policy incentives can deliver the 2020 targets for the use of renewable energy sources and decrease the non-ETS CO₂ emissions below the target for Portugal. In 2020 the BaU scenario has 32% RES in final energy consumption (target for Portugal is 31%), 10.5% biofuels in road transport (target is 10%) and 33.0 Mt CO₂ from Non-ETS sources (national cap for CO₂ only is 34.1 Mt). In this scenario the total investment and operational costs of renewable technologies represent 1.63% of the 2020 GDP. However, this does not ensure an overall EU emission reduction for 2020 of -20% or -30% from 1990 levels.

The results also show that, with a relatively small cost increase, it is possible to achieve such an EU-wide reduction target in 2020 while going further in the promotion of RES. In the RES scenario 35% of final energy consumption is RES, 30.4% in RES-T and 37% in RES-30. RES in road transport are of 14.7% in RES, 14.6% in RES Trade and 17.5% in RES-30%. In terms of cost increase of total investment and operational costs of renewable technologies this represents in the RES scenario more 0.19% of the 2020 GDP when compared to BaU; in RES-T more 0.27% than in BaU and in the RES-30% more 0.28% than in BaU.

In the RES and RES-30% scenarios the share of renewables is higher than in BaU due to the combined implementation of RES and climate targets. Thus it seems that the climate target is driving RES penetration beyond the RES target. In the RES-T scenario the RES target is complied with but not exceeded because it is more competitive to sell excess “virtual RES” to other member-states, using the virtual trade mechanism in RES production rights.

Regarding renewable electricity, it seems that the climate and RES policy targets do not have a significant effect in the profile of major renewable electricity technologies, such as wind and hydro. However, they significantly affect the share of geothermal and biomass. The statistical transfer mechanism, more than the climate target, has the effect of increasing the amount of renewable electricity especially through the increased use of biomass technologies and reduced use of both coal and gas.

In terms of heat production the combination of RES and climate targets make the use of gas and solar for heat generation more appealing. Bioenergy is only competitive if the climate targets are stricter or if the statistical transfer of RES is implemented. The other RES resources for heat production are only marginally affected by these targets.

Finally, both renewable electricity and bioenergy (including biofuels) for heat production and road transport play an important role in all scenarios. However, the current policy incentives are mainly focused on the promotion of renewable electricity. Since much of the RES and emission targets are achieved by increased use of national bioenergy both in the industry, transport and electricity production sectors this

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35 The target is 31% and not 30%. This minor difference in this scenario is due to the way how the target is set in the Pan-European TIMES model since there is a difference in the way model commodities are accounted and in the way they appear in the energy balance from which the target is set. This should not be read as if the RES target is not complied with in the RES-T scenario.
seems to indicate that this form of energy should be specifically addressed in policy design in order to realize fully the national potential.

6. References


ROMANIA
1. Introduction

This chapter describes the modelling outcomes for Romania within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- **A BaU scenario (BaU)**, based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the *Reference Document on Renewable Energy Sources Policy and Potential* (Deliverables D2.2 and D2.3).

- **A RES Reference Scenario (RES)** for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Romania this means 24% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO\textsubscript{2} emissions cap of 98.5 Mtons, combined with the 75.9 Mtons cap for industrial emissions between 2008 and 2012.

- **A RES Trade Scenario (RES-T)** in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- **A RES Climate Scenario (RES-30%)**, in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/export are discussed, and in section 4, the CO\textsubscript{2} emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

The Romanian energy sector is characterized by:
- co-generation plants for urban heating;
- extensive use of coal-fired installations for power and heating generation systems;
- use of hydroelectric power plants and still potential for development in this sector;
- nuclear energy provision from the Romanian -Cernavoda plant.

Romania is an important producer of gas, oil and solid fuels. Domestic production covers a large part of energy needs (70% in 2007). To supplement this, Romania also imported oil, gas. The percentage of renewable sources in production of primary energy supply and generation in electricity is more than the EU average. There is a small but significant contribution to growth of nuclear energy.

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36 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
Two more nuclear units rated 710 MW each are to be added to the existing 1420 MW capacity in Cernavoda plant. Coal continues to represent an important fuel for electricity. Final energy consumption has decreased considerably since 1990 and remains the industry with the highest energy consumption.

The indicators linked to the energy efficiency improved, but this relates more to structural changes in the economy rather than to real energy savings.

According to the baseline scenario for Romania prepared by the European Commission, the final energy consumption should increase from around 23.58 Mtoe in 2005 to 30.48 Mtoe in 2020. In the same period the share of RES in the final energy consumption should increase from 17.8% to 24% in 2020. Romania hopes to become a key electricity exporter to the rest of the European Union by 2020. This will be accomplished by the doubling of the country’s power output to 100 TWh by 2020, exceeding domestic energy needs. Romania also plans to promote renewable energy so that these sources account for 33% of overall power consumption by 2010.

In implementing the European Union's Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market, Romania has chosen to promote the production of energy from renewable sources by adopting a system, based on "Green Certificates" (as more fully detailed in Government Decisions 443/2003 and 1892/2004).

A new law regarding energy production from renewable resources, Law 220/2008 has been approved by the Parliament, and was endorsed by the President in October 2008. The Law includes a new and improved Green Certificates scheme.

Romanian gross domestic product (GDP) went up by 2.9 % in the last trimester of the last year, balancing the total increase of 2008 by 7.1 %, despite the decrease in demand brought activity cuts in most of the sectors of economy, according to the data issued today by the National Institute of Statistics (INS). GDP value was of 159.43 billion lei (41.8 billion euro) in the last third of 2008 with a total of 503.959 billion lei (136.8 billion euro) in 2008.

Romania's economy could idle next year after a 4 percent contraction in 2009, as the only sector to post an increase is the construction sector, according to a prognosis for the period 2009 – 2013 published by Romania's Prognosis Commission (CNP). CNP sees an insignificant advance of the gross domestic product (GDP) by 0.1 percent in real terms in 2010. The nominal GDP is estimated at 568.5 billion lei, up from 531.25 billion lei in 2009. The GDP amounted to 503.96 billion lei last year. The Forecast Commission anticipates a comeback of Romania's economy in 2011, with a GDP advance of 2.4 percent, followed by other positive rates: 3.7 percent in 2012 and 4.4 percent in 2013.

2. Renewable technology deployment

2.1 Primary and final energy use

Primary energy resources were in 2007 47,500 ktoe ; gas is the dominant fuel, accounting for 29.8% of primary energy resources in 2007, followed by oil at 29.3%, coal at 23.7%, with electricity from hydro, nuclear and import having a 7.1% share.
The existing utilisation of RES in Romania is primarily in the hydro power and biomass sectors; for biomass especially in the residential rural sector where firewood, forest and agricultural waste are used for heating in traditional stoves. The majority of all RES-E is generated through large-scale hydro power. The high potential of small-scale hydro power (< 10 MW) has remained almost untouched.

Other areas of RES utilisation are poorly developed. A small number of wind, solar, biomass (DH) and geothermal pilot projects have been implemented.

Production of biofuels is rapidly increasing and is estimated to count for 2,326 GWh (200 toe biodiesel) in 2008.
Final energy use in 2007 was about 25,000 ktoe, divided in industry- 10,000 ktoe, residential- 7,560 ktoe, transport- 4740 ktoe, agriculture- 260 ktoe, tertiary- 2440 ktoe.

Currently the RES share in the final energy use is about 18%. If the BAU scenario will be considered then in 2020 the final energy use of renewable will be split into 30% for electricity, 10% for heat; 45% for bio-energy and the rest for other RES. If we consider the RES trade then the electricity and specially bio-energy from RES will increase considerable.

The RES trade scenario will be advantageous for Romania as the hydro, wind and biomass potential is large, permitting efficient investments to export GCs.
2.2 Use of renewable energy sources

As it was mentioned before the existing utilisation of RES in Romania is primarily in the hydro power and biomass sectors; for biomass especially in the residential sector. The majority of all RES-E is generated through large-scale hydro power. The high potential of small-scale hydro power (< 10 MW) has remained almost untouched. In the power sector, wind energy as the biomass CHP will be the new entrants.

Biomass will continue to have the main position as renewable in the residential sector in all scenarios, while biofuels use is seen to register the most dynamic evolution for use in transport, replacing part of fossil fuels. In fact Romania may export the surplus of produced biofuels after fulfilling the 10% target by 2020.

![Graph: Direct use of renewable energy sources in the different sectors](image)

Figure 2.4 Direct use of renewable energy sources in the different sectors

2.2.1 Electricity generation

Currently the share of RES in total electricity production is around 31.5% equivalent to 18.5 TWh. For 2010 the E-RES should be around 21.8 TWh representing 33% of national gross electricity consumption. In all scenarios, except BAU it can be seen a decrease of electricity from coal, a stagnation or decrease in electricity from gas and an increase of nuclear and E-RES production from 2000 to 2020. In Romania there is a clear defined policy for nuclear electricity development. Due to this nuclear policy, the RSE development will be driven by the RES-directive rather than the Climate directive.

Among RES resources and technologies, the wind energy is expected to have the strongest development, from few MW installed today, to some 3000 MW by 2020. The technical and economical potential is several times larger, but the main limitation will be induced by the grid acceptance.
Also CHP fuelled by biomass are expected to have a significant evolution, based on large resources and land availability (2-3 millions ha) for energy crops.

Figure 2.5 Total electricity generation

Figure 2.6 Electricity generation from renewable energy sources
2.2.2 Heat production
The relevant existing heating technologies in Romanian dwellings are:
- stoves on biomass, natural gas or coal (in 60% of the dwellings);
- centralized district heating from large (and mainly obsolete) CHP units, or boilers (26%);
- local (per dwelling or per building with several flats) central heating boiler fuelled by natural gas (12%).

Almost all heating systems in rural area are based on traditional stoves, while in large cities DH or local central heating boiler are used. There are some 8 millions such rural stoves in Romania fuelled by forest or agricultural waste. This is the only use or RES for heat today.

![Figure 2.7: Total input for heat production](image)

Today RES share in total heat production is some 20%. If we consider the trade scenario it is expected that the share will increase towards 2020 to around 25-26% while considering BAU scenario RES contribution will be steady.
Figure 2.8  Heat production from renewable energy sources

Biomass will continue to be the main RES for heating, but by using more advanced technologies as efficient boilers for small DH systems or CHP units. Nevertheless the use of biomass in rural stoves will have the main share (55%) also in 2020. Solar heat will penetrate with a visible share too, mainly for hot water (with a share of 20% from total heat production from renewable).

2.2.3  Transport fuels

Today all biofuels contributions regard biodiesel, mainly based on rapeoil. There is no yet 2nd generation biofuel technology available on the market. This may be operating from around 2012.
In 2000 the shares of fossil diesel and gasoline were almost equal. No significant biofuel share was registered. In 2006 appeared the indigenous biofuel production contribution. The diesel share increased versus the gasoline share.

Figure 2.9  Conventional and non-conventional transport fuels

Figure 2.10  Development of non-conventional transport fuels
3. Trade and import dependency

The import of fossil fuels, mainly gas, will continue in all scenarios, of course in different amounts, depending on RES contributions. We can expect a significant increase of gas import especially in RES 2020 and RES-30% scenario from 110 PJ in present up to 480 PJ. Regarding the oil products, the import level will keep the same share during the time.

Figure 3.1 *Net import / export of fossil energy carriers*
Romania will be a significant exporter of biofuels, with no important differences according to the scenario. Indigenous biofuel production is driven by the land availability and traditional ability for agricultural products.

Figure 3.2  *Inter-EU trade and import from outside EU27 of biofuels and electricity*

Figure 3.3  *Virtual trade of renewable energy in the RES Trade scenario*
4. Impacts of policies on emissions and costs

4.1 Emissions

The emissions trend reflects the changes in this period, characterized by transition to a market economy. The emissions trend can be split into two parts: the period of 1989-1996 and the period of 1996-2006. The decline of economic activities and energy consumption from 1989 to 1992 directly caused the decrease of total emissions in that period.

Due to the differences in economic development and the need for economic growth, Romania received a percent of +19% in 2020 compared to 2005 for the evolution of emissions within non ETS sectors (transport, agriculture, waste, services, houses especially heat, small installations which are not the object of the trading scheme).

4.2 Costs

Renewable energy is typically characterized by higher up-front costs resulting in significantly reduced fuel and/or operating costs (although not all technologies fit this characterisation, for example, biomass energy can involve substantial ongoing costs for fuel and operations). Costs are typically born directly by market participants; either energy producers or consumers or both.

The cost for the system resulted from the PRIMES model is around 1021 billions €, 606.7 billions €, representing the investment cost.
Considering the GDP at country level, the share of renewable costs is about 0.6% at 2000 year level up to 2.8% in 2020 in BAU scenario and could be 3.1% in the RES trade.

5. Conclusions

- The mix of primary energy resources will remain balanced between gas, oil, coal, nuclear and renewables, with a clear increase of RES, even in the BAU scenarios
- The largest RES potential able, if developed, to contribute decisively to the RES quota is the biomass potential, due to land availability and traditional ability for agricultural crops and forest works
- The large scale hydro electricity will continue to supply the majority of RES-E. New significant contributions are expected from small hydro, wind and biomass (in CHP).
- Due to the nuclear policy, the RES development will be driven more by the RES-directive rather than the Climate directive
- Biofuels will be largely developed, permitting important export in EU.
- The sectors of transport and energy will visibly experience the RES penetration
- RES heat will stil be based on rural use for heating of forest and agricultural waste, but it is expected a technological switch from traditional to modern and efficient technologies

6. References


SLOVENIA
1. Introduction

This chapter describes the modelling outcomes for Slovenia within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For Slovenia this means 25% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO₂ emissions cap of 8.6 Mtons.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% instead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

The Slovenian domestic resources are very scarce, being mainly constituted by nuclear energy, solid fuels (the country’s brown coal resources account for 95% of coal consumption) and hydroelectricity. Slovenia imports natural gas and almost entirely the oil products necessary to the fulfillment of energy demand (Ministry of the Environment, 2005), with a 55.9% dependence on external energy supplies in 2005 (EREC, 2008).

The power plants installed capacity is about 2900 MW (2003) distributed as follows: 48% thermal (the most used fossil fuels are lignite and brown coal), 30% hydro and 23% nuclear power plant. The national demand of electricity is completely fulfilled by the domestic production and the surplus is exported to the neighboring countries, mainly Croatia. Slovenia’s energy intensity is much higher than the EU-25 average.

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37 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
As concerns heat production, most of the commercial heat produced in Slovenia comes from municipal and auto-producer CHP plants, the latter mainly in the wood processing industry to support their primary production (BIOCOGEN, 2006). The share of RES heating and cooling was of 4.5% in 2006.

The RES share in total primary energy consumption achieved 11% in 2006 (EREC, 2008). In particular, the share of all biofuels in the transport fuels was by energy 2% in 2006 and should achieve 5% of petrol and diesel use in 2010, just slightly below the reference value of 5.75%, according to the European Biofuels Directive (Commission of the European Communities, 2008).

The share of renewables in primary energy supply is steadily increasing reaching, in 2005, the 16% of the gross final energy consumption and, in 2006, the 24% of the gross electricity production (EREC, 2008). In particular, in Slovenia (REEEP, 2006),

- Hydropower plants (large and small) have the largest share (46%) amongst the RES and also still the largest potential for development. Gross electricity potential of Slovenian rivers is 19400 GWh/y, most of it for small hydro power plants up to 10 MW.
- Wind energy is currently used at few locations, mainly for recording purposes or for water pumping and feed grinding.
- The existing capacity of geothermal resources amounts to about 103 MW of heat plant providing heat to health spas, agriculture and institutions, whereas the theoretical potential is 19.6 PJ/a.
- Low intensity solar energy is not currently implemented widespread.

Slovenia is currently far away from meeting its RES targets by 2010, mainly set by the 2004 National Energy Program (from 9% to 12% share of RES in primary energy balance and from 22% to 25% in heat supply) as well as by the renewable electricity directive (33.6% of gross electricity consumption) (EREC, 2008).

In the last few years the Ministry for Environment, Spatial Planning and Energy through the Agency for Efficient Use and Renewable Energy supports the investments in RES and cogeneration with subsidies for investment projects. The subsidies are foreseen in the each year budget, the available amount of money for supports is limited. More information are available in (REEEP, 2006) and (EREC, 2008).

For modelling purposes, some assumptions were introduced to shape the national sectoral socio-economic figures (RES2020, 2009). Future energy service demands were based on population (Eurostat statistics) and macro-economic projections (GEM-E3 model’s outputs). Table 1.1 resumes the population annual growth rates for Slovenia as well as the average GDP annual growth rates, based on a GDP level, in 2000, of 20.8 million euro (RES2020, 2008).

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<td>Population</td>
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<td>2.3%</td>
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Table 1.1: Annual growth rates for Slovenia
2. Renewable technology deployment

2.1 Primary and final energy use

In the base year the total primary energy supply is characterized by a prevalent consumption of oil (38%) and coal (21%) followed by nuclear (18%), renewables (12%) and gas (12%). In the reference scenario (BaU) the primary energy consumption increase from the initial 264 PJ to 319 PJ in 2020 (Figure 2.1). This is mainly due to a strong increase of electricity import, from 3.3 to 10.6 PJ, as well as of renewables (+86%) and natural gas (+54%) use respect to the base year. In the RES scenarios, only in the 2020 under more stringent boundary conditions an inversion of trend is observed, in particular, an average 4% reduction is achieved in 2020 respect to 2015 in total primary energy supply.

As concerns commodities consumption, oil is the most used fuel, mostly utilized in Transport, followed by renewables that have an increasing role in all scenarios. In particular, in the RES scenarios renewables double their share in 2020 respect to the values of year 2000, substituting mainly coal whose share is reduced by -50%, -55% and -69% respectively in RES Reference, RES-T and RES-30% scenarios.

Renewables contribution to the fulfillment of final end-uses demands is shown in Figure 2.2. Their share, is about 15% in the base year in 2020, increasing on the full time horizon in all the RES scenarios up to values very close to the 25% target set by the European Directive for Slovenia. In fact, the renewables share in 2020 is about 24% in the RES reference scenario. The climate target foster a 2% a further increase but the highest percentage is achieved in RES-T (28%). In particular, this share is achieved by selling green certificates to other European countries.
Regarding non-renewable fuels (Figure 2.3 a) oil, electricity and gas are predominant fuels in the base year, representing respectively about 63%, 16.4% and 15.7% of final energy consumption. These fuels are still the most used on the full time horizon in BAU scenario in which natural gas doubles its share (from 24 PJ in 2000 to 43 PJ in 2020), oil share increases +13% and a electricity use decreases 4%. In 2020, non renewable fuels consumption decrease substantially in all the RES scenarios being substituted by renewables. This is confirmed by the increasing trend of renewables (Figure 2.3 b) that can be observed in either in BaU and the RES scenarios. On the full time horizon, the largest contribution is deployed by bio-energy and electricity generated from renewables, with a small contribution of solar (included in “Other RES”).

Figure 2.2 Final energy use

Figure 2.3 Final energy use of a) non-renewables and b) renewables

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation
2.2 Use of renewable energy sources

Figure 2.4 shows the sectoral share of renewables by scenario. In the base year renewable energy sources are mostly utilized by Residential and Central Heat and Power production (respectively 50% and 44%). In Residential biofuels use is prevalent, whereas, hydro is the only one that is utilized in Central Heat and Power production.

Renewables use becomes consistent also in Transport and Industry on the full time horizon. The effects of different boundary conditions is more evident in these two sectors as well as in Commercial sectors, in which renewables use strongly depends upon the scenarios assumptions. In 2020, in the RES-T scenario Transport has the highest renewables share (about 8.6 PJ, +72% respect to BaU) and solar thermal penetrate in the Commercial sector (0.33 PJ). On the contrary, Industry has the highest renewables share in RES-30% (about 7.9 PJ, 114% respect to BaU). On the other hand, renewables share in the Residential and Conversion sectors are less influenced by the scenarios’ constraints, being almost constant in all scenarios.

In RES-30% climate policy boosts renewables penetration, fostering the substitution of fossil fuels (e.g. in the Industry sector gas share decrease by 1.6 PJ respect to the base year).

![Figure 2.4: Direct use of renewable energy sources in the different sectors](image)

2.2.1 Electricity generation

The fuel mix for electricity generation is represented in Figure 2.5. The total generated electricity increases until 2010 in all scenarios. After 2010 a further increase can be noticed in the BaU scenario achieving a share of 16.3 TWh in 2020. On the contrary, there is a slight decrease in the RES scenarios, which average share is about 14.4 PJ in 2020.
On the full time horizon there is an increasing importance of renewables in the electricity production, which share increases from 30% in the base year increases to about 40% in 2020 in all the RES scenarios (+45% in RES-T).

Nuclear has the highest deployment in 2010, being constant from 2010 onwards in all scenarios. Coal consumption decreases mainly in RES-30% scenario (-68%), being substituted by natural gas that quadruples its base year production, achieving 1.73 TWh in 2020.

![Total electricity generation](image)

**Figure 2.5 Total electricity generation**

Among renewable energy sources, hydropower is the most utilised in electricity generation, with a share higher than 70% in each time period and all scenarios. From 2015, wind energy share increases significantly, being the second in importance after hydropower with a 19% share for RES and RES-30% on the full time horizon. Also biomass contribution increases remarkably from the initial 0.38%, achieving a 14% share in RES-T.

On the other hand, PV and biogas are still not used, due to the limited availability of biogas and the high investment prices of PV.
2.2.2 Heat production

Heat production increases until 2015 in all the scenarios, with a lower growth rate for the RES scenarios. After 2015 an increasing trend can still be observed in BaU whereas for the RES scenarios a steady decrease can be noticed.

In the base year oil share is prevalent (43%), followed by gas (27%) and renewables (22%), electricity (5%) and coal (3%). On the time horizon, there is a strong reduction of oil consumption (from 37.6 PJ in the base year up to 21.8 PJ in BaU and, on average, to 13.5 PJ in the RES scenarios, with a minimum of 12.9 PJ for RES-30%). Oil heating plants are substituted by gas and renewables fuelled technologies. The virtual trade mechanism in RES-T scenario boosts the use of renewables for heat production, which share increase by 6% and 1% respect to RES and RES-30% scenarios in 2020.

Figure 2.6 Electricity generation from renewable energy sources
Focusing on renewables energy sources (Figure 2.8), a prevalent contribution of bio-energy, can be noticed, which is mainly used in Residential and Commercial to fulfil space heating demand. In Residential solar thermal has also an increasing importance with a share of about 5 PJ in 2020 in the RES scenarios. On the full time horizon, renewables use for heat production increases in all scenarios (from 18.6 PJ in the base year until to 32.6 PJ in BaU and to a maximum value of 37.3 PJ in RES-T). From the results it can be seen that the emission trade scheme boosts the utilisation renewables that show the highest increase RES-T (about 98%).
2.2.3 Transport fuels

In transport fossil are the most used fuels on the whole time horizon (Figure 2.9). Nevertheless the 2% share of non-fossil sources forced by the EU Directive in 2010 increases steadily until 2020 up to 11%. Among fossil fuels, gasoline is the most used, with a share always higher than 57% compared to the total fossil fuels consumption, followed by diesel, whose share decrease from 30% to 25% in the BaU scenario.
Among non-conventional fuels (Figure 2.10), biofuels are the mostly used, achieving the EU 5.75% and 10% targets in 2010 and 2020 in all the RES scenarios. Electricity contribute is very small (about 1% in 2020) and, hydrogen is not used due to its still high prices.

Among biofuels, a first generation fuel, based on biochemical conversion of biomass to ethanol (BIOETH) is prevalently used, together with a minimum share of biodiesel and second-generation bio-fuel (methanol). Trade mechanisms drive the penetration of second generation biofuels: in fact, methanol achieves the highest consumption in RES-T scenario (76% of total biofuels in 2020).

Climate policy (RES-30% scenario) in 2020 leads a slight reduction of Transport sector’s consumption (Figure 2.9) that is due mainly to a smaller use of biofuels that decreases by 2% in RES-30% respect to the RES reference scenario (Figure 2.10).
3. Trade and import dependency

Figure 3.1 shows a comparison between imports and exports in 2020 for all scenarios respect to the base year. It can be seen that renewables directive allows a reduction of oil products import, becoming more effective in combination with the climate policy (RES-30% scenario). In this case oil import decreases -1.4%, compensated by an increase of gas and coal (respectively +65% and +25% respect to the base year).
Figure 3.1  *Net import / export of fossil energy carriers*

Figure 3.2 shows the imports and exports of bio-fuels and electricity in Slovenia. Electricity is imported mainly from European Countries in the RES scenarios. Obviously, the export of bio-fuels is deeply influenced by the certificate trade process. In fact, in the RES reference and in the RES-30% scenarios Slovenia is a net exporter of bio-fuels (respectively 39.7 PJ and 35.7 PJ in 2020) whereas in RES-T, biofuels’ import towards EU and the rest of World countries is strongly reduced by the purchasing green certificates. Therefore the total amount of exported biofuels in RES-T is about 8 PJ.
However, in RES-T Slovenia is a seller of green certificates to the other EU countries (Figure 3.3) with an amount contribution ranging from 8.3 PJ in 2010 to 14.3 PJ in 2020. As well known, final energy from renewables does not contribute to certificates trades, that concerns only green electricity.

Figure 3.2 Inter-EU trade and import from outside EU27 of biofuels and electricity

Figure 3.3 Virtual trade of renewable energy in the RES Trade scenario
4. Impacts of policies on emissions and costs

4.1 Emissions
On the full time horizon CO₂ emissions increase 11.3% in BaU and decrease in all the RES scenarios, respectively 10.7% in RES reference, 16% in RES-30% and 25.7% in RES-T. A huge reduction is obtained in the ETS sector (-33% in RES reference, -39% in RES-T and -58% in RES-30%), whereas the non ETS sectors show an increase in all scenarios (+22% in BaU, +11 in RES reference, +6.4% in RES-T and +5.7% in RES-30%) even if remaining under the Slovenian target of the European directive (8.6 Mt).

Among the ETS sectors, the hugest reduction is observed in electricity and heat production for the RES-30% scenario (about -78%, from 5.2 Mt in the base year to 1.2 Mt in 2020). On the contrary, among the non ETS sectors, the highest increase is observed in Transport (about 47% in the RES reference scenario, from 3.7 Mt in the base year to 5.7 Mt in 2020).

In 2020 carbon capture and sequestration are activated in the RES reference and RES-30% scenarios with the following contributions: -0.15 Mt CO₂ from afforestation in RES reference and -2.4 Mt CO₂ from carbon capture and storage in the electricity and cogeneration power plants in the RES-30% scenario.

Figure 4.1 CO₂ emissions

4.2 Costs
The variation of the total system’s cost in the analyzed scenarios emphasizes the impact of the different policies in monetary terms. In general, the total cost increase is quite small (Table 4.1). The highest value is obtained in RES-30%, which increases 1.5% respect to BaU and 0.5% respect to RES reference. The cost increase is mainly determined by the welfare loss that is higher in the RES-30% scenario (about +67%), in which the climate constraint is tighter.
As shown in Table 4.2, the highest investment and operational costs of renewable technologies are observed in RES-T for the years 2010 and 2020, whereas the RES-30% scenario has the highest investments costs in 2015, due to an earlier deployment of renewables, as emphasized in Figure 2.4.

The largest economic impact of the RES-T scenario is also evident in the costs of renewable technologies as a share of GDP (Table 4.3).

### Table 4.2 Total investment costs and operational costs of renewable technologies

<table>
<thead>
<tr>
<th>Scenario/Period</th>
<th>2000</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total investment costs BaU</td>
<td>0.08</td>
<td>232.55</td>
<td>408.14</td>
<td>494.99</td>
</tr>
<tr>
<td>RES</td>
<td>0.08</td>
<td>236.09</td>
<td>426.33</td>
<td>572.64</td>
</tr>
<tr>
<td>RES-T</td>
<td>0.08</td>
<td>237.45</td>
<td>415.01</td>
<td>617.59</td>
</tr>
<tr>
<td>RES-30%</td>
<td>0.08</td>
<td>237.33</td>
<td>430.29</td>
<td>577.86</td>
</tr>
<tr>
<td>Total operational costs BaU</td>
<td>11.78</td>
<td>42.84</td>
<td>62.66</td>
<td>84.64</td>
</tr>
<tr>
<td>RES</td>
<td>11.78</td>
<td>43.61</td>
<td>65.78</td>
<td>94.03</td>
</tr>
<tr>
<td>RES-T</td>
<td>11.78</td>
<td>44.45</td>
<td>65.82</td>
<td>122.13</td>
</tr>
<tr>
<td>RES-30%</td>
<td>11.78</td>
<td>44.41</td>
<td>67.68</td>
<td>99.03</td>
</tr>
</tbody>
</table>

5. Conclusions

In a “Business as Usual” development the Slovenia energy system does not achieve the 25% EU target of renewable end-uses set by the European Directive in 2020. Nevertheless, the different boundary conditions hypothesized in the RES scenarios allow investigating the role and the effectiveness of various policy measures in the achievement of such a target in the medium term.

In fact, on the full time horizon renewables share in BaU is about 21% whereas in the RES scenarios it ranges from 24% to 28%. The highest percentage of RES-T is due to the trade mechanism that favor the use of renewables through the sale of green certificates to other countries. Renewables penetration is boosted by green certificate trades also in heat production (in particular their share is almost doubled both in RES-T and in RES-30%).
As concerns the sectors, renewable energy sources are mainly utilized in Residential and Conversion. In particular, in the Conversion sector, renewable share increases in all the RES scenarios from 30% to 40% on the full time horizon. In 2020 hydro is still the main utilised renewable energy source for electricity generation (with an estimated share higher than 70% in every scenario) followed by wind power, which share is about 19% in both RES reference and RES-30%.

As concerns trade and import dependence, the achievement of the target on renewables fosters a reduction of fossil fuels imports in all the RES scenarios with the exception of natural gas, whose imports slightly increase in RES reference and RES-30%.

CO$_2$ emissions increase 11.3% in BaU from 2000 to 2020, however the RES policies bring on a general reduction of CO$_2$ emissions. In particular, in the RES scenarios the CO$_2$ emissions keep under the national target set for Slovenia by the European Directive, decreasing respectively 10.7% in RES reference, 16% in RES-30% and 25.7% in RES-T respect to the base year.

The contribution to such a reduction comes exclusively from the ETS sectors that show a consistent decrease (-33 in RES reference, -39% in RES-T and -58% in RES-30%) which is partially mitigated by the increase in the ETS sectors (in particular, +22% in BaU scenario, +11 in RES reference, +6.4% in RES-T and +5.7% in RES-30%).

In particular, carbon capture and sequestration as well as afforestation contribute both to CO2 reduction, carbon capture and sequestration technologies being activated after 2015 in the scenarios RES reference and RES-30%. In RES reference, afforestation contributes to the capture of 0.15 Mt CO2 whereas in RES-30% both afforestation and carbon capture and storage allow achieving a reduction of 2.4 Mt CO2.

From a monetary point of view the results emphasise that with a modest increase of total energy system cost and welfare loss it is possible to achieve both the reduction of CO2 emissions and an enhanced use of renewable in agreement with the EU directives.
6. References


SPAIN
1. Introduction

This chapter describes the modelling outcomes for Spain within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on an EU level. For Spain this means 20% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO2 emissions cap of 183.6 Mtons.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO2 emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

The Spanish economy is characterized by a relatively higher energy intensity than the rest of Europe, by a high dependence on energy imports, but also by very rapid changes of the energy system in the last few years, making the energy situation of Spain quite unique for the observed changes. Spanish current supply structure and policies are described in chapter 10 of the RES2020 report ‘Reference Document on Renewable Energy Sources Policy and Potential’, Deliverables D.2.2 and D.2.3, by EREC. However, given the rapid changes observed in the last few years, and not reflected in the report above, a summary of the situation, with the most recent available data, is provided here.

Current energy and emission situation

- The share of RES in total primary energy consumption was 6.8% in 2006, 7% in 2007 and 7.6% in 2008. The consumption of Renewable Energy in 2007 grew 11% with respect to 2006.

38 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
• The **share of RES in the gross final energy consumption** was 3.6% in 2005, 3.4% in 2006 and 3.7% in 2007.
• The **share of RES in the gross electricity production** was 18.8% in 2006 (including hydroelectricity) with 57167 GWh (Coal: 69988 GWh, Nuclear: 60021 GWh), 20.2% in 2007 with 72530 GWh (Coal: 74204 GWh, Nuclear: 55102 GWh) and 19.7% in 2008.
• The **share of RES heating and cooling** was of 3.6% in 2006.
• The **share of biofuels** in the transport sector in 2006 was 0.53% and 1.16% in 2007.
• Spain energy dependence on imports amounted to 78% in 2006, 79.1% in 2007 and 78.4% in 2008.
• **Wind power** represented 9% of total electricity production in 2007 with an increase in the installed capacity of 18.7% as regards 2006. 16.6 GW of wind were installed in Spain in 2008.
• **Hydropower production** reached 29523 GWh in 2006 and 30511 GWh in 2007.
• In 2006, **PV** reached 118 MW of capacity installed, 607 MW in 2007 and 3120 MW in 2008; **Biogas** 160 MW, and **Biomass** 409 MW.
• 270 ktoe of **biofuels** were produced in 2006 (158 ktoe of bioethanol and 112 ktoe of biodiesel) while the domestic consumption was 170 ktoe (114 ktoe of bioethanol and 56 ktoe of biodiesel). The surplus was exported. In 2007, biofuels production was around 313 ktoe (180 ktoe of bioethanol and 133 ktoe of biodiesel) while the domestic consumption was around 387 ktoe (126 ktoe of bioethanol and 261 ktoe of biodiesel). Biodiesel was imported, bioethanol exported.

In terms of **greenhouse gas emissions**, Spain faces a strong increase of emissions since 1990, mainly explained by the economic growth of the country: while the Kyoto target is +15% in 2008-2012 compared to 1990, the emissions increased by 50.6% between 1990 and 2006 and are expected to increase by 37% in 2008-2012 compared to 1990. In fact, Spain started buying permits from Hungary (6 MtCO2) and is negotiating with other Eastern European countries.

**Future social-economic data**

In January 2008, there were approximately 46 million inhabitants from which 11% were immigrants (5 millions).

In 2000, GDP in Spain was 630.3 million €2000. Next table shows the annual growth for population and the total GDP used in the Spanish model. They are consistent with national statistics.

Main economic branches are those dedicated to trade, computing, tourism (market services) and public administrations, domestic services, non profit institutions (non market services), followed by the energy sector. The services sector represents more than half of the total employed people, followed by industry and energy. The construction sector, which has played a very important role in the Spanish economy in the last years, is now in recession and prospects for immediate future are quite bad. This would lead to an important loss of jobs, and possibly a lower growth of the GDP. The current crisis is not taken into account in the projections.

<table>
<thead>
<tr>
<th>POP annual growth</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP (millions €)</td>
<td>847650</td>
<td>1065000</td>
<td>1237900</td>
<td>1410800</td>
</tr>
</tbody>
</table>

Table 1.1. Annual population and GDP growth rates for Spain

**Policies for renewables**

The Spanish Renewable Energy Plan (Plan de Energías Renovables en España, PER) for 2005-2010 expects a contribution from RES (hydroelectricity included) of 12.1% of primary energy consumption in
2010, electricity generation from RES of 30.3% of gross electricity consumption, biofuels consumption of 5.83% of gasoline and diesel use for transport in 2010, and RES contribution of 4445 ktoe for heating and cooling. A new Plan is now being elaborating.

The most important policies implemented to support the PER are:

- **Financial incentives and standards** such as feed-in tariffs for renewable electricity generation, excise duty exemption for biofuels, investment subsidies, building energy code, biofuels quotas, etc., as described in the chapter 10 of the report ‘Reference Document on Renewable Energy Sources Policy and Potential’, Deliverables D.2.2 and D.2.3, by EREC.

These policies resulted in a rapid increase of wind and solar installed capacities. However, biomass has not developed as fast as expected (nor for electricity neither for heating purposes). Spain has very low district heat supply.

- The **most recent policy changes** (not included in the report above since these policies were recently implemented) are:
  a) Regarding biofuels, Act 12/2007 ("16th Additional regulation to the Act 34/1998 of the Hydrocarbons Sector") makes the blending of biofuels into petroleum fuel obligatory, establishing an interim target of 1.9% of biofuels to be blended into regular fuels in 2008, which will become mandatory proportions of 3.4% in 2009 and 5.83% in 2010 (the latter being included in the PER).
  b) Approved in October 2008, the Ministerial Order 2877/2008 provides the framework for the application of Act 12/2007 distinguishing between biofuels mixed with gasoline and those mixed with gas-oil and imposing a minimum target for each of them separately: 2.5% in 2009 and 3.9% in 2010.
  c) As regards the feed-in tariffs, the Act 1578/2008 (sept. 2008) fixes new conditions for the feed-in tariffs (amongst other, lower prices) applied to the photovoltaic installations, given the very rapid growth of the installed capacity observed in the last years.

- Finally, the future of the **nuclear energy** is unclear. There is no nuclear moratorium in Spain but the current Government does not support the installation of new plants, and the latter are perceived as a high risk investment by the energy sector companies. The extension of the technical life of the existing nuclear power plants is promoted. In the current analysis, it was assumed that no new nuclear plants would be implemented after the extension of life of the existing ones.
2. Renewable technology deployment

2.1 Primary and final energy use

For 2010 and 2015, total primary energy supply is almost the same in all the scenarios. However, in 2020 there is a significant difference between the RES scenarios and the BaU. By 2020, total primary energy supply decreases by 6%-8% depending on the RES scenario compared with the BaU scenario, result of complementary factors characterizing the energy systems and described in the next sections: decrease of the final energy demands, given the implementation of conservation measures and also the decrease of the demands for the energy services when RES and emission constraints are added; shutdown of inefficient technologies such as the coal power plants; penetration of more efficient technologies (for example, more efficient lighting) and energies (partial substitution of coal by gas and renewable, whose use, when expressed in fossil energy equivalent as regards the renewable, is more efficient than the use of coal).

The percentage of renewables increases from 5% of total primary energy in 2000 to 12%-15% in 2020 depending on the scenarios. An important part of the increase of the share of renewable is already observed in the BAU scenario between 2000 and 2020 (from 5% to 12%) results of the incentives included in the BAU, mainly the feed-in tariffs and the carbon tax imposed to the ETS sectors.

Natural gas also increases its contribution in all the scenarios from 11% in 2000 to 18%-20% in 2020. An important factor behind this increase, observed also in the BAU, is the penetration of combined cycle gas plant from 2005, forced exogenously in the model in order to represent the real energy system. A slight additional increase of gas is observed in the RES scenarios. Oil share in primary energy consumption slightly decrease from 55% in 2000 to 50%-53% in 2020, the main consumption being the transportation sector. The share of coal in the total primary energy supply decreases, in 2020 in the RES scenarios, main-
ly corresponding to the shutdown of coal power plants (the penetration of coal power plants with CCS could have replaced the conventional coal power plants; however, such a substitution, observed in some climate strategies, would not help satisfying the RES target as imposed here).

Figure 2.2 Final energy use

Figure 2.2 illustrates the evolution of final energy use. As in the primary energy supply, by 2020 there are differences in the total final energy use between the BaU scenario and the RES ones. Final energy use decreases by 4% (RES-2020) to 6% (RES-T and RES-30%) compared with the BaU one. Some more explanations related to this decrease are provided below.

The figure below gives the share of RES in final energy for the different scenarios. The contribution of renewable energy in final energy increases from 7% in 2000 to slightly more than 16% in 2020 in the BAU, and around 19% in the RES scenarios, depending on the scenario (see figure below). It must be understood that the slight difference between the 20% target imposed for Spain and the result observed in the model in 2020 is due to a modelling difficulty to exactly represent the complex way the RES target is defined in the Directive.
The share of RES in the final energy observed in the BAU in 2020 shows that the existing policies (feed-in tariffs, but also ETS) contribute to the penetration of renewable, but a gap remains in order to reach the RES target as defined in the Directive.

The possibility of trading green certificates remains without impact on the share of RES. However, the total energy use decreases when green certificates are traded, and Spain is seller of green certificates. The decrease of the final energy use when trade is possible seems to be motivated by the preference for Spain to sell some green certificates and keep satisfying its RES ratio target by implementing higher conservation measures (gas oriented) more than by increasing “too much” the production and use of RES.

When the climate target is stricter, the share of RES increases: the absolute values (total final energy and total RES) are close to the ones of RES-Trade, but the contrary to RES-Trade, the RES are now fully used for the domestic consumption and not for exports of green certificates.

Figure 2.3  Final energy use of a) non-renewables and b) renewables

1) The sections below describe in more detail renewable and non-renewable electricity and heat generation

Figure 2.3 shows the evolution of non-renewable and renewable fuel energy use.

Non-renewable fuels use for final energy increases in the BAU until 2020. The biggest relative growth corresponds to coal (more than doubled) followed by natural gas and oil. The industry sector is the main responsible of such a growth in the coal consumption. Iron industry and in general metallurgy are the most coal intensive processes in the sector. The emission restrictions contribute to a reduced penetration of coal in the RES scenarios compared to the BAU, and due to the stricter CO₂ emission restrictions, coal consumption in the RES-30% scenario is lower than in the other two RES scenarios. Coal, as well as gas, whose consumption is also smaller in the RES scenarios compared to the BAU, are substituted by biofuels, mainly in the industrial sector. Although not clearly seen in the figure, the consumption of gas is even more reduced when trade of green certificates occurs; the decrease of gas use corresponds to the implementation of conservation measures in the industrial sector (implemented only in that case) such that the RES target remains satisfied, as explained above.

The decrease of the non-renewable electricity observed in the RES scenarios compared to the BAU is not fully compensated by the increase of the renewable electricity. Indeed, the total (non-renewable and renewable) electricity consumption is smaller in the RES scenarios compared to the BAU thanks to the implementation of conservation measures mainly in industry.
When analysing the share of the non-renewable energies in final energy use, oil is the main fuel with more than 60% of the total fossil fuels in 2020 in all the scenarios, and transport is the main consumer of oil. The smaller consumption of oil in the RES scenarios compared to the BAU is motivated by the substitution by biofuels in transport and industry, as well as the implementation of conservation measures in the aviation and in the space heating of commercial buildings.

As a total, the difference between total final energy use of non-renewables among the BaU scenario and the RES ones amounts to 6% in the RES-2020 and close to 10% in the RES-T and RES-30% scenarios compared to the BaU.

Final energy use of renewables grows in all the periods and scenarios and reaches 1.6 times the 2000 level in the BAU, and almost 2 times the 2000 level in the RES scenarios. However, the total electricity based on renewable remains stable in 2020 in all scenarios but RES-30%: the RES target combined with the 20% emission target do not appear to be sufficient incentives to increase more than the current policies do, the installed capacity of renewable in the Spanish electricity sector (although the share of renewable in the electricity sectors increases given the slight decrease of the non-renewable in the same sector). Only the stricter climate target of RES-30% scenario drives up the renewable electricity (on top of the reduction of coal consumption in final energy, the increase of biomass in industry, etc.).

It is interesting to evaluate if the objective of the PER (30% of renewable, hydroelectricity excluded - in the production of electricity by 2010) is reached: the corresponding share is 16% in all scenarios in 2010, but 31% and more in 2030. In other words, this PER’s objective is not reached in 2010. More details are provided in the electricity section.

The difference between the RES and the BAU comes mainly from the biofuels use in transportation. In other words, the gap between the BAU and the Directive’s target for renewable is covered mainly by the penetration of biofuels in transport and industry: the penetration of biofuels in transport is forced by the specific target related to transport (it does not increase when the emission target is fixed to 30%), while the penetration of biofuels in industry, which increases in RES-30%, is driven by the climate target.

In 2020, half of the final energy use of renewables comes from renewable electricity. The other half is mainly bioenergy and the rest geothermal and solar (6%) and renewable heat in a very small proportion (1%). Solar biggest consumption takes place in the residential sector, mainly for water heating, while at the same time fossil fuel consumption decreases in this sector and biofuels increase in transport and industry.

### 2.2 Use of renewable energy sources

![Diagram](image_url)

Figure 2.4 *Direct use of renewable energy sources in the different sectors*
Figure 2.4 shows the use of renewable technologies in the different sectors. All sectors but residential and agriculture are characterized by a big increase in 2020 in the use of renewable energy compared to 2000. In fact, road transport goes from no renewable fuel use in 2000 to a share of RES of 10% in the RES scenarios in 2020: this is the direct result of the transport target fixed in the RES scenarios.

The possibility of trading certificates does not change the situation significantly in terms of renewable energy use in comparison with the situation without certificate trade, except a slightly higher renewable energy use in the industry sector. However, as noted in a previous section, Spain exports some green certificates when trade is possible, and maintains its targeted RES ratio not only by slightly increasing the use of renewable in industry, but mostly by reducing the total energy consumption thanks to energy conservation in the same sector.

Furthermore, the scenario with the highest total direct use of renewable energy sources is the RES-30%. The stricter climate target of this scenario leads to a higher renewable use in the central heat and power sector.

Differences among the BaU and RES scenarios are most important in 2020, especially in the transport and industry sectors where more fossil fuels are substituted by bioenergy given the specific target as regards transport, and given the emission target as regards industry, as already noted in above sections.

### 2.2.1 Electricity generation

![Graph showing total electricity generation](image)

Figure 2.5 *Total electricity generation*

Total electricity generation is shown in Figure 2.5. Differences among scenarios are small until 2020 when all RES scenarios show a marked decrease of total electricity production compared to the BaU. This decrease corresponds to the implementation of conservation measures in industry.
The other most important difference among the scenarios is the progressive reduction of electricity generation from coal, already visible in the BAU but higher in the RES scenarios. The stricter climate target in RES-30% scenario leads to the highest reduction of coal use by power plants.

Renewable and natural gas substitute coal and oil for electricity production. The high penetration of gas in 2010 in all scenarios is explained by the penetration of combined cycle gas plant from 2005, forced exogenously in the model in order to represent the real energy system.

Renewable share in total electricity production grows in all the scenarios during all the periods. Comparing with 2000, the growth in 2020 is close to 250%. However, there are no significant differences between the renewable production between the BaU scenario and the RES ones. Renewables share in 2020 for the BaU scenario is 40%, 44% in the RES-2020 and RES-T and 47% in the RES-30%. The higher share observed in RES and RES-Trade is due to the lower overall electricity production in these RES scenarios (the absolute electricity generation from renewable does not increase), while a slight absolute increase is observed when the climate target is 30% instead of 20%. In other words, the penetration of renewable in the generation of electricity results mainly from the incentives included in the BaU scenario (feed-in tariffs, carbon tax imposed to the ETS sectors) while the imposed targets in the RES scenarios don’t contribute to any additional installed capacity except when the emission target is stricter. As see in previous sections, the satisfaction of the RES target relies more on the increase of the use of biofuels.

Nuclear generation is stable (given the assumption of no new nuclear plants in Spain), after a relatively small decrease at the beginning representing the shutdown of two nuclear power plants observed in the reality. Therefore, its share reduces from 28% in 2000 to 17% in 2020 for the RES scenarios and 16% for the BaU.

Oil use in electricity production reduces in 2010 and remains the same in all the following periods and all the scenarios.

CCS technologies do not penetrate before 2020 in RES scenarios (only in 2025 in RES-Trade) scenario in 2020, but remains a very small proportion of the electricity generation (less than 1%).

---

**Figure 2.6** Electricity generation from renewable energy sources
Electricity generation from RES is shown in Figure 2.6. By 2020, most of the renewable electricity generation comes from wind power (from 66% in RES-30% to 70% in the others, BaU included) followed by hydropower. Solar electricity penetrates in 2010, and remains constant until the end of the whole period except for the scenario RES-30% in 2020: this is the only scenario where concentrating solar thermal technologies enter the system. The penetration of solar power plants (only PV except at the end period of the RES-30%) is in fact forced in the model to represent the current installed capacity in Spain. In other words, according to the data included in the model, solar PV does not belong to the solutions selected by the model, wind power plants being the preferred technologies, except in the case when a stricter GHG target is imposed, making CSP competitive.

Wind plays the most important role in renewable electricity generation, mainly based on wind-onshore; however, wind offshore penetrates in 2020 in all the scenarios reaching 26% of the total wind power production (35% of new plants). This wind offshore penetration is the result of the fact that the total onshore potential is fully used. Geothermal appears in the RES scenarios in 2020 with a very small share.

As already seen before, only the stricter climate target of the RES-30% scenario has important effects on renewable electricity generation leading to a higher penetration of renewable electricity, mainly from CSP technologies.

Also noted previously, the objective of the PER (30% of renewable, hydroelectricity excluded - in the production of electricity by 2010) is not reached in 2010 in any scenario but only in 2030 (the corresponding share is 16% in all scenarios in 2010, but 31% and more in 2030). Let’s look at some of the specific 2010 objectives of the PER:
- Solar PV is fixed to 3 GW in 2010 in all scenarios to represent the real installed capacity (against 0.4 GW targeted in the PER)
- Solar thermal does not penetrate before 2020 (0.5 GW targeted in 2010 in the PER)
- Wind reaches 19 GW (20 GW targeted in the PER)

2.2.2 Heat production

Fuel inputs for heat production are shown in Figure 2.7. There is a marked decrease in fuel consumption for heat production in the RES scenarios with respect to the BaU one in 2020. That is mainly due to the penetration of conservation measures in the use of heat for space heating. Renewable penetration in heat production represents 15% of the total fuel input in the BaU scenario, 19% in the reference RES scenario and 20% in the other RES. The biggest reductions in the whole period correspond to oil and electricity use. In the RES scenarios, fossil fuels (mainly gas) are substituted by bioenergy. The most important substitutions and energy conservation measures are observed in the RES-30% due to the stricter limits in the CO₂ emissions, and in the RES-T scenario, where the decrease of gas is by far the most important (combined with a penetration of bioenergy only slightly higher than in RES-30), permitting to satisfy the RES target without increasing “too much” the renewable, as explained previously.

Residential and commercial sectors are the most heat consumers in all the scenarios and all the periods. Heat consumption in industry decreases from 2000 to 2020 starting with a share of 15% in 2000 and finishing with less than 1% in 2020 in all the scenarios.
As illustrated by Figure 2.8 more than half of the renewable fuel input for heat production corresponds to biomass in all the periods and scenarios. There are marked differences among scenarios in the absolute production of heat with renewable especially in 2020. RES scenarios use more bioenergy and solar than BaU scenario to produce heat. Renewable electricity used to produce heat increases but the biggest increase is that of solar reaching a share of 16% in 2020.

As said before, when there is the possibility of trading virtual green certificates among countries, as it is in the RES-T scenario, the production of heat from renewable (bioenergy) increases in order to sell certificates.
2.2.3 Transport fuels

In 2000, fossil fuels represented 99% of the total transport fuels, the remaining 1% being electricity. There was no biofuels consumption at all. Consumption of diesel was 58% of the total fuel consumption and gasoline was 28%. The consumption of diesel was twice as much as gasoline. For all the periods and scenarios the relation between diesel and gasoline consumption remain the same.

Road transport represents the most important part of fuel consumption in transportation (around 80%) followed by aviation (from 14 in 2000 to 17% in 2020 in all scenarios), ships, and finally, trains.

The share of non-fossil fuels in the total transport fuels by 2020 is 8% in the RES scenarios and less than 7% in the BaU. In road transport only, non-fossil fuels represent respectively 4.5 and 8.5% of the consumed fuels in 2010 and 2020 in the BAU, and 5.8 and 10.1% in the RES scenarios, result of the 2010 and 2020 obligation of the European Directive included in the RES scenarios. While the Renewable Directive objectives are not reached in the BaU scenario, neither the climate constraints nor the possibility of trading green certificates provides an incentive for a penetration of non-fossil fuel penetration higher than the Directive’s target.

In 2020 and in the BaU scenario, the main biofuel used is biodiesel (93% of all biofuels) and only 3% is bioethanol (the difference being biogas). In 2020 and, respectively in RES-2020 and RES-Trade, bioethanol enters the transport system in a small proportion, 19% and 17% of the total biofuels, while biodiesel consumption represents 77% and 74% of the total biofuels (the rest being based on biogas). When CO₂ emission limits are stricter, in 2020 bioethanol penetrates in a higher proportion of 33% while biodiesel has a share of 63%. Measures to reduce CO₂ emissions favour the bioethanol consumption. In this scenario, RES-30%, there is an important consumption of bioethanol not blended with gasoline close to the total amount of bioethanol consumed in the other RES scenarios.
Second generation biofuels don’t play any significant role, and green certificates do not help their introduction.

Figure 2.9  Conventional and non-conventional transport fuels

Figure 2.10 Development of non-conventional transport fuels
3. Trade and import dependency

Figure 3.1 presents the net imports of fossil energy carriers in Spain. Natural gas imports increase, on average, close to 100% from 2000 to 2020 in all the scenarios. Coal imports increase in the BaU scenario and decrease around 50% of the 2000 value in the RES-2020 and RES-T, and 65% in the RES-30% due to the CO₂ emission restrictions, inducing a reduction of coal use. Oil imports increase by around 7% of the 2000 value in the RES scenarios and 11% in the BaU. However, the biggest increase is that for biofuels imports (figure 3.2), mainly in RES scenarios and among them in the RES-30%, where 95% of the biofuels come from outside EU. Therefore, Spain is net biofuel importer from outside EU and within the internal market. Biofuel imports are mainly bioethanol. Biofuel traded in the EU is biodiesel. Within the RES scenarios, biofuels imports increase when there is a stricter CO₂ emission limit (corresponding to a higher penetration of biofuels in transport and industry) as well as when there is a trade of certificates, compared to the RES scenario. It is interesting to note that the dependency on non-EU imports is higher in the case of the strict climate target, probably corresponding to a higher demand for biofuels by all EU countries, reducing the availability of the biofuels produced within the EU.

In fact, it appears better for Spain, according to the data included in the model, to import most of the biofuels needed for the domestic consumption instead of producing them locally with domestic biomass.

Spain will also continue to be a net importer of electricity from the EU countries.

To summarize, the RES and climate policies don’t reduce the energy dependency of Spain on imports. Moreover, stricter climate targets increase the dependency of Spain on biofuel imports from outside EU.

![Figure 3.1 Net import/export of fossil energy carriers](image-url)
The possibility of statistical transfers of renewable energy among countries allowed in RES-T scenario results in a net export of electricity (only in 2010 - related to the high installed capacity of solar PV as observed in the reality) and final energy green certificates in 2010, 2015 and 2020 (Figure 3.3.). Several dynamics related to this trade have been noted in previous sections, such as the reduction of the final energy consumption so that the RES target remains satisfied, and won’t be repeated here.

![Graph showing inter-EU trade and import from outside EU27 of biofuels and electricity]

**Figure 3.2** *Inter-EU trade and import from outside EU27 of biofuels and electricity*

**Figure 3.3** *Virtual trade of renewable energy in the RES Trade scenario*
4. Impacts of policies on emissions and costs

4.1 Emissions

The emissions of the BAU increase by 15% from 2000 to 2020. The sectors with the higher increases in CO₂ emissions are industry-ETS and transport. In the transport sector, the majority of the emissions come from road transportation, half of them from the use of diesel in trucks. As a result, the contribution of the power sector to the total emissions decrease, representing 31% of total emissions in 2000 but 20% in 2020 in the BAU. This corresponds to the penetration of renewables in the power sector, important also in the BAU as seen previously.

In 2020, total CO₂ emissions are lower than those in 2000 in all the RES scenarios: they decrease from 2.4% in RES-2020, 3.1% in RES-T to 8.6% in RES-30% compared to 2000 emissions. These decreases remain lower than the overall European target, meaning that other European countries support a much higher share of the European emission reductions. CO₂ emissions decrease in the electricity sectors in all the periods and scenarios, more significantly in the RES, and especially in the RES-30% resulting from the stricter CO₂ constraints. Non ETS sector CO₂ emissions increase along the evaluated period especially in the BaU scenario, but their share of the total emissions remains constant: 50%. When renewable and climate targets are imposed, these sectors slightly reduce their emissions, but relatively less than the ETS sectors, and the share of the non-ETS emissions increase until representing 59% of the total CO₂ emissions in 2020.

![Figure 4.1 CO₂ emissions](image-url)
4.2 Costs

Total investment costs and operational costs of renewable technologies are shown in the next table:

<table>
<thead>
<tr>
<th>Cost of Renewable Technologies (millions €)</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU</td>
<td>1913</td>
<td>5867</td>
<td>11766</td>
<td>18728</td>
</tr>
<tr>
<td>RES</td>
<td>1913</td>
<td>5235</td>
<td>11641</td>
<td>19328</td>
</tr>
<tr>
<td>RES-T</td>
<td>1913</td>
<td>5397</td>
<td>11561</td>
<td>19562</td>
</tr>
<tr>
<td>RES-30</td>
<td>1913</td>
<td>5383</td>
<td>11690</td>
<td>18693</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost of Renewable Technologies as a share of GDP</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU</td>
<td>0.23%</td>
<td>0.55%</td>
<td>0.95%</td>
<td>1.33%</td>
</tr>
<tr>
<td>RES</td>
<td>0.23%</td>
<td>0.49%</td>
<td>0.94%</td>
<td>1.37%</td>
</tr>
<tr>
<td>RES-T</td>
<td>0.23%</td>
<td>0.51%</td>
<td>0.93%</td>
<td>1.39%</td>
</tr>
<tr>
<td>RES-30</td>
<td>0.23%</td>
<td>0.51%</td>
<td>0.94%</td>
<td>1.32%</td>
</tr>
</tbody>
</table>

Total costs of the system are presented below:

<table>
<thead>
<tr>
<th>Total system costs (billions €)</th>
<th>BaU</th>
<th>RES</th>
<th>RES-T</th>
<th>RES-30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>O&amp;M fix costs</td>
<td>338</td>
<td>337</td>
<td>337</td>
<td>337</td>
</tr>
<tr>
<td>O&amp;M variable costs</td>
<td>1420</td>
<td>1420</td>
<td>1419</td>
<td>1417</td>
</tr>
<tr>
<td>Welfare loss (elastic demands)</td>
<td>0</td>
<td>13</td>
<td>13</td>
<td>24</td>
</tr>
<tr>
<td>Tax / Subsidy</td>
<td>87</td>
<td>7</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Total costs (diff. wrt BAU)</td>
<td>3763</td>
<td>3772(9.0)</td>
<td>3772(9.5)</td>
<td>3783(20.0)</td>
</tr>
</tbody>
</table>

The absolute costs must be considered with precaution. It is better to look at the differences with the BAU.

It is interesting to note that the costs of renewable technologies are smaller in RES-30 compared to the BAU, while the other two RES scenarios need higher costs as regards the renewable technologies only in 2020. In other words, the RES and climate targets seem to result, during the first part of the horizon, in a “more efficient allocation” of the investments and use of technologies related to renewable, while the total costs increase only later. The results tend to indicate also a cost transfer from the renewable technologies of the end-use sectors to the power plants when RES targets and especially the strict climate target are added. Let’s remind that conservation measures and demand reductions also occur in 2020, resulting in smaller energy needs in the end-use sectors and therefore smaller costs.

The total costs illustrate the important contribution of the welfare losses related to the decrease of the end-use energy services: the welfare losses represent the most important additional cost of the RES with respect to BAU. Also, the 30% climate target induces a doubling of the total cost of the scenario (defined as the difference with the BAU) compared to the 20% climate target.

The reductions of the demands for final services are up to 5% in residential and commercial sectors, up to 13% in industry, and not more than 2.5% in transport, in 2020, in RES scenarios.
5. Conclusions

From the overall results obtained in this study we can conclude that the current policy incentives for renewable energies have the effect of reaching 16% of RES in the total final energy, compared to the objective of 20% set in the Renewable Directive. In road transport, non-fossil fuels represent respectively 4.5 and 8.5% of the consumed fuels in 2010 and 2020 in the base case, compared to the objectives of 5.8 and 10%. Therefore, in order to meet the Spanish commitment, an additional effort must be made. The analysis of the scenarios where the 20% target is imposed shows that the additional RES deployment should be oriented mainly to bioenergy use in transport and industry, as well as the implementation of conservation measures. In other words, the specific target related to transport appears to drive the most important additional changes in the Spanish energy system compared to the changes observed as a result of the existing policies. The role of the conservation measures is to reduce the total energy demands and thus reduce the need to invest “too much” in renewable energy in order to satisfy the target.

The RES target combined with the -20% emission target does not appear to be a sufficient incentive to increase more than the current policies do, the installed capacity of renewable in the Spanish electricity sector (although the share of renewable in the electricity sectors increases given the slight decrease of the non-renewable in the same sector). Only the stricter climate target of RES-30% scenario drives up the renewable electricity, substituting coal power plants. This increase in electricity from renewable comes from the production of concentrated solar power plants, which penetrates only in the case of this stricter climate target.

However, the stricter climate target has no impact on the penetration of biofuels in transportation, and only a specific target on the fuels consumed in transport results in changes in this sector.

It seems that CCS technologies are not competitive enough to enter significantly into the system in order to reduce CO₂ emissions.

The RES and climate policies don’t reduce the energy dependency of Spain on imports. Moreover, stricter climate targets increase the dependency of Spain on biofuel imports from outside EU. In fact, it appears better for Spain, according to the data included in the model, to import most of the biofuels needed for the domestic consumption instead of producing them locally with domestic biomass.

The possibility of trading green certificates remains without impact on the share of RES. However, the total energy use decreases when green certificates are traded, and Spain is seller of green certificates that come first from the electricity sector and then from the final energy sectors: Spain decides to sell some green certificates and keep satisfying its RES ratio target by implementing higher conservation measures (gas oriented) more than by increasing “too much” the production and use of RES.

The global RES objective of the PER (30% of renewable, hydroelectricity excluded - in the production of electricity by 2010) is not reached in 2010: the corresponding share is 16% in all scenarios in 2010, but 31% and more in 2030. The specific objective related to the installed PV capacity is already fully satisfied, the one related to wind in practically reached, while CSP does not penetrate.

The mix of fuels used to produce heat changes when the renewable objective is imposed, leading to a reduction of gas and an increase of solar heat and heat from biomass. When there is the possibility of trading virtual green certificates, the production of heat from bioenergy increases.

Total CO₂ emissions increase by 15% in the BaU scenario in the evaluated period, given the penetration of renewable energy in the BAU (especially in the electricity sector, whose contribution to the total emissions decrease). However, when imposing the renewable and climate objectives, the 2020 emissions are
lower than the 2000 ones, but in proportions that remains far from the 20% or 30% objectives at the European level, meaning that other European countries support a much higher share of the European emission reductions. The reductions take place mainly in the electricity sector, followed by the industry sector, and, in a minor quantity, in the other sectors. Let’s remind the important role of conservation measures in industry.

Finally, the RES scenarios do not represent higher costs for renewable technologies until 2020 (in fact, in RES-30% costs for renewable technologies are even below BaU’s also in 2020). A better allocation of the renewable technologies seems to occur. The results tend to indicate also a cost transfer from the renewable technologies of the end-use sectors to the power plants when RES targets and especially the strict climate target are added. Let’s remind that conservation measures and demand reductions also occur in 2020, resulting in smaller energy needs in the end-use sectors and therefore smaller costs.

6. References


SWEDEN
1. Introduction

This chapter describes the modelling outcomes for Sweden within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A Business as Usually scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES-Ref) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on an EU level. For Sweden this means 49% share of RES in 2020 and, for all sectors which do not fall under the European Emissions Trading scheme, a CO₂ emissions cap of 30.3 Mtons.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO₂ emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

One of the characteristics of the Swedish electricity system is the low share of fossil fuels, see Figure 1.1. The large quantity of electricity with low running costs (hydro power and nuclear power) has resulted in proportionately high electricity consumption per capita. In 2005, Sweden had the highest share of renewable energy sources (RES) according to the calculation rules of the RES directive (RES2020, 2009a); the sources were biomass, hydropower and a small (but growing) share of wind power. In an average year, 46% of total net production of electricity derived from hydro power (and 46% from nuclear power). The reference year 2000 was a hydrological wet year resulting in a high share of hydropower (55% of total electricity generation) and a correspondingly lower share of nuclear power (39% of total electricity generation). (SEA, 2008). This is important to know and to take into account when analysing the results.

The Swedish electricity certificate system is the main support system to increase the production of electricity from RES and peat (large hydro power is excluded from the system). Installed capacity of electric-

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39 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
ity from RES (RES-e) has increased with 1000 MW between 2000 and 2007, Nordel 2008. For detailed description of all policies supporting renewable energy see RES2020, 2009b.

Figure 1.1 Installed power capacity in Sweden at the end of year 2007 according to Nordel, 2008.

In 2005, one unit of 610 MW was decommissioned while the existing units have been upgraded with 260 MW between 2005 and 2007. The electricity generation from nuclear plants were 55 TWh in year 2000 and 70 TWh in year 2005. From year 2010, existing nuclear power is assumed to yearly generate 68 TWh.

There has been a ban on development of new nuclear power in Sweden but in early 2009, the Swedish government decided to lift this. The ban has accordingly been included in the model but is now removed from the model as well. Due to long planning process for new nuclear facilities, new nuclear power is in the model first assumed to be able to generate electricity in year 2020.

There were 8.9 million people in Sweden in year 2000. In the model, the population is assumed to have increased with 240 thousand by 2020. The GDP for Sweden is in the model assumed to increase with 13 % between 2000 and 2020. The assumed average annual GDP growths rates are an output from the GEM-E3 model and together with the annual population growth presented further in RES2020 (2008).

2. Introduction Renewable technology deployment

2.1 Primary and final energy use

There is a minor increase of total primary energy in Sweden between 2000 and 2020. The increase is smaller when imposing a climate and renewable policy. The consumption of oil is reduced over time in all scenarios. In 2020, the total supplies of fossil energy carriers are 10 % higher in the BaU scenario compared with the two scenarios with the lowest quantities of fossil fuels (RES-T and RES 30%). Natural gas decreases the most in the RES-T, while coal have the largest reduction in the RES 30% scenario, both compared with the BaU scenario. In the results, nuclear increases in all scenarios between 2000 and 2010 due to the exceptionally low production in year 2000 and, further, nuclear increases between 2015 and 2020 for all scenarios and replaces oil and coal. In year 2020, there is a net import of electricity in the BaU scenario, while the three RES scenarios have a net export due to increasing amount of renewables to meet the RES targets.

There is an increase of renewable energy sources in the BaU scenario, primarily from wind power and biomass. However, the quantities are smaller even if the total primary energy supply is larger. The RES-T scenario has the highest share and quantities of RES (the increase from the BaU scenario is mainly in wind power).
Figure 2.1  *Primary energy supply*

![Primary energy supply diagram](image)

Figure 2.2  *Final energy use*

![Final energy use diagram](image)

Table 2.1 *Share of Renewable Energy Sources according to the RES directive.*

<table>
<thead>
<tr>
<th>Time</th>
<th>RES-2020</th>
<th>RES-2020T</th>
<th>RES-30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>43%</td>
<td>43%</td>
<td>43%</td>
</tr>
<tr>
<td>2010</td>
<td>44%</td>
<td>44%</td>
<td>44%</td>
</tr>
<tr>
<td>2015</td>
<td>44%</td>
<td>44%</td>
<td>44%</td>
</tr>
<tr>
<td>2020</td>
<td>48%</td>
<td>48%</td>
<td>50%</td>
</tr>
<tr>
<td>BaU</td>
<td>43%</td>
<td>43%</td>
<td>41%</td>
</tr>
<tr>
<td>RES-2020</td>
<td>43%</td>
<td>44%</td>
<td>42%</td>
</tr>
<tr>
<td>RES-2020T</td>
<td>43%</td>
<td>44%</td>
<td>42%</td>
</tr>
<tr>
<td>RES-30%</td>
<td>43%</td>
<td>44%</td>
<td>42%</td>
</tr>
</tbody>
</table>
2.2 Use of renewable energy sources

There is a widespread use of renewable energy in Sweden. Renewables represents more than 30% of the used energy within three sectors; central heat and power, industry and agriculture. Of these, the two first are the two largest in quantities. Hydropower is the main source within the sector central heat and power, whereas biomass dominates the renewable energy used within their industry sector. The pulp and paper industry is the single biggest consumer of biomass in Sweden.

Sweden has a large pulp and paper industry with a variety of different technologies and different use of biofuels and bi-products. The industry is often also a supplier to district heating grids. The pulp and paper industry both uses energy and is a supplier of energy, which makes it complex to model. Even if the PAN European TIMES model is a detailed model, representing a large complexity, all national specifics have not been covered within the RES2020 project. The drop in biomass use in year 2010 within the pulp and paper sector shown in the results in Figure 2.4 is probably a consequence of the sector not being modeled with the degree of details necessary in order to represent the full complexity.

With the exception of year 2010, the biomass increases in all sectors and scenarios. The largest percentage increase is in the Transport sector, although from a low value. In the BaU scenario and in the RES-Ref
scenario, the largest increase (in PJ) is in the industry sector whereas the largest increase in the RES-T and the RES-30% scenarios are within central heating and power. A more detailed analysis of the electricity, heat and transport sectors is provided below.

![Diagram showing energy sources by sector and year]

**Figure 2.4 Direct use of renewable energy sources in the different sectors**

### 2.2.1 Electricity generation

The electricity generation continues to be half nuclear power and half renewables, Figure 2.5. As described in chapter 1.1, year 2000 was an unusually hydro-rich year resulting in a high share of hydro power and a lower share of nuclear power. For this reason, we have focused our analysis of the Swedish electricity generation on year 2010 and onwards.

There is an increasing electricity demand which is met by new investments in wind and nuclear power. The investments in nuclear power are identical in all scenarios; 2 GW in year 2020 which equals the maximum allowed growth of nuclear power. In the BaU scenario, the installed wind power capacity increases with 2.1 GW between 2010 and 2020. In the RES-Ref and RES-30% scenarios, the increase is 5 GW (and reaches maximum off-shore capacity). The increase is largest in the RES-T scenario, when installed wind power capacity increases by 7 GW. Even though the installed wind power capacity grows more compared with nuclear power, the yearly increase of electricity generation is larger from nuclear power than from wind power in all scenarios with exception of the RES-T scenario. Yearly generated electricity per MW from nuclear power is almost three times higher compared with wind power (new nuclear power is assumed to have a 90% availability factor).

The growth of electricity from renewable energy sources (RES-e) is largest in the RES trading scenario, with an increase of 34% between 2010 and 2020. The main increase is wind power followed by biomass, see Figure 2.6. Although the increase of RES-e is smaller with a tougher climate target, as in the RES-30% scenario compared with the RES-Ref scenario, the share of RES-e within the total electricity generation is equal.
Figure 2.5  Total electricity generation

Figure 2.6  Electricity generation from renewable energy sources
2.2.2 Heat production

Like the electricity sector, the Swedish heat sector has a large share of renewable energy. The largest share of renewable energy, as seen in Figure 2.7, stems from biomass and non-fossil electricity (heat pumps, electric boilers and electricity resistance), see Figure 2.8.

The definition of heat production is wide, covering both space heating and a more general use of process energy within the industry sector (excluding fuels for electricity generation and mechanical drive). Approximately 10% of total heat production is input to water and space heating (including district heating), a share which is reduced over time when the demand within the industry sector increases and when the share of heat pumps for space and water heating increases. In addition, there are energy-savings of multifamily space heating in all three RES scenarios, largest in the RES-30% scenario.

As a result of existing taxes, the use of oil for water and space heating is reduced by almost 90% in the BaU scenario from the base year and completely phased out in year 2020 for all three RES scenarios. The simultaneous decrease of oil and increase of demand is met by a mix of technologies, i.e heat pumps, electric boilers and wood-pellets burner.

In year 2020, the use of renewables in heat production is 24 PJ lower in the RES-T scenario than in the RES-Ref scenario. This corresponds to the difference in renewables used for electricity generation between the two scenarios, although with opposite signs: for electricity generation, the RES-T scenario uses 24 PJ more renewables compared with the RES-Ref scenario. Hence, in presence of a European RES trading system, the limited biomass resources preferable are used within the electricity sector.

![Figure 2.7 Total input for heat production](image_url)
2.2.3 Transport fuels

The electricity used for railway transport represents the non-fossil energy in 2000 seen in Figure 2.9. In the base year, 92% of the energy to railways was electricity; the remaining 8% was diesel oil.

The Swedish car stock was in 2000 dominated by gasoline cars (95%), followed by diesel cars. Freight traffic on roads has equal shares of diesel and gasoline trucks, while bus traffic is dominated by diesel buses and a growing stock of ethanol and biogas buses.

Hydrogen enters for inter-city buses in all scenarios already in 2010 (which is a too optimistic scenario considering that it in 2009 still are no conventional buses running on hydrogen). In the BaU scenario, hydrogen is produced from black liquor while hydrogen in the three RES scenarios is produced from natural gas during the two first periods of hydrogen use and from coal in 2020. Hence, fossil fuels are dominating as a resource for hydrogen production in the three RES scenarios, which might be opposite to expectations. However, the use of bio-fuels is almost 10 PJ larger in the three RES scenarios than in the BaU, which equals the total amount of hydrogen.

There are a rich mix of different technologies and fuels used in all four scenarios, from blending of ethanol into gasoline, blending of biodiesel and bio-FT-diesel in diesel, to biogas cars and bio-methanol buses. Although no significant differences between the three RES scenarios could be identified.

Figure 2.8 Heat production from renewable energy sources
Figure 2.9  Conventional and non-conventional transport fuels

Figure 2.10  Development of non-conventional transport fuels
3. Trade and import dependency

Sweden has no domestic extraction of fossil fuels. In the results in Figure 3.1 a small decrease in the use of fossil fuels can be seen, resulting in a small decrease in import dependency. Sweden has large biomass sources and even if there is a small import of biomass in the RES-30% scenario, as seen in Figure 3.2, the domestic sources are the greater part. In spite of the large sources of biomass, a large share of biofuels used in the transport sector is imported in the BaU and the RES trading scenarios. The import is mainly bio-RME. In the RES reference scenario, similar quantities of bio-RME are imported, but methanol is exported in a larger quantity resulting in the net export of biofuels seen in Figure 3.2. With RES targets, a larger share of the total biomass and biofuels are used in the transport sector compared with the BaU scenario.

Figure 3.1  *Net import/export of fossil energy carriers*

Figure 3.2  *Net import/export and use of biomass and biofuels.*
Sweden is a long narrow country with electric interconnections to five different countries. The trade direction varies with both season and time of the day. Although Sweden had a surplus of inexpensive hydro power in year 2000, Sweden was a net importer of electricity; the reason was that Norway had an even larger surplus resulting in less power generation from the Swedish nuclear reactors. Looking at the history, Sweden has been both net importer and exporter of electricity. The results of year 2020 in Figure 3.2 shows that Sweden is a net importer in the BaU scenario while a net exporter in the three RES scenarios. The tougher climate target in the RES-30% scenario does not significantly change the trade flows, indicating that the RES target, by increasing RES-e, is the main driver for the electricity surplus.

In the BaU scenario, Sweden is a net importer of biofuels. In the RES reference scenario, when all countries have renewable and climate targets, the competition for renewables increase and Sweden exports methanol (from domestic biomass) and continues to import bio-RME from outside Europe. In the RES-trading scenario, with an European trading system of green certificates for the electricity and end-use sectors Sweden becomes a net importer of biofuels both within the European Union and from outside.

In the RES trading scenario, Sweden is a net importer of biofuels, but a net exporter of green certificates (both for the power sector and for the end-use sector). The results show that it is more cost efficient to use the domestic renewable sources within the stationary energy system and export green certificates (both for electricity and end use sectors) and to import biofuels (RME) for the transport sector in order to meet the target of 10% biofuels in 2020 within transport sector.

Under current assumptions, the results clearly indicate that there are economic benefits from using biofuels within Sweden compared with using it in many of the other countries within the European Union.
Figure 3.1 Net trade with green certificates to Sweden in the RES-T scenario in EURO2000/GJ. (Negative values represent export of certificates).

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green certificates for electricity sectors</td>
<td>-86.1</td>
<td></td>
</tr>
<tr>
<td>Green certificates for end-use sectors</td>
<td>8.0</td>
<td>11.7</td>
</tr>
</tbody>
</table>

4. Impacts of policies on emissions and costs

4.1 Emissions

In year 2000, the transport sector was the main CO2 emitter. Although the electricity and heat sector (in the results) doubles their emissions between 2000 and 2015, the transport sector remains the biggest source of CO2 emissions. The increase in the electricity and heat sector is mainly an increase in use of oil-boilers for district heating in year 2010. However, this result should be questioned, since there in 2008 rather was a decrease in the use of oil for district heating.

In 2020, the main CO2 reductions are within the emission trading sectors (ETS) both compared with year 2015 and compared with the BaU. Although the solely biggest reductions are within electricity and heat sector, the emission in the sector only fall below the emissions in base-year in the RES-T and the RES-30% scenarios. Not surprising, the total CO2 emission are lowest in the RES-30% scenario. However, the 30% target is almost reached in the RES-T scenario as well. Hence, an European trade with renewables certificates drives the CO2 reductions in Sweden.

Figure 4.1 CO2 emissions in different sectors (Mton CO2)
4.2 Costs

In the study, the total system cost for all modeled countries and the entire modeling period are minimized for each scenario. The resulting total costs for the Swedish energy system are presented in Table 4.1. The BaU scenario is presented with the resulting values, while the three RES scenarios are presented as the respective increase from the BaU scenario values. When endogenous trade is not included, the RES-T scenario has the largest, but still low, increase of the total system costs with 0.6%. If endogenous trade is included in the model, the system costs are almost equal in all four scenarios. Sweden even gains from a modest European Carbon target compared with the BaU scenario, and with the tougher 30% target, the total system cost for the entire period only increases with 0.1%.

Table 4.1 The total System Cost excluding and including endogenous trade (billion EUR2000).

<table>
<thead>
<tr>
<th></th>
<th>BaU</th>
<th>RES</th>
<th>RES-T</th>
<th>RES-30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>-</td>
<td>1.3</td>
<td>1.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Fixed</td>
<td>335</td>
<td>0.7</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Variable</td>
<td>58</td>
<td>-0.1</td>
<td>-1.1</td>
<td>-1.2</td>
</tr>
<tr>
<td>Tax/Subsidy</td>
<td>631</td>
<td>-0.1</td>
<td>-0.1</td>
<td>-0.2</td>
</tr>
<tr>
<td>Welfare Loss (Elast Dem)</td>
<td>2</td>
<td>3.4</td>
<td>4.5</td>
<td>6.3</td>
</tr>
<tr>
<td>TOTAL (excl Trade)</td>
<td>1026</td>
<td>5.3</td>
<td>5.9</td>
<td>5.6</td>
</tr>
<tr>
<td>Endogenous Trade</td>
<td>17</td>
<td>-5.4</td>
<td>-6.3</td>
<td>-4.7</td>
</tr>
<tr>
<td>TOTAL (incl Trade)</td>
<td>1043</td>
<td>-0.1</td>
<td>-0.4</td>
<td>1.0</td>
</tr>
</tbody>
</table>

There are only minor differences in yearly costs of renewables as percentage of GDP between the scenarios, see Table 4.2. Although the system costs are highest in the RES-30% scenario, the largest investment costs in renewables as percentage of GDP are in the RES-T scenario when Sweden is a large exporter of green electricity certificates and invests more in wind power compared with the other two RES scenarios.

Table 4.2 The yearly average cost of Renewables as a % of GDP.

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaU</td>
<td>0.46%</td>
<td>0.51%</td>
<td>0.61%</td>
<td>0.61%</td>
</tr>
<tr>
<td>RES</td>
<td>0.46%</td>
<td>0.51%</td>
<td>0.60%</td>
<td>0.72%</td>
</tr>
<tr>
<td>RES-T</td>
<td>0.46%</td>
<td>0.51%</td>
<td>0.59%</td>
<td>0.82%</td>
</tr>
<tr>
<td>RES-30%</td>
<td>0.46%</td>
<td>0.52%</td>
<td>0.60%</td>
<td>0.72%</td>
</tr>
</tbody>
</table>

5. Conclusions

When comparing the trade flows of biofuels (chapter 3), the results clearly indicate that there are economic benefits from using biofuels within Sweden compared with using it in other countries. In year 2020, the use of renewable primary energy sources are largest in the RES-T scenarios, although the total system cost are lower than the other scenarios. Hence, Sweden will gain from a European trade with virtual trade in renewable energy sources certificates.

The share of renewable energy sources defined according to the RES directive is highest in the RES-30% scenario, indicating that the climate policy drives toward an increasing share of renewables within the final use of energy. Meanwhile, a European trade with renewables certificates drives the CO2 reductions in Sweden. Consequently, the trade with renewable certificate and the tougher climate target concurrent with each other.
Finally, Sweden gains from energy trading with other countries. When including the endogenous trade, the richness of renewable energy sources even results in a lower system cost in the RES and RES-T scenarios than in the BaU scenario.

6. References


1. Introduction

This chapter describes the modelling outcomes for Slovakia within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on an EU level. For Slovakia this means 14% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a maximum increase of CO2 emissions of 13% compared to 2005.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/exports are discussed, and in section 4, the CO2 emissions and system costs. Section 5 contains the key conclusions.

1.1 National energy system and RES policies

The following bullet points give a short overview about the current status of renewable energy sources within the Slovakian energy system.

- Key figures:
  - The share of RES in total primary energy consumption was of 4.72 % in 2006.
  - The share of RES in the gross final energy consumption was 6.7 % in 2005.
  - The share of RES in the gross electricity production was 17.12 % in 2006 and 16.3 %.
  - The share of RES heating and cooling was of 0.59 % in 2006.
  - The share of all biofuels in the transport sector in 2006 was 2.1 %.
  - Slovakia dependence on external energy supplies is of about 90 %.

In the following, the main national targets and EU targets for Slovakia concerning the use of renewable energies are listed. Further details on these targets and on their implementation by the Slovakian govern-

40 In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
ment can be found in the deliverables D.2.2 and D.2.3 of the RES2020 project (Reference Document on Renewable Energy Sources Policy and Potential).

- Mandatory targets set by the newly proposed RES Framework Directive from 2008:
  - 14% share of RES on the final consumption of energy in 2020.
  - At least 10% share of biofuels of final consumption of energy in transport in that Member State in 2020.

- Indicative Target set by the RES- electricity European Directive from 2001:
  - 31% Share of RES on gross electricity consumption by 2010.

- Indicative Target set by the European Biofuels Directive from 2003:
  - Biofuels consumption of 5.75% of petrol and diesel use for transport in 2010.

- National Commitments:
  - New internal targets for RES heat and electricity by 2010 and 2015

Ongoing Legislatives measures:
  - Law on RES electricity to be prepared by end of 2007 (proposal still not published, preparation process in delay).
  - Support programme for households and housing associations for solar thermal and biomass technologies installation (programme had to be prepared till the end of 2007 according to governmental resolution, commitment not fulfilled)

However In 2007, the Slovakian Government came with 3 development scenarios, proposition to decrease the target to 19% RES-e in 2010; only 1.35% growth of RES –e compared to 2002

2. Renewable technology deployment

2.1 Primary and final energy use

The results in the following paragraphs show the outcome of a model based scenario analysis. Accordingly this is not an outlook showing the most probable development. Instead, the effects of different political measures on the energy system with this model are displayed. This should be taken into account while studying this report and analyzing its results.

The primary energy consumption (PEC) of Slovakia is 658 PJ in the base year (2000). It’s based on four main energy carriers with its shares of 17.1% (oil), 26.5% (gas), 26.8% (coal) and 27.0 % (Nuclear). These almost equally split shares of gas, coal and nuclear is a clear characteristic for the base year structure of the Slovakian energy system.
Figure 2.1 *Primary energy supply*

Over the period of time, there’s a constant increase of the PEC in all four scenarios up to 808 PJ (2020, BaU). In the reference development, the use of gas (+105 PJ or +8.1 % in 2020 compared to 2000, BaU) and renewables (+37 PJ or +4.0 % in 2020 compared to 2000, BaU) increase, while all others shares (except the import of electricity) are declining (-7.0 % nuclear, -5.0 % oil, -3.3 % coal). Even if the share of coal is falling, the absolute use in 2020 is higher than in the base year (+14 PJ in BaU).

Comparing the four scenarios, there’s no clear difference till 2015. In 2020, all three RES-scenarios have a slightly lower total consumption than the BaU run (-37 PJ RES, -37 PJ RES-T, -39 PJ RES-30%). Concerning the shares of the different energy carriers, it could be pointed out that the use of renewable sources are in the RES of course higher than in the base results (share of 7.6 % in 2020 BaU, 11.0 % RES, 10.9 % RES-T, 10.9% RES-30%).

The three RES scenarios show quit similar results, just with the exception of having electricity imports in case of a strict climate target (5 PJ of import in 2020 RES-30%).
The following paragraph will discuss the development of the final energy consumption (FEC). Comparable with the PEC, the FEC shows a constant increase during the model horizon (from 369 PJ in 2000 to 608 PJ in 2020 BaU). Again comparable to PEC consumption, the development between the scenarios is similar till 2015, showing a lower total value in all three RES scenarios in 2020.

The results of the reference run show an increased use of renewables at the FEC from 13 PJ (3.6 % in 2000) to 41 PJ (6.7 % in 2020, BaU). The RES directive sees a target for Slovakia of 14% share of RES on the final consumption of energy in 2020. In the scenario RES, this target has to be reached domestically. Thereby, the share of renewables is 14 % in 2020 using the relevant PRIMES calculation rules. Using the numbers and the balancing rules of the figure above, the share is 9.9 % in 2020 (RES).

If a trade of green certificates is implemented, the RES targets don’t have to be reached stand alone by the country (scenario RES-T). In this case of Slovakia, the share of renewables in the RES-T scenario is lower than in RES in 2020. For that reason, Slovakia is a buyer of green certificates in 2020 (also in 2010). The requirements of stricter climate targets (scenario RES-30%) don’t lead to a higher share of renewables. The share in RES-30% isn’t above the national target.
Analysing the FEC separated into non-renewables and renewables, the use of non-renewables show a clear increase in the BaU scenario (+211 PJ in 2020 compared to 2000), while the amount in the three RES scenarios remain more or less on a constant level between 2010 and 2020. The boost in BaU is mainly driven by gas (+112 PJ in 2020 compared to 2000 BaU) and also by electricity (+48 PJ) and oil (+38 PJ). While the total amount in the reference run is 567 PJ (2020), the results of the RES runs vary between 507 PJ (RES-30%) and 517 PJ (RES-T) with lower shares of coal and higher shares of gas.

The use of renewable energy sources as part of the FEC increases constantly in the reference run from 13 PJ (2000) to 41 PJ (2020). It total, the renewable amount is dominated by electricity from renewable sources (63.3 % in 2020, BaU), but with a drop of this share over time.

The three RES scenarios show a higher use of renewables, especially in 2020 (from +13 PJ in 2020 RES-30% compared to BaU 2020 to +16 PJ in RES). The additional amounts mainly come from a growth of renewable heat (11 PJ in 2020 in RES) and bio energy (16 PJ in 2020 in RES).

2.2 Use of renewable energy sources

In the base year, the direct use of renewable energy sources in Slovakia in concentrated on the central heat and power generation as well as on the industry sector. The total value of 22 PJ (2000) is divided into 73.0 % central heat & power and 27.0 % industry. Over the time, the use increased in the BaU run up to 40 PJ in 2020. This rise is driven by industry (+10 PJ in 2020 compared to 2000, BaU) and transport (+5 PJ). Thereby, the share used in central heat and power generation declines in all scenarios.

In the comparison of the scenarios it can be observed, that the share of renewables used in the conversion/production sector is lower in all three RES scenarios compared to the reference development. While the share is 44.6 % in BaU (2020), it’s only between 38.9 % (RES) and 40.0 % (RES-30%) when a RES directive is applied. Other sectoral changes could be noticed in a clear growth of the share of renewables used in the transport sector in case of a RES directive (+17.0 % between 2020 and 2000 in RES, +17.3 % in RES-T and RES-30%).

Neither the implementation of a green certificate trade, nor a stricter climate protection targets leads to significant changes in the direct use of renewables. It could be also pointed out, that in the RES scenarios also in the residential sector renewables are directly used. While the share is only 3.5 % in BaU, it goes up to a share of 9.1 % of all direct used renewables which are used in the residential sector.
2.2.1 Electricity generation

Taking a look at the electricity generation, it is dominated by the use of nuclear energy in the base year. 14 TWh of nuclear imply a share of 50.6 % in 2000 of total electricity generation. The other half consists of coal (18.7 %), renewables (17.3 %) and gas (11.4 %). There’s also a small amount of oil, but this energy carrier doesn’t play a future role.

Over the time there’s a constant increase of the total electricity generation of 12 TWh between 2020 and 2000 in the reference run. This development is driven by a massive rump up of gas (+10 TWh or +319.8 % between 2020 and 2000 in BaU). Compared to the BaU scenario, an RES directive just leads to slight changes in 2020. While the total amount is almost the same (40 TWh), the share of renewables is higher (21.9 % in RES to 18.0 % in BaU in 2020) and the share of coal lower (11.7 % in RES to 14.4 % in BaU in 2020).

The implementation of the possibility of trading green certificates, doesn’t lead to a significant change in the structure of electricity generation in Slovakia. Focussing on nuclear, it can be noticed than in 2020, almost the same amount as in the base is produced by nuclear in all scenarios (14 TWh).
In the base year, the key technology for the generation of electricity from renewable energy sources is clearly hydro, having a market share of 92.5% when producing 5 TWh. The extension of electricity from renewables is driven by biomass (+2 TWh in 2020 compared to 2000 BaU) and wind (+1 TWh in 2020 compared to 2000 BaU).

**Figure 2.5 Total electricity generation**

**Figure 2.6 Electricity generation from renewable energy sources**
In the three RES scenarios, the amount of electricity from renewables is about 2 TWh higher than in BaU in 2020. This difference is based both on wind and biomass.

### 2.2.2 Heat production

While there’s a jump in total heat production from 2000 to 2010 (+52.3 % or 114 PJ comparing BaU 2010 and 2000), the ongoing development just shows a smoother increase. In the base scenario, the total production is 331 PJ in 2010, 354 PJ in 2015 and 378 PJ in 2020. In the base year, the production is based both on coal (43.3%) and gas (42.9 %). The increase is clearly caused by an extended use of gas for heat production (+110 PJ in 2020 to 2000 in BaU). The use of renewables increases in the BaU scenario from 9 PJ in 2000 to 20 PJ in 2020.

Comparing the four scenarios, all of them having a RES share show a lower total heat production compared to BaU in 2020. Concerning the shares, basically a higher use of renewables (5.3 % in 2020 BaU, 7.3 % in 2020 RES) and a lower one of oil (5.6 % in 2020 BaU, 4.3 % in 2020 RES) should be mentioned.

![Figure 2.7: Total input for heat production](image)

The driver for the use of renewables is more the RES directive than the climate one. This could be observed by comparing the use of renewables for heat production in 2020 between RES and RES-30%. At the scenario RES, the production from renewables is little higher than at scenario RES-30%. So no additional renewables are put in by a stricter GHG constraint.

The growth of heat from renewable sources is caused by an extended use of bio energy (+16 PJ in 2020 in RES compared to 2000). Beginning 2015, also solar energy is used (with a share of about 4 % in all scenarios).
2.2.3 Transport fuels

The transport sector is over the whole time horizon typically dominated by fossil fuels. They have a share of still 90.2% in 2020 (BaU) which is little lower than the one at the beginning (95.0% in 2000).

Figure 2.8 Heat production from renewable energy sources

Figure 2.9 Conventional and non-conventional transport fuels
The use of non-fossil fuels in the three RES scenarios is clearly higher compared to BaU. The total amount rises up to 13 PJ in 2020, which equals a share of 13.8 % (see scenario RES and RES-T). Comparing the three RES scenarios, there couldn’t be any clear difference pointed out. Thereby, there’s no impact by a trading scheme of green certificates or a stricter GHG target on the conventional and non-conventional transport fuel consumption.

The non-fossil fuel consumption in the transport sector consists of electricity and biofuels. The use of electricity is the same in all scenarios and stays on a constant level between 2010 and 2020 (4 PJ). While the only non-fossil fuel is electricity in the base year, its share decline to about 32 % in the scenarios with a RES target.

3. Trade and import dependency

While Slovakia imports in total 413 PJ of fossil energy carriers, this amount increases in all scenarios up to 529 PJ in 2020 in BaU. Looking at first at the reference development, there’s a strong increase of imports of gas (+105 PJ in 2020 compared to 2000, BaU). There’s also an increase of coal (+35 PJ) but a decline of oil products (-23 PJ in 2020 BaU compared to 2000).

If a RES target without climate target (RES,RES-T) is in use, the share of gas of the total imports of fossil energy carriers is higher than in the BaU case both if a trade of green certificates is allowed or not (53.4 % gas in 2020 RES, 51.7 % in BaU). Therefore, the share of coal is falling.
Looking at the trade of electricity and biofuels inside and also outside the EU with Slovakia, there’s an export of electricity both inside (6 PJ) and outside (1 PJ) the European Union. In 2020, Slovakia imports electricity within the EU (17 PJ). This import is clearly reduced in case of a RES-directive down to 1 PJ in 2020 RES and RES-T. A stricter climate target makes Slovakia even become an electricity exporter again (5 PJ, all inside EU).

Figure 3.1 Net import / export of fossil energy carriers

Figure 3.2 Inter-EU trade and import from outside EU27 of biofuels and electricity
Concerning bio fuels, Slovakia imports about 1 PJ in all three RES scenarios in 2020 while there’s no trade of biofuels at all in BaU. For the amount of traded bio fuels in the RES-scenarios, it doesn’t make a difference even if there’s a green certificate trade possible or not, neither if the climate targets are stricter.

Slovakia uses the implementation of a trade of green certificates to import these in 2010 (about 2 PJ) and 2020 (about 1 PJ). That means that it would be cost effective to lower the burden sharing RES target of Slovakia (lower domestically reached share).

![Virtual trade of renewable energy in the RES Trade scenario](image)

**Figure 3.3 Virtual trade of renewable energy in the RES Trade scenario**

## 4. Impacts of policies on emissions and costs

### 4.1 Emissions

The total CO₂ emissions of Slovakia in 2000 are dominated by the ETS emissions. These emissions of the sectors electricity, transformation-ETS and industry ETS are responsible for 60.4 % of the total amount. The highest share of the ETS emissions in 2000 has the industry (36.3 % of the total ETS and Non-ETS ones) followed by the electricity sector (23.2 %). Looking at the Non-ETS sector, the highest share in the base year has the transport sector, followed by residential, non-energy intensive industry and commercial. The total amount is 35 Mio. t. CO₂ emissions of Slovakia in 2000.

In the base run, there’s a constant increase over time up to 47 Mio. t. (+32.3 %) in 2020 (BaU). The split between ETS and Non-ETS stays almost on the same level with about 60 % occurring in the ETS sector.

Comparing all scenarios, there are no significant differences before 2020. In 2020, the lowest total emissions occur under the conditions of a stricter GHG regime at reach a level of 41 Mio. t. But still this lowest level is a clear increase to the base year 2000 of 16.0 %. This lower level compared to BaU is caused by
reduced emissions in industry ETS (-2 Mio. t. in 2020 in RES-30% compared to BaU 2020) and electricity (-3 Mio. t.). For that reason, the ETS share is lower in RES-30% scenario compared to BaU.

Comparing both the scenario with and without green certificate trade it could be pointed out that the implementation of the trading scheme doesn’t have an impact on the emissions.

Figure 4.1  CO₂ emissions

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In general, the total system costs are the lowest in the reference run. Any additional constraint leads to higher cost. The stricter the constraints the higher the total costs (RES-30% +1.8 billion € compared to BaU). There’s no difference in system costs if a virtual trade of green certificates is allowed (both +0.8 billion € compared to BaU).

5. Conclusions

In the base year, the share of renewable energy sources in the Slovakian energy system is 3.6 % of the total primary energy consumption. By implementing a RES directive, the share of renewables increases in 2020 up to 11.0 % (RES) while in the BaU scenario, it just increases up to 7.6 %. There’s no clear difference concerning the use of renewable energy sources as a share of the total primary energy consumption neither if a trade of green certificates is implemented nor if the climate targets are sharpened. Accordingly, in Slovakia just a small amount of green certificates are traded. In 2020, Slovakia buys 0.9 PJ of green certificates. Thereby it would lower the total costs of a European Energy system by a small amount if the RES directive for Slovakia would be relaxed.
The growth of renewables is based on the final energy consumption level on an increased use of bio energy, mainly in transport sector and residential. Additional, in the conversion sector there is more biomass and wind used for electricity generation and also more bio energy for renewable heat production.
UNITED KINGDOM
1. Introduction

This chapter describes the modelling outcomes for UK within the RES2020 project. All the country reports together form the basis for a synthesis report in which the results on the pan-European level will be discussed.

To repeat shortly the following scenarios have been analysed:

- A BaU scenario (BaU), based on policies currently in practice (so without the ingredients of the January 2008 energy and climate package). Detailed information on renewable energy policies for individual countries can be found in the Reference Document on Renewable Energy Sources Policy and Potential (Deliverables D2.2 and D2.3).

- A RES Reference Scenario (RES) for the 2020 policies, in which the essentials of the EU Energy and Climate packages of January 2008 are implemented. This includes the 20% targets for RES and GHG emission reductions on a EU level. For UK this means 15% share of RES in 2020 and for all sectors which do not fall under the European Emissions Trading scheme a CO2 emissions cap of 282 Mtons.

- A RES Trade Scenario (RES-T) in which RES policies are identical to the RES Reference Scenario, but where next to physical trade of (renewable) electricity and bio-fuels, a virtual trade mechanism in RES production rights is in place. This is in line with the ‘statistical transfer’ approach in the EU Renewable Directive as adopted in December 2008. Although the debate on the exact form of this is still ongoing, it is quite certain that there will be an instrument introduced to allow for such trade between EU Member States.

- A RES Climate Scenario (RES-30%), in which RES policies are again identical to the RES Reference Scenario, but the greenhouse gas emission reduction objective is 30% in stead of 20%.

In the remainder of this introduction, we shortly describe the national energy system and current RES policies in place. Section 2 describes the scenario outcomes in terms of the specific RES technologies that are deployed in the different scenarios. In section 3, impacts in terms of trade and import/export are discussed, and in section 4, the CO2 emissions. Section 5 describes the economic impacts of the different RES deployment pathways, and section 6 contains the key conclusions.

1.1 National energy system and RES policies

In the year 2000, the total primary energy supply for United Kingdom accounted about 9500 PJ including both the net import of commodities and the domestic production. Regarding the different energy carriers, sum of oil (35.8% of the total supply), gas (37.4%) and coal (15.4%) were over 88% of total supply, whereas sum of renewables, electricity import and wastes were about 1.6%, that means the domestic production of electricity satisfied most of the demand, and the renewable technologies had a small penetration.

As concerns electricity, domestic production from nuclear, thermal power plants (public and auto-producers) and hydro/wind plants was about 1360 PJ (1300 PJ net generation) representing around 96% of total available electricity, against 4% of import (51 PJ).

Below a list of the key figures describing the recent energy situation:

- The share of RES in total primary energy consumption was of 1.98% in 2006.
- The share of RES in the gross final energy consumption was 1.3% in 2005.
- The share of RES in the electricity production was 4.6% in 2006 up from 4.2% in 2005.

In this report, the term ‘scenario’ refers to a defined set of policy measures that affect the development pathway of RES options. ‘Policy package’ might be an alternative, if not more correct term. Here, the word scenario is not used in its meaning of an internally consistent set of assumptions about what might happen in ‘the outside world’.
The share of all biofuels in the transport sector in 2006 was 0.54% by volume, or some 0.45% by energy content.

The United-Kingdom’s dependence on external energy supplies was about 13% in 2005.

And hereinafter some key RES targets for the future periods (European Directives or national Commitments):

- 15% share of RES on the final consumption of energy in 2020.
- At least 10% share of renewable energy in final consumption of energy in transport by 2020.
- 10% share of RES on gross electricity consumption by 2010.
- A renewable electricity penetration of 20% of all electricity power generation by 2020.

According to the analysis of the Cambridge Econometrics, the GDP growth rate will range between 2.3% - 2.5% in the period 2000 - 2020. As concerns population, growth rate for official projection is 0.5% a year, based on the actual (2000-2006) rate. Service sector already accounts for 68%-70% of GDP (particularly banking, insurance and business services) that means this sector already dominates the UK economy although the manufacturing remains an important sector.

2. Renewable technology deployment

2.1 Primary and final energy use

Results of modeling, related to primary energy supply (Figure 2.1), show that the UK’s energy system is expected to maintain a quite constant profile up to 2015; comparisons by periods and by scenarios indicate that shares of fuels and the absolute values (total primary energy use) seem to be quite similar to the base year situation. Natural gas (in particular), renewables and oil products cover the decreasing consumptions of coal and the partial phase-out of nuclear. In the period 2020, the system reacts to the different scenario assumptions and constraints showing significant differences between BaU case and the others, especially for the fossil fuels supply (absolute values and shares) and total primary energy requirement.
In the last period of the modeling, nuclear contribution to the supply mix is expected to be reduced by half compared to 2015 in all the scenarios whereas the coal share evidently decreases only in the alternative scenarios (environmental constraints).

The shape of the total final energy consumption (by periods and by scenarios) follows a similar pattern as in the primary energy supply results.

Details about renewables/non-renewables final energy uses are shown below (Figure 2.2 and Figure 2.3); according to the targets set by the Directive on the Promotion of the use of energy from renewable sources, UK should reach 15% share of RES of the final energy consumption in 2020.
Results show that share of renewables in the BaU scenario is expected to be far compared to the target (about 6.5% versus 15%) and close to the target in the alternative scenarios (13%-13.5% versus 15%) even so lower than the ambitious threshold. In the RES-T scenario, allowing the RES transfer, UK becomes a buyer of green certificates in 2020; as a consequence renewables use is expected to be lower than renewables use in the other alternative cases (Figure 2.3 – b), and the final energy use of non-renewables (natural gas in particular) higher if compared to alternative cases (Figure 3.3 – a). Total electricity consumption increases time by time, but Figures emphasize the shift to renewables, for producing electricity, with a share of renewables that increases in the alternative scenarios as well as in the BaU scenario. In particular, the electricity production by RES in the BaU case is close to the values of the alternative cases, that means the reference evolution (including just the reference policies) of the UK power system seems in coherence with the targets to be reached in the alternative cases, whereas there are other sectors or other commodities that react to the set of targets (assumptions and constraints) diverging from their reference paths.

Figure 2.3 Final energy use of a) non-renewables and b) renewables

2.2 Use of renewable energy sources

According to the targets set by the Directive on the Promotion of the use of energy from renewable sources, UK should reach at least 10% share of renewable energy in final consumption of energy in transport by 2020; as concerns generation mix, an indicative target (not explicitly modeled) set by the RES-electricity European Directive from 2001 is 10% share of RES on gross electricity consumption by 2010. But several sources indicate that the UK will not meet its RES electricity target set by the European Commission, highlighting the delay and the slowness of the policy implementation, and the inertia of the power system to the penetration of the RES.

Contribution of residential sector, toward the threshold of the target, increases time by time starting from 2010, while the central heat and power share accounts significant values only in the period 2020 and only for the alternative scenarios.

According to the existing directive on the promotion of the use of biofuels, or other renewables fuels, for transport, a notable penetration of RES in the sector is expected since 2010.

An important remark can be done about the use of renewables in the industry sector: allowing the RES transfer, industrial use of renewables in 2020 increases very slowly compared to the other alternative cases. A comparison by scenarios in 2020 shows that all the sectors react to the RES-T scenario set of constraints, decreasing the use of renewables, but for industry this behaviour seems to be really considerable.

Use of RES in the agriculture and commercial sectors is expected to be not relevant over the time horizon, and consumptions are expected quite constant.
2.2.1 Electricity generation

According to national commitment, the UK Government announced in January 2000 a 10% target RES-electricity supplied in the UK from renewable energy sources by 2010. This target has been embodied in the Government's Energy White Paper published in February 2003, which also introduced an aspiration to achieve a renewable electricity penetration of 20% of all electricity power generation by 2020 (aspiration to double the 2010 target by 2020).

Details on electricity generation sector are shown in Figure 2.5; up to 2015 there aren’t significant differences among scenarios, the shape of total electricity generation over the time is quite smooth over 350 TWh, and the renewables share reaches 15%. In 2020 system react to the alternative scenarios with a general decrease of electricity production (since the electricity import is quite constant over the time horizon, this means that electricity demand can be reduced). Shares of renewables by scenarios in 2020 reach 20% in the BaU and 25%-33% in the alternative scenarios.

Figure 2.4 Direct use of renewable energy sources in the different sectors
Among the RES technologies, near term growth is dominated by on and off-shore wind technologies according to the important exploitable potential; hydro provides a constant value of electricity over the time horizon, and penetration of biomass and ocean technologies becomes relevant just in 2020 for the alternative scenarios without RES transfer mechanism.

Results of the modeling allow to remark some important features of the UK electricity supply: in future the electricity generation will be strongly dependant on gas plants and wind turbines (especially in the alternative scenarios); in 2020 sum of the contributions of natural gas and wind technologies will reach over 73% in all the alternative cases (60% in the reference case) showing very much reduced fuel diversity and the consequent uncertainty related to the commodity price volatility and to the wind operational intermittency.
Another key point, related to the Figure 2.6, concerns the location of the wind turbines model suggests to build over the time horizon. The main wind potential is located in the North West of Scotland but the current (and probably future) demand is located in the South East of England, an important challenge to be faced will be to improve and manage the transmission networks and/or cross-country interconnections in order to deliver the electricity production and trade the surplus/deficit.

2.2.2 Heat production
Penetration of RES for heat production stands around 1%-3% up to 2015, in 2020 system reacts to the target 20-20-20 with a reduction of total consumption (indirect effect) and at the same time with a fast penetration of renewables in the alternative scenarios (direct effect) reaching a share of over 10% in the RES-Ref and RES-30% scenarios (Figure 2.7).
According to the Figure 2.7, in 2020 system requires a significant increase of RES for producing heat, in particular the share of bioenergy (Figure 2.8) is expected to be over 82% in all the alternative scenarios. Including in the system the RES transfer mechanism, solar share falls to zero, and the total heat production from RES decreases.

Figure 2.7 Total input for heat production

Figure 2.8 Heat production from renewable energy sources
All the scenarios reflect a penetration of district heating, share of renewables for producing heat to be delivered by district heating (central CHP and district heating plants) increases quickly already in 2010, and it ranges around the 15%-35% in the alternative scenarios in the period 2020 with a large dominance of CHP production, whereas consumption for heating appliances (consuming RES) is quite flat over the time horizon.

It’s important to remark that comparing results related to the scenario RES-Ref and scenario RES-30%; since the emission target of the second scenario is more strict, system reacts reducing the consumptions (energy efficiency, -2% compared to the RES-Ref scenario) both for electricity and for other commodities. Total consumption of RES, for the two cases in 2020, is quite the same but the allocation by sector is completely different, shifted toward industry sector in the first case (REF-Res) and shifted toward generation and transport sectors in the second case.

### 2.2.3 Transport fuels

Results in Figure 2.9 show the penetration of RES in transport sector; the alternative scenarios are quite similar up to 2015 (biofuels share increase up to 4% in 2010 and up to 5.5% in 2015); in the period 2020 RES share ranges between 6.9% (RES Transfer scenario) and 8.2% (RES-30%). Figures are lower than the ambitious targets set for the period 2010 and the period 2020. Cumulative values (conventional – non conventional consumptions) add up the same total values period by period (e.g. in 2015 all the scenarios sum 2399 PJ) except for the RE-30% case in 2020 that shows a lower consumption (effect of energy efficiency).

![Figure 2.9 Conventional and non-conventional transport fuels](image)

Mix of transport fuel in the time horizon is dominated by fossil fuels with a very small share for electricity and a slow penetration of renewables, moreover system reflects a fast growth of diesel consumption as substitute for gasoline.
Among the non-conventional transport fuels system tends towards the biofuels, the contribution of electricity slightly increases and penetration of hydrogen is delayed to future periods as well as penetration of second generation biofuels.

![Graph showing development of non-conventional transport fuels](image)

**Figure 2.10** Development of non-conventional transport fuels

Share of biodiesel (for blending) in 2010 reaches over the 70% among the biofuels consumption, and decreases in all the scenarios (slowly in the BaU) because of the penetration of biodiesel (pure) technologies and biogas, reaching a share of 35%-45% in the alternative scenarios and 66% in the BaU.

### 3. Trade and import dependency

Results (Figure 3.1) show the energy dependency of the country comparing the base year (independence) situation with the last model period scenario by scenario. In the base year UK was a net exporter of fuels, up to 2003 UK was a net exporter of gas in spite of since 2000 gas production has declined; as a consequence of flat consumption this has increased the demand for imported gas starting from the first model period. The United Kingdom has generally also been a net exporter of total oil and petroleum products since 80’s with a level of crude oil exports that reflected North Sea production. In the period 2020, UK is expected to be a net importer both for natural gas and also for oil products without significant differences among the alternative scenarios. Even if the total amount of energy (PJ) to be imported is expected to be quite similar in all the scenarios, in the BaU case the UK energy system requires coal, natural gas and oil products and the mix imported is less clean than in the alternative cases (penetration of natural gas). Among the alternative cases, the RES-T shows the highest values of import, according to the previous figures and remarks highlighting an higher fossil fuels consumption, as a consequence of the RES transfer allowed. It seems that not even the market of certificates (combined to the environmental targets) is a measure able to reduce (as sub-effect) the dependency of UK from energy commodity imports by pushing the domestic coal uses.
According to the values of Figure 3.1, UK will require huge quantities of natural gas in future; our modeling approach doesn’t distinguish between dry gas and LNG and results show the total values of natural gas to be imported, but particular care will have to be focused on the assessment of the existing and new infrastructures (pipeline system and LNG regasification terminals) for importing natural gas taking into account the position of UK at the end of the East-West gas corridors and at the end of South-North gas corridors.

Figure 3.1  *Net import / export of fossil energy carriers*

Figure 3.2  *Inter-EU trade and import from outside EU27 of biofuels and electricity*
In all the alternative scenarios most of the biofuels are imported by inter-EU trades; as concerns electricity import, there aren’t significant differences among scenarios (see Figure 3.2).

According to some remarks already discussed, UK becomes a buyer of green certificates in 2020, scenario related to the market of green certificates shows the effects on the use of renewables (lower, bioenergy in particular) and on the natural gas consumption (higher). In 2020 ratio between biofuels traded (imported) and biofuels consumption is over 50% both in the reference case and in all the alternative scenarios; biomass trade (import) compared to the biomass use becomes relevant only in the RES-Ref scenario (over 30%).

![Virtual trade of renewable energy in the RES Trade scenario](image)

**Figure 3.3 Virtual trade of renewable energy in the RES Trade scenario**

### 4. Impacts of policies on emissions and costs

#### 4.1 Emissions

Emissions of the UK’s energy system are shown below (Figure 4.1); in 2020 system reacts to the new constraints decreasing the emission in the electricity generation sector (ETS sector) and decreasing the emissions of residential sector (Non-ETS sector); neither transport nor commercial concur to the abatement of CO2 emission, and contribution of industry (ETS and Non-ETS sub-sectors) is not very relevant. Scenario including a strict constraint (RES-30%) on CO2 allow to reach the minimum value of emission, the only RES policies combined with the larger emission constraint result less effective for minimising the emissions.
4.2 Costs

Results about costs by scenario and by renewable technology are shown below. Last table presents the cost of renewables as a percentage of GDP. Comparing the tables, investments on renewable CHP and auto-production up to 2015 are not relevant, but in 2020 it is expected an important change and the multipliers of value 2015, to obtain value 2020, are around 10 – 30 times. According to the Figure 2.8 heat production by renewables seems to be the set of variables to be forced in 2020 for facing the alternative scenarios constraints since ratio between investment cost in the alternative cases and investment costs in BaU case is the largest one (12 - 35).

Hereinafter the tables list the main information about costs for RES by scenario.

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In terms of CO₂ reduction scenario RES-30% allows the best response but the cost of renewables (as a percentage of the GDP) is the highest one. Similar performances but different costs for scenarios RES-Ref and RES-T; even if until 2015 costs of renewables (in terms of GDP) are different, the effects on the emissions are quite the same whereas in 2020 the expected costs seem similar but appreciable differences for the emissions are expected since the use of certificates trade (Figure 4.1).

5. Conclusions

Results of modelling show a strong inertia up to 2015, only in the last period system reacts to different targets with different choices by scenarios. In the reference case the most important variables seem very far from the targets to be satisfied, while the alternative scenarios evolve towards the ambitious thresholds through the flexibility of the industrial, residential and generation sectors.

Total system costs ranking by scenario reflects the expected hierarchy (RES-30%, RE-Ref, RES-T, BaU by decreasing total cost) according to the targets of each case; in particular results show that the last period is expected to be extremely expansive (cost of renewables as a % of GDP) because of the plan of investments on renewables is not smooth over the time horizon.
As concerns the UK’s supply subsystem, according to these results, the increasing dependence on gas (to be imported both for combined cycle gas turbine plants and also for final uses, see Figure 3.1) and wind power in all the paths analysed, will be a key challenge to be faced, as much as the environmental issues, in order to reduce the risk of supply interruptions and the vulnerability of the whole energy system. Criterion of security of supply should always be considered into the results analyses, or directly included into the scenario analyses approach, for taking into account all the components of an energy decision making process at the same time.

UK seems to require substantial investments over the next two decades: for gas infrastructure, power stations (nuclear issue has to be made clear) and for electricity networks in addition to the costs for RES technologies and commodities. For this reason the allocation of investments will have to be carefully evaluating before choosing because this analysis seems to indicate that not all the decision variables resulting from model’s runs (including measures modelled to tackle climate change and meet the 20-20-20 targets) will also bring benefits to the UK’s security of energy supplies (e.g. dependence form import of natural gas as well as from import of biofuels).

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RES2020 Project: Reference Document on Renewable Energy Sources Policy and Potential Deliverables D.2.2 and D.2.3

More information on the Project Website: www.res2020.eu

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