Ea Energy Analyses

Long-term energy scenarios for Estonia

SCENARIOS FOR 2030 AND 2050

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Ea Energy Analyses
Frederiksholms Kanal 4, 3. th.
1220 Copenhagen K
Denmark
T: +45 88 70 70 83
info@eaea.dk
www.eaea.dk

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Preface

This study forms a part of the work on the Estonian long-term energy strategy (ENMAK) that includes the period from now to 2030 and a vision for 2050.

The steering committee consisted of representatives from Ministry of the Economic and Communication, Ministry of Environment, Elering, Enterprise Estonia, and Estonian Development Fund. An advisory board, composed of 20 experts, has followed the progress of the project and commented the analyses. Furthemore, we have been working together with a number of Estonian expert groups covering consumption, energy carriers, district heating, scenarios and energy supply security.

For the study of the electricity and district heating systems in Estonia and in the neighbouring region, the starting point has been the study made for the Baltic Sea Region Energy Co-operation (BASREC): *Energy policy strategies of the Baltic Sea Region for the post-Kyoto period* (Ea Energy Analyses, 2012).

The scenarios presented in this report focus on the primary result of different development paths for the energy sector towards 2050. This includes operation of the energy system, investments in new generation, price developments, and CO_2 emissions. The results will be used in a subsequent project where a strategic environmental impact analysis will be performed including assessment of job creation, health issues and other relevant impacts.

There are several appendices to this main report:

- Data report with description of all inputs, energy prices, technology prices, CO_2 prices, energy demand forecasts and planned investments in generation and transmission.
- Detailed output from the models. Including full loads hours per plant, emissions and levelised cost of energy. The information is collected in a report and a number of spreadsheets.
- The two models BALMOREL and STREAM complete with data sets.

The study was initiated in December 2012 and concluded in July 2013.

1 Executive summary

In the long perspective, i.e.,since the first oil crisis in 1973, many European countries have had stable and continuous energy policies. The policies have been guided by goals of security of supply, environment and economy. The last 15 years the EU has supported this development with European-wide initiatives, like minimum fuel taxes, CO_2 emission quotas and minimum energy efficiency requirements. This is expected to continue in the future, e.g. towards 2030 and 2050.

On the way crises and surprises will occur. The current collapse of the EU ETS CO_2 quota price can be seen as such a surprise. Fuel prices may fluctuate and policy focus may vary. Security of supply, environmental protection or economy may be high or low on the agenda. However, in the long run an active energy policy can be expected to be relevant and important.

The EU has a clear framework to steer its energy and climate policies up to 2020. This framework integrates different policy objectives such as reducing greenhouse gas (GHG) emissions, securing energy supply and supporting growth, competitiveness and jobs through a high technology, cost effective and resource efficient approach. These policy objectives are delivered by three headline targets for GHG emission reductions, renewable energy and energy savings[1]. In December 2013 the EU Commission will propose goals for 2030 – probably for CO_2 and for renewable energy.

Estonia

Estonia has a relatively high primary energy intensity in spite of a moderate industrial sector. A relatively low share of combined heat and power (CHP) in the district heating systems and relatively inefficient oil shale power plants contribute to the high energy intensity. From 2001 to 2011 the intensity measured in final energy has decreased: with an average economy growth above 3%, the growth in final energy consumption has only been 0.5 % p.a. The average energy demand for heating is relatively high[2]: 280 kWh/m^2, and the process of realising energy improvements in existing buildings can be slow – but crucial for the long term development of the energy consumption.

Estonia has significant resources of oil shale, biomass and wind. The balanced utilisation of these can – together with increased energy efficiency and use of CHP for district heating – be corner stones for the Estonian energy strategy.

[1] EU Green Paper. European Commission, 2013.
[2] Delivered heat demand including electricity for heating purposes. This is without conversion factors.

Scenarios for the future: 2030 and 2050

In this project, a number of different future scenarios are explored. The purpose is not to predict the future, but to focus on a few, selected issues, and understand their consequences. When selecting the setup of scenarios, both national and international issues are in focus:

- Global climate change policy, and challenges related to carbon leakage to Russia.
- Security of supply in Estonia
- National policy on renewable energy in Estonia
- The use of oil shale in Estonia

Eight scenarios are simulated with the BALMOREL model of the district heating and electricity systems. The electricity system interacts across national borders, and is studied for the entire Baltic Sea region: The Baltic States, the Nordic countries, Germany, Poland and North-West Russia. The eight scenarios are:

- **Liberal market**: Medium CO_2 prices, corresponding the IEA's new policy scenario (see Table 1). Oil shale is priced at the substitution price. Perfect electricity market in the entire model area. Investments in generation from 2020 and in transmission from 2026.
- The **110%** scenario: As the liberal market, but with a specific requirement to the electricity capacity in Estonia. The extra local capacity is an investment in security of supply.
- **Renewable energy** scenario, with a transition to 100% renewable energy for district heating and electricity in Estonia in 2050. A reduced energy demand is used.
- The **oil shale** scenario, with oil shale available at mining costs. The other scenarios use a higher opportunity cost for oil shale.
- **Retort gas** scenario, where retort gas from the production of shale oil is used for electricity generation.
- A **CO_2 market collapse**, with a zero CO_2 price
- A **CO_2 concern** scenario, with the high CO_2 price scenario from IEA World Energy Outlook and a price of 100 €/ton in 2050 (see Table 1).
- A **CO_2 leakage** scenario, where a zero CO_2 price used in Russia.

Four scenarios – 110%, renewable energy, oil shale and retort gas – can be considered as national Estonian scenarios, while the other four have an international perspective.

	2020	2030	2050
CO_2 collapse	0	0	0
Medium (IEA, new policy)	23	30	47
CO_2 concern (IEA, 450 ppm)	34	73	100

Table 1. Assumed CO_2 prices, €/ton. IEA prices until 2035 has been extrapolated to 2050.

Model results

Reduced use of oil shale

Based on the inputs the model finds optimal investments and optimal dispatch of electricity generation in the entire region. A significant result across scenarios is the reduced use of oil shale for Estonian electricity generation. Electricity based on oil shale is – in general – not competitive and the model rebuilds existing plants from oil shale to coal as soon as possible. The reason for this is that the cost of oil shale has been set to the substitution price. This price corresponds to the value of oil shale for producing shale oil. With the relatively high oil price predicted by IEA this use of oil shale is more attractive than using it for electricity generation.

Several countries in the region have decided not to invest in new coal power capacity (e.g. the Nordic countries). Others have the policy that the weight given to climate change is expressed in the CO_2 price and that a ban on new coal power plants is not relevant.

Electric capacity requirement:
110% rule

Comparing the *110%* and the *liberal* scenarios it is possible to assess the consequences of having a 110% rule (only) in Estonia. The 110% rule secures that there will always be local capacity to cover the peak electricity demand in Estonia. Wind, solar and transmission lines are ignored in the calculation of local capacity. The simulations show that there is sufficient capacity (existing and commercially built) until 2024, but after this year extra investment must take place in Estonia to meet the 110% requirement. In total 489 MW extra capacity of gas turbines in Estonia can be attributed to the 110% rule (2024-2030). These turbines will have relatively low operation time.

For Estonia the total cost of the rule is 227 M€ (net present value, 5%). For generators the loss is 566 M€. For the whole region the total cost is 346 M€. Germany, Poland and Russia has a surplus because of the rule. The Estonian cost of the 110% rule corresponds to 9 €/MWh of all electricity used between 2024 and 2050.

Renewable energy

The simulations show that the most cost-effective way for Estonia to realise its 2020 renewable energy goal of 17.4 % RE of electricity demand is through

101 MW_{el} new and existing biomass CHP plant in combination with the existing and planned wind (313 MW) and biogas plants (6 MW_{el}).

In all scenarios, except the CO_2 collapse scenario, the goal can be realised without subsidies. It should be noted that the current low CO_2 price is not sufficient to facilitate this development. In the CO_2 collapse scenario cost similar to 9 €/MWh (of all electricity demand) is needed to realise the renewable energy target.

Additional wind power expansion is close to being economical. With a medium CO_2 price it is economically feasible to invest in wind power at sites with good wind resources. Currently the CO_2 price is close to zero and with this price wind cannot compete with e.g. coal power.

In the model all existing subsidies are excluded, however the 2020 targets is set up as a requirement. The understanding is that the current subsidies are meant as a transition, and will not exist in the long run. Technology costs are decreasing and CO_2 prices are increasing (in all but one scenario) and this could make renewable energy profitable. The EU 2020 requirement will drive regional investments in renewable energy for this and the following years. In Estonia another 845 MW wind power is added in 2022-2024 (liberal scenario).

Estonia has a significant biomass potential. In most scenarios this resource is very attractive. The local resource can be supplemented by import from neighbouring countries. This is however not necessary as the local resource of approximate 44 PJ for energy purposes is not exceeded in any scenarios. A maximum of 43.5 PJ is used, meaning the entire resource is fully utilised inland.

The renewable energy scenario (where also a reduction in energy consumption takes place) costs 896 M€ less than the liberal scenario for Estonia. The cost of realising the lower energy consumption is not included here. Looking only on the requirement of 50% and 100% renewable energy in 2030 and 2050 (i.e. with standard energy consumption) reveals a total cost in the model area of 135 M€ - but a benefit in Estonia of 62 M€. This result depends on the interest rate. If e.g. a 10 % interest rate is used, this will be turned into a loss for Estonia 45 M€.

CO$_2$ price scenarios

Only the CO$_2$ concern scenario is in line with the EU 2050 road map. In this scenario emissions from the electricity and district heating sectors are reduced by 93% from 2012 to 2050 in the model area – and by 96% in Estonia alone.

Discussion

EU energy and climate regulation is likely to remain an important driver for the future Estonian energy policy. By the end of 2013 the EU Commission is expected to suggest binding 2030 goals for CO$_2$ and renewable energy. These could (as for 2020) include requirements for energy efficiency, renewable energy and CO$_2$ reductions. An important starting point when framing a new Estonian energy strategy would therefore be to develop expectations for the EU requirements for 2030. Although many aspects are the responsibility of market actors, an active energy policy is still relevant.

Oil Shale for electricity or fuel?

Estonia has unusually high primary energy intensity per GDP: 50% higher than Latvia and Lithuania and six times higher than Denmark (see chapter 2). The relatively low efficiency of oil shale power plants is part of the explanation. The study indicates that the traditional way of using oil shale for electricity generation is not competitive. It is more profitable to rebuild the three newest oil shale plants to coal or biomass. In most scenarios (except the oil shale scenario and the CO$_2$ collapse scenario) oil shale is not used for electricity generation after 2022.

CHP

Having access to a district heating network with a heat demand is a strong starting point for producing electricity. The levelised cost of electricity produced as combined heat and power (CHP) is in the range of 50-70 €/MWh compared to electricity only generation with typical prices of 70 – 100 €/MWh.

40% of the current district heating demand in Estonia is supplied by CHP. The European average is 60%, and in Denmark the figure is 71%[3]. This indicates an unutilised potential for CHP in Estonia. The BALMOREL model analyses show that it is profitable to increase the share of CHP to around 70%. Notably, the simulations indicate, that biomass based CHP is economically attractive even in small to medium sized district heating networks. District heating can help make the system more dynamic, since a fuel shift is cheaper to implement in a central system.

[3] See: www.cospp.com/articles/print/volume-10/issue-4/features/district-heating-in-germany-a-market-renaissance.html

It could be relevant to study in more detail the potentials and barriers for further expanding the district heating supply, and the possibilities for increasing the CHP share in districts heating system.

The use of heat storages can increase value of generated electricity – with increased electricity generation capacity, electricity can be produced during the hours with the highest electricity price. Heat storages can also reduce the need for peak load boiler generation in district heating systems, thereby reducing fuel costs significantly. The simulations show that investments in heat storage are attractive in all scenarios indicating that this choice is robust.

By January 2014 Estonia shall notify the European Commission about their plans to develop district heating and CHP.

Energy efficiency

Probably the best *no regret* option for any country is to increase the energy efficiency. It is well-known that a potential for profitable energy efficiency projects exists. Realising this economic potential is attractive in all cases. In long-term scenarios with high fuel or CO_2 prices it may even be relevant to go beyond what seems attractive today.

With the new EU energy efficiency directive from 2012, Estonia is obliged to analyse the instruments used to promote energy efficiency. One possible option is to introduce energy efficiency obligations to energy companies – a set-up that has been successful in Denmark[4].

In this study a business as usual and an energy efficiency prognosis have been developed. The cost of supplying the energy efficiency scenario (net present value) is 834–1033 M€ less than the business as usual scenario[5]. The cost of reaching the energy efficiency scenario (investments by building owners, campaigning costs etc) has not been analysed in this study.

Buildings in Estonia have a relatively high energy demand for heating, approx. 280 kWh/m^2[6] indicating that there is a significant potential for reducing the demand. At the same time a very large share of the demand for heating in detached house is provided by fire-wood. The scenarios foresee a reduction in

[4] See: European Commission (2012): Energy efficiency directive. For evaluation of the Danish obligation scheme see: Bundgaard et al. (2013 a and b).
[5] The net present value also includes the change in costs related to investments in supply. All scenarios have model based investment in generation from 2020 and in transmission lines from 2026.
[6] Delivered heat demand including electricity for heating purposes. This is without conversion factors.

the demand for heating (stronger in the energy efficiency prognosis) as well as a gradual substitution of firewood by modern heating technologies like electric heat pumps and district heating. Though using fire-wood is a renewable energy source it is rather labour intensive and the efficiency of the stoves is rather low. Moreover, from an energy system perspective it is not suitable to use biomass, which is likely to become a more scarce resource in future, for low temperature heating.

Security of supply

It can be relevant to modernise the 110% rule which is imposed in Estonia to secure security of supply. An improved rule could focus on reliability. This term includes both adequacy (to have the capacity to cover demand all year round) and security of supply (the ability to withstand sudden disturbances in the system). Studies of reliability can point to the need of more generation capacity as well as other steps, e.g. improved protection equipment, increased transmission capacity or demand response. Reliability studies typically include all hours of the year and have a probabilistic approach, allowing imports and wind power to contribute to the security of supply.

Biomass

A strategy for the use of biomass could be considered. In the simulations biomass consumption will increase by a factor two in Estonia and by a factor five in the whole region (2020 compared to 2012). Development of sustainable biomass resources from forest and wetlands could increase the role of Estonia as a supplier of biomass to the growing market. No biomass is imported in any scenarios but the national resource for energy purposes is almost fully utilised.

Transport

In the short term, the greatest potential for reducing the energy demand and greenhouse gas emissions in the transport sector comes from improving the energy efficiency of new cars. According to the EU new cars in the EU should on average emit 130 grams of CO_2 per kilometre (g/km) by 2015 and 95 g/km by 2020. However, currently the emissions of new cars in Estonia are about 20% higher than the EU average. In Denmark, Finland and Norway CO_2differentiated taxation has had significant impact on consumer choice and proved a powerful tool to curb emissions from new cars[7].

In the longer-term the introduction of new drivetrain technologies such as electric vehicles (including plugin-hybrids) will become key to further reducing emissions. Currently, these technologies do not provide a viable alternative to

[7] See: Nordic Energy Technology Perspectives, IEA and Nordic Energy Research, 2012.

the conventional combustion engine technology due to the high cost of batteries and range limitations. Therefore a large-scale introduction will depend on a favourable technological development at international level.

In the longer term it will also become important to enable a lower growth of transport demand, for example through physical planning and transportation demand management to reduce transport needs. Facilitating modal shift to lightrail, rail and cycling within passenger transport and to rail within freight transport would also contribute to reducing energy demand and greenhouse gas emission.

2 Estonian energy landscape

The development in the Estonian energy consumption has been modest the last ten years. Consumption has increased by 7% from 2001 to 2011 (see Figure 1). In the same period the GDP has increased with 48% – illustrating the possibilities of decoupling economic growth and energy consumption.

Compared to other countries the energy consumption of the residential sector makes up a relatively high share of the final energy consumption in Estonia.

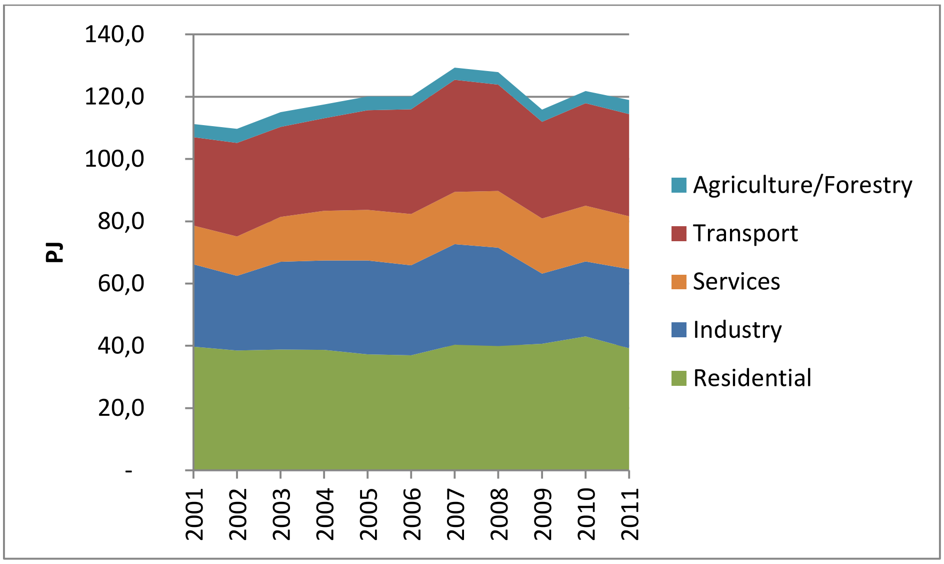


Figure 1: Development in final energy consumption in Estonia (Eurostat 2013).

Comparing Estonia to neighbouring countries reveals some important differences (Figure 2 and Figure 3). Figure 2 shows that there appears to be a strong tendency towards a lower energy intensity as the economy grows. Estonia and Denmark both have relatively little industry – but the energy intensity (final energy per €) of Estonia is three times higher. The difference may be due to: An autonomous development together with higher wealth (e.g. better comfort and lower energy consumption due to well-insulated houses) and a policy driven improvement in form of strong policy instruments to promote energy efficiency. Denmark has a long tradition of using several policy instruments to improve energy efficiency (e.g. high energy taxes, energy efficiency obligations for energy companies, strong building codes, energy audits in industry).

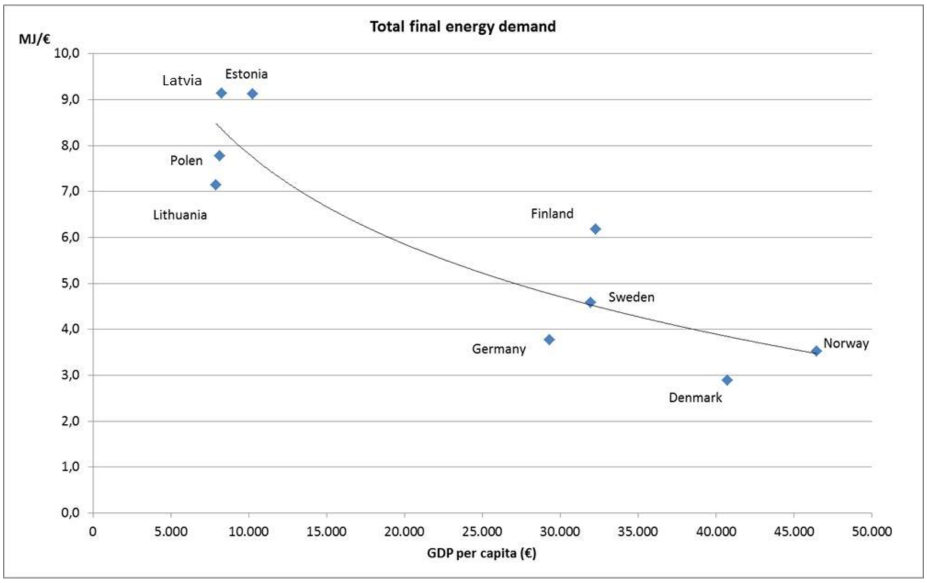


Figure 2: Final energy intensity and GDP per capita.

Estonia is a very energy intensive country measured in primary energy per GDP (Figure 3). The relatively high losses in the energy sector can be explained by export of electricity (the fuel is accounted in the primary energy consumption, but exported electricity is only accounted by its energy content), relatively low conversion efficiencies (e.g. 30% on old oil shale plants) and losses in the district heating networks. About 40% of the district heat is generated via combined heat and power (in Denmark this value is 71%).

In 2010 Estonia exported 3.3 TWh. This export has increased the total primary energy consumption by 10-15%. Export of electricity produced on oil shale is also followed by an increase in GDP, which is the same impact that can be achieved with export of e.g. shale oil.

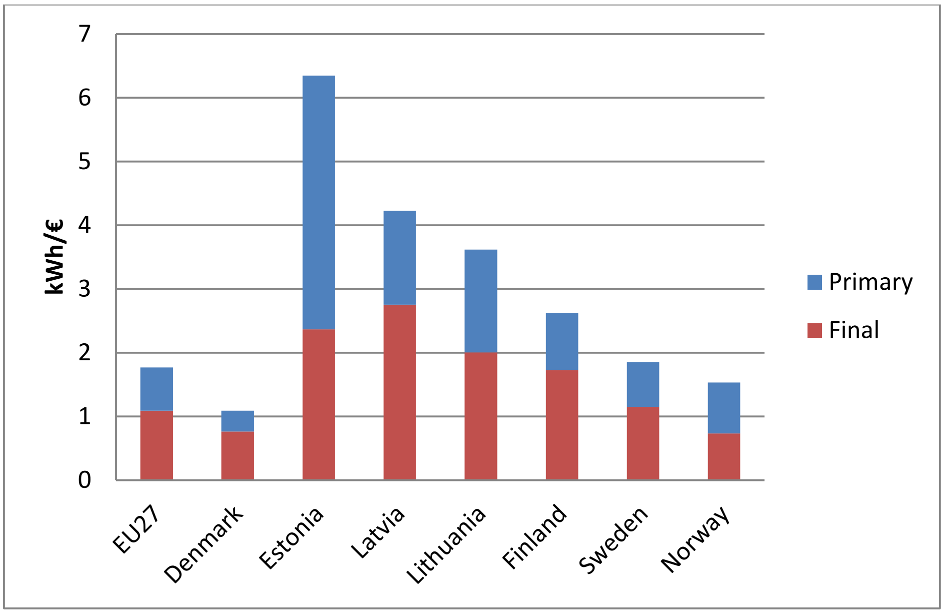


Figure 3: Energy intensity of the economy 2010 (Eurostat 2012a).

Estonia already has a high share of renewable energy, mainly in the form of wood used for heating. The declared goal is to reach 25% renewable energy in the gross final energy consumption by 2020, see Figure 4.

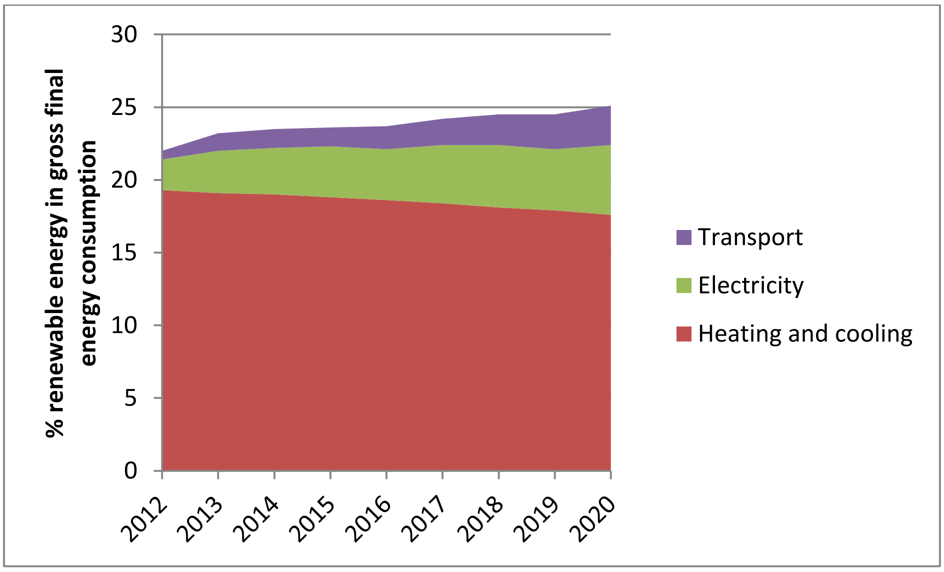


Figure 4: Expected development in the share of renewable energy in Estonia (NREAP, 2011).

Oil shale

Oil shale is sedimentary rock containing up to 50% organic matter. Once extracted from the ground, the rock can either be used directly as a fuel, for example for a power plant or an industry, or be processed to produce shale oil and other chemicals and materials[8]. Mining started before 1930 and peaked in 1980 with 30 Mton/year.

Estonia has decided that a maximum of 20 Mton (24 Mton tradable) oil shale is allowed to be extracted per year (corresponding to approx. 140 PJ after subtraction of mining losses). The resource would at this pace last for at least 50 years of mining.

Because of its relatively low energy content oil shale is typically not transported over long distances, but is instead utilised locally. In Estonia oil shale has been used for electricity generation since 1940. Oil shale based electricity has for many years exceeded local needs and electricity has therefore been exported to neighbouring countries.

Oil shale has also been used to produce shale oil that can be refined to diesel oil. As capacity for producing shale oil becomes available, this use of the oil shale competes with the alternative use in power plants.

Emissions

Oil shale used in a new power plant (circulated fluidized bed boilers) results in a CO_2 emission in the order of 1000g/kWh, which is higher than coal based plants. The relatively low efficiency of the oil shale plants increases the specific emissions.

Older power plants (pulverized combustion boilers) have much higher SO_2, NO_x and fly-ash emissions than newer ones. For example, in new plants SO_2 emissions have been reduced from 2,000 mg/m^3 to 0-20 mg/m^3.

Price of oil shale

If oil shale can only be used for power generation it is natural to set the cost of oil shale to the mining costs. This procedure is part of the background for the historical large Estonian oil shale based electricity generation. However, since oil shale can also be used for producing shale oil, the substitution price need to be applied. Only if electricity generation is profitable based on the substitution price, then the oil shale should be used for electricity generation. With the current price of oil around 100 $/barrel it is more profitable to produce shale oil than electricity.

For this study a simplified substitution price has been calculated. The short run substitution price is defined as:

[8] This section is partly based on European Academies (2007).

Fuel oil price x plant efficiency
– oil shale plant OPEX – plant CO_2 costs

Plant efficiency is set to 70% and OPEX to 21 €/ton. With these values the substitution price is a function of oil price (positively related) and CO_2 price (negatively related). Note that the power plant also pays the CO_2 price.

Electricity should be generated by oil shale when the electricity price is higher than:

Oil shale substitution price / plant efficiency + OPEX + CO_2 costs

Using oil shale to produce shale oil will increase the global CO_2 emissions because the plant efficiency is lower for oil shale than for raw oil.

Retort gas

In the text above it is assumed that oil shale is used to produce diesel, which can be used in transport. However, it is also possible to stop the refining process some steps earlier and produce a product similar to fuel oil. In this case the end product is less refined and less expensive, but in addition to the oil, retort gas is produced. The retort gas can be used for various purposes, e.g. as fuel in a gas engine producing electricity.

Biomass resources

Estonia has considerable biomass resources and is a net exporter of wood pellets.

	Potential
Wood	49 PJ
Waste	3 PJ
Straw, hay, reed	1 PJ
Biogas	9 PJ
Peat	4 PJ

Table 2: Estonian biomass potential in 2030 (Resource group, 2013).

Also neighbouring countries have significant biomass resources. It is therefore possible to import biomass, also in form of wood chips. Import could be used for local consumption or to produce wood pellets for export.

Wind resources

Estonia has good potentials for wind power, e.g. offshore and in coastal areas. E.g. BASREC (2012) describes that Estonia has 4 TWh offshore wind power potential in the *very high* category (indicating the best combination of wind speeds and sea depth).

Security of supply

It is important for any country to have a high level of security of electricity supply. Many different aspects are covered by the term security of supply, e.g.:

- Having capacity to cover the electricity demand with local generation.
- Low probability of lack of electricity supply (including black-out and brown-outs[9]). This concerns the overall probability of lacking supply, including the probability of failure in generation and grid, locally and regionally.
- Independence of other countries (e.g. natural gas from Russia, or oil from OPEC)[10].

110% rule

In Estonia a 110% rule has been applied to the electricity sector[11]. It has been required that the country must always have sufficient inland capacity for electricity generation to cover its yearly peak demand. Intermittent generation like wind and solar are not included in the calculation[12]. With the existing power plants it is expected that the 110% requirement will be fulfilled without any extra investments in new capacity until 2024.

If energy markets were well functioning and energy consumption was truly price sensitive, there would be no need for a requirement for a certain amount of inland electricity generation capacity. Price driven import as well as price driven demand reduction in Estonia and other countries would guarantee that peak demand could always be met (maybe at a high price). However, electricity demand is typically not very flexible, and large parts of the consumption are usually not sensible to high prices (e.g. spot prices above 250 €/MWh).Moreover, Estonia is neighbour to Russia, where market rules are

[9] The term brown-out describes the situation where selected consumers are disconnected with the purpose to keep the balance in the system. Black-out is the case where an entire area is disconnected due to a major fault.
[10] Gas supply security for the Baltic States is discussed in Noél et al. (2013).
[11] See chapter 6 for analyses of the economic consequences of the 110% rule.
[12] For this project the 110% rule has been formulated: Local capacity must be 110% of hourly peak demand – 150 MW. Reserves, wind and solar are not included.

very different from Estonia and the Nordic countries. This makes it relevant to analyse a national scenario with requirements regarding local capacity[13].

Transmission lines to and from neighbouring countries have no value under the 110% rule. Today Estonia has transmission lines in the order of 2,100 MW. In 2022, the interconnector capacity to the Baltic States is expected to be 5,250 MW[14].

With this high degree of interconnections it is clear that the 110% rule is overly simplistic. An improved method of ensuring security of supply should focus on the probability of lack of supply. Such a probabilistic method would cover all year (not only peak hours[15]) and would include transmission lines and intermittent generation. The focus of such a method would be the short-term (dynamic) risk of the electricity system.

In general interconnected electricity systems have a much higher security of supply than isolated systems. However, new types of risks exist in interconnected system – import of blackouts, for example voltage collapse, that occur with only seconds notice and therefore can be difficult to be protected against.

Transmission grid connection

Estonia and the two other Baltic countries are today AC connected to Russia and Belarus. Estonia is furthermore DC connected to Finland – today with 350 MW, and from 2014 with 1,000 MW through Estlink 1 and 2.

In this study connections between the Baltic States and Russia are expected to be 3 x 500 MW. The interconnector from Lithuania to Kaliningrad is set to 700 MW. This capacity is AC today and should be replaced with DC connections if the AC areas are modified. In practice the new capacity may be different to the existing, but this discussion is not the focus of this study.

[13] In ENTSO-E's Adequacy report from 2012 the Baltic region (Baltic and Nordic countries, Poland and Germany) is highlighted as the exception among all the regions, where negative values of the power balance (Remaining Capacity, RC, minus Adequacy Reference Margin, ARM) are foreseen. However, looking deeper into the importing possibilities, one can see that the region could easily transmit missing electricity from neighbouring areas, as its importing capacity seems adequate.

[14] See: elering.ee/generation-capacity-and-interconnections-are-sufficient-to-cover-estonias-electricity-consumption/&article_searchword=&from=&to=

[15] Please note, that many blackouts happen in cases with only modest demand, e.g. the 2003 blackouts in USA, Italy and Denmark/Sweden.

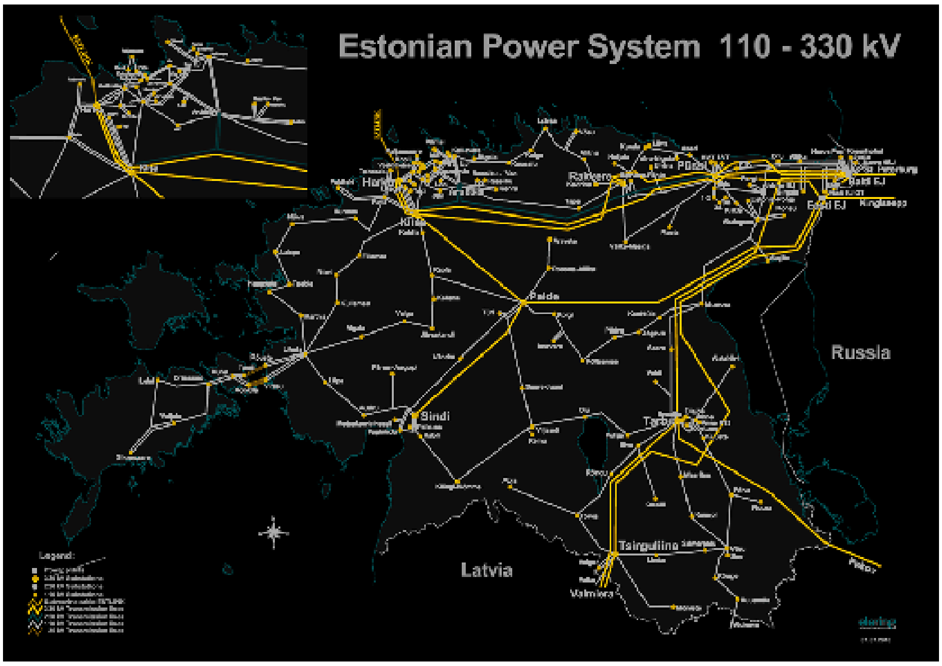


Figure 5: Estonian transmission system (www.elering.ee).

Figure 6: Natural gas network in Estonia (www.egvorguteenus.ee).

Auctioning of CO_2 quotas

Estonia and the other European countries will receive revenues from auctioning of CO_2 quotas as part of the carbon emissions trading system. It is a new type of revenue for the states, which may be difficult to predict.

In 2020 Estonia is expected to auction quotas corresponding to 9.4 Mt CO_2. In most of the scenarios a CO_2 price of 23 € in 2020 is assumed, corresponding to a revenue to the Estonian state of 180 M€. In the CO_2 concern scenario the revenue would increase to 270 M€ in 2020 – and in the CO_2 collapse scenario there would not be any revenue for auctioning of CO_2 quotas. Revenues are not influenced by the national CO_2 emission.

For the time after 2020 the amount of quotas is expected to decrease – and the CO_2 price is expected to increase.

3 The regional perspective

The Baltic Sea Region (as modelled in this report) holds a total population of around 165 million people with an aggregated gross electricity consumption of approx. 1,300 TWh. The majority of the countries in the Baltic Sea Region have well developed district heating systems but an unexploited potential to expand the district heating in parts of the region, particularly in Germany and to a lesser degree in Poland still remains[16]. The gross demand for district heating in region is 2,050 PJ (570 TWh).

The Nordic countries and central Europe are presently well interconnected, but the three Baltic countries are currently only able to exchange energy with the Nordic countries through a single interconnector between Estonia and Finland (EstLink 1). However, new interconnectors are scheduled, which will connect Lithuania with Sweden (SwedLit/NordBalt, 2015), Poland with Lithuania (LitPol, 2015) and reinforce the connection between Estonia and Finland (Estlink 2, 2014).

The Baltic States would like to leave the Russian synchronous area, however, negotiation are complex (Elering, 2013). Studies of the cost and benefits of changing AC connection to the UCTE area are underway.

Power exchanges

The Baltic States and the Nordic countries form a common power exchange, Nord Pool. Since 2010 Estonia has been a part of Nord Pool and as of January 2013 all Estonian electricity generators are operating on the market. Lithuania joined Nord Pool in 2012 and Latvia in June 2013. The Baltic States and the Nordic countries are thus now fully integrated – with competition about the electricity delivery hour by hour.

In Germany power is exchanged through the European Energy Exchange and in Poland through the Polish Power Exchange. Nord Pool and the European Energy Exchange are linked through so-called market coupling to ensure efficient use of existing cross-border interconnections.

The Russian market consists of eight wholesale generating companies of which six are based on thermal generation, a company with only hydro power

[16] The possibilities for expanding district heating supply have been examined on an EU-wide scale in the project ECOHEATCOO (Euroheat & Power, 2005-6) , see work package 4, "Possibilities with more heating in Europe" http://www.euroheat.org/files/filer/ecoheatcool/documents/Ecoheatcool_WP4_Web.pdf

plants (RusHydro) and a company with only nuclear power plants (Rosenergoatom). In addition, there are 14 so-called territorial generating companies consisting of the smaller power plants and combined heat and power plants[17].

The long-term aim is according to the "Roadmap of the EU-Russia Energy Co-operation until 2050" to link the markets of the EU and Russia by 2050.

Decisions on gas interconnections and a regional LNG terminal are still pending. Different locations in the Estonia and in Finland have been studied. Lithuania will open a terminal in 2014.

EU

The Energy Provision[18] in the EU Treaty stipulates that the EU energy policy shall aim to:

- Ensure the functioning of the energy market;
- ensure security of energy supply in the Union;
- promote energy efficiency and energy saving and the development of new and renewable forms of energy; and
- promote the interconnection of energy networks.

The EU has a clear framework to steer its energy and climate policies up to 2020. This framework integrates different policy objectives such as reducing greenhouse gas (GHG) emissions, securing energy supply and supporting growth, competitiveness and jobs through a high technology, cost effective and resource efficient approach. These policy objectives are delivered by three headline targets for GHG emission reductions, renewable energy and energy savings[19]. In March 2013, the Commission issued a green paper on a 2030 framework for climate and energy policies. The green paper highlights energy efficiency improvements and smarter infrastructure as *no regret* options. In December 2013 the EU Commission will propose goals for 2030 – probably with binding 2030 goals for CO_2 emissions and for renewable energy. The EU is likely to continue to be an important driver in energy policy.

The following briefly highlights key elements of the action plan for the EU Strategy for the Baltic Sea region and the EU directives for energy efficiency and renewable energy.

[17] Roadmap of the EU-Russia Energy Cooperation until 2050 Progress report, July 2011, http://ec.europa.eu/energy/international/russia/press_en.htm
[18] Article 194
[19] EU Green Paper. European Commission, 2013.

Action plan for the EU Strategy for the Baltic Sea Region

According to the “Commission Communication and Presidency Conclusions on the Energy Roadmap 2050”, the core elements in developing a low-carbon 2050 energy system are energy infrastructure, renewable sources of energy, energy efficiency, and security of supply at affordable prices. These aspects are also the cornerstones of long term-energy policy planning in the Baltic Sea region.

The second action plan for the EU Strategy for the Baltic Sea Region (EUSBSR), published February 2013, lists 17 priority areas and 5 horizontal actions, which represent the main areas where the EUSBSR can contribute to improvements, either by tackling the main challenges or by seizing key opportunities[20].

Energy is one of the priority areas. The work of this priority area is coordinated by Denmark and Latvia and aims to improve the access to, and the efficiency and security of the energy markets. Two action areas specified for the current work period are as follows:

1. Action: Towards a well-functioning energy market:
    - Monitor the implementation of the Baltic Energy Market Interconnection Plan (BEMIP). Lead: Lithuania. Deadline: Progress report July 2013.
    - Sharing best practises of regional cooperation of BEMIP with EU Eastern Partnership countries. Lead: Lithuania. Deadline: Progress review November 2013.
    - Extend the Nordic electricity market model to the three Baltic States. Lead: Latvia. Deadline: 2013.
    - Potentially: Investment in infrastructure in the Baltic Sea Region. Lead: Denmark.
2. Action: Increase the use of renewable energy sources and promote energy efficiency:
    - Enhanced market integration of RES and best practice sharing. Lead: Latvia.
    - Promote measures to develop the usage of sustainable biofuels. Lead: Latvia.
    - Demonstration of coordinated offshore wind farm connection solutions, e.g. at Krieger’s Flak (Denmark, Germany). Lead: Denmark. Deadline: 2018.
    - Promoting energy efficiency measures. Lead: Latvia. Deadline: 2015.

[20] Action plan for the European Union Strategy for the Baltic Sea Region, Commission of the European Communities, SEC(2009) 712/2, February 2013

- Potentially: Exploration of cooperation mechanisms. Lead: Sweden.

Energy efficiency

EU's new directive for energy efficiency (2012/27/EU) came into force in December 2012. As a consequence all Member States must implement an energy efficiency obligation or specify alternative instruments that will have same effect as the energy efficiency obligation, namely yielding an annual final energy reduction of 1.5% (article 7). The choice of instrument must be reported to the EU by 31st December 2013. The obliged parties should be energy distributors and/or retail energy sales companies and may offer subsidies or consultancy support to efficiently reduce consumption.

The directive for energy efficiency also requires that Member States by 31st December 2015 carry out a comprehensive assessment of cost-efficient potential for high efficiency cogeneration and efficient district heating/cooling (article 14). Furthermore, priority or guaranteed access plus priority dispatch should be granted for high efficiency cogeneration (article 15).

Renewable energy

The renewable energy directive (2009/28/EC) sets binding targets for the share of renewable energy sources in energy consumption in the EU Member States. The overall EU target is a 20% share of renewable energy sources that is further allocated to the countries with national targets varying from 10% to 49%. For Estonia the goal is 25%. The directive includes mechanisms that enable Member States to cooperate in order to reach their targets cost-efficiently. The European Commission wishes to increase the use of these mechanisms.

BASREC communiqué, May 2012

The Baltic Sea Region is politically and economically integrated and represented in a number of regional organisations and initiatives such as the Baltic Sea Region Energy Cooperation (BASREC)[21].

BASREC will in the current period 2012-2015 concentrate its cooperation on[22]:

- Security of energy supply and predictability of energy demand;
- Analysis of options for the development and integration of energy infrastructure in the region, in particular regional electricity and gas markets, including legal frameworks ;
- Increased energy efficiency and savings;

[21] BASREC – Baltic Sea Region Energy Cooperation Initiative, (initiated in 1999), includes the Governments of Denmark, Estonia, Finland, Germany, Iceland, Latvia, Lithuania, Norway, Poland, Russia and Sweden. The European Commission is represented by DG Transport and Energy. The participation in this work also involves the Council of Baltic Sea States (CBSS) and the Nordic Council of Ministers (NCM).

[22] Communiqué adopted at the BASREC meeting of energy ministers in Berlin, 14-15 may 2012

- Increased use of renewable resources available in the region, including integration of fluctuating wind power into the electricity system;
- Rehabilitation and development of district heating and cooling systems and CHP;
- Demonstration of transportation and storage of CO_2;
- Low-carbon energy policies up to 2050;
- Capacity building in the energy sector of the region.

BASREC studies

BASREC has in the period 2009-2011 instigated a number of studies aimed at enabling a well-functioning energy system within the Baltic Sea Region.

In 2009, the study 'Energy perspectives for the Baltic Sea region – Setting an agenda for the future', conducted by Nordic Council of Ministers, Baltic Development Forum and Ea Energy Analyses, in dialogue with among others BASREC and UBC, showed through small-tech and big-tech scenario analyses that stakeholder and country cooperation will reduce the cost of CO_2 reduction and that energy co-operation can indeed leave each country better off when implementing targets on climate protection, as well as in ensuring greater security of energy supply.

The follow-up study 'Energy perspectives for the Kaliningrad region as an integrated part of the Baltic Sea Region', 2010, concluded that closer cooperation, dialogue and joint energy planning initiatives are necessary elements, if the electricity system in the Baltic Sea Region is to develop in an economically and environmentally sustainable fashion; thus avoiding expensive, isolated solutions that are primarily driven by local demands for improved security of energy supply. This is particularly true when looking at the relationship between the EU countries and their Russian neighbour in the Baltic Sea Region.

Both studies have been discussed with politicians, civil servants, energy companies and other relevant stakeholders in the countries around the Baltic Sea Region including Russia. One outcome of the consultation of stakeholders was that the BASREC and the Nordic Council of Ministers launched a pilot regional training programme BALREPA[23] in energy planning that ties a link between regional visions and scenario analyses, municipal energy planning, and implementation of concrete energy projects.

[23] More information on the Baltic Rotating Energy Planning Academy can be found at www.BALREPA.org. The pilot was tested in Kaliningrad, Lithuania and Latvia in the period 2011-2012.

A third energy scenario study – 'Energy policy strategies of the Baltic sea Region for the post-Kyoto period', 2012 demonstrated that, given the insecurity over a post-Kyoto international climate agreement, the Baltic Sea Region can be a frontrunner in developing energy strategies for the post-Kyoto period.

The resulting strategies shall emphasize the coherence of climate policy and energy security objectives. As part of the study, a number of policy scenarios were evaluated against a reference scenario, with focus on economic impacts, implications for the regional energy system and the security of supply in the region for the year 2020 and beyond. The study focused on the electricity and district heating sectors in the Baltic Sea countries including North-West Russia and explored how the targets can be achieved at the least possible cost. The electricity market model Balmorel was used to simulate optimal dispatch and investments given the provision of framework conditions and technology cost. Data for the technologies that the model can choose between are drawn from a comprehensive technology catalogue.

The quantitative results of the scenario analyses were translated into concrete policy recommendations for designing energy policy of the region. The study results were presented at the COP17 in South Africa and at United Nations Conference on Sustainable Development in Rio, Brazil.

4 Energy consumption towards 2050

The development of the energy consumption greatly influences the energy supply scenarios. This chapter describes how the prognosis has been developed and incorporated in the STREAM model. In chapter 7 the total fuel consumption, emissions and use of renewable energy will be shown for all scenarios.

For projection of the energy consumption the core assumption of the model is that changes in GDP leads to changes in energy service demand (e.g. the need heating, process energy, transport services, electricity for appliances and lighting etc.,). The energy service demand is provided through conversion of an energy carrier such as firewood, gasoline, electricity etc. to the energy service in question. Often statistical information relates to the energy carrier and not the basic energy service demand, which makes it necessary to make best estimates of the conversion efficiencies.

The STREAM model is based on a bottom-up approach. This means that the user defines the input to the model – for instance, X% heat pumps for heating, X% bio-ethanol in the transport sector – and on this basis an output is calculated. The model does not perform an economic optimisation specifying exactly which set of measures are the most advantageous to combine under the given conditions. To support the choices in the model levelised cost of delivering energy services are computed for different heating technologies.

The projection of economic growth is provided by the Estonian Ministry of Finance. It foresees a relatively strong growth of approx. 3.5% in the period to 2020 thereafter declining to reach just above 1% in the last decade before 2050.

	2010-2020	2020-2030	2030-2040	2040-2050
Assumed GDP growth	3.48%	2.51%	1.89%	1.15%

Table 3: Assumed GDP growth rates. Source: Estonian Ministry of Finance.

To the extent possible the projection of energy services and energy demand is based on bottom-up analyses and historic elasticities. In addition, experience from countries with higher GDP than Estonia is used as benchmarks for the projections.

The table below describes which approaches are used to forecast the demand for energy (energy services) within the different sectors of the Estonian economy.

Sector	Approach used to determine demand for energy services
Residential	Electricity demand: Projection based on historic correlations and estimates by consumption workgroup. No relevant energy service indicator. Heat demand: Energy service indicator is heated m^2. A bottom-up analysis is used to determine heat demand.
Tertiary	Electricity demand: Projection based on historic correlations and estimates by consumption workgroup. No relevant service indicator. Heat demand: Energy service is heated m^2. A bottom-up analysis is used to determine heat demand.
Industry	Electricity demand: Projection based on historic correlations and estimates by consumption workgroup. No relevant energy service indicator. Process heat: Projection based on historic correlations and estimates by consumption workgroup. No relevant service indicator.
Transport	Person kilometre (pkm) and ton kilometers (tkm) for freight are used as energy service indicators. Growth rates are based on historic developments (correlation with GDP) for the short-term and benchmarks for other countries for the long-term projections.
Agriculture & Fisheries	Constant energy demand (as it has been historically).

Table 4: Approaches applied in the energy demand analysis (own assessments).

Status and trends

Residential sector

Existing buildings in Estonia have a rather high specific energy demand, namely approx. 280 kWh/m^2[24]. The projection of the future heat demand is based on a bottom-up analysis, which considers the development of new building stock, renovation of existing buildings, as well as demolition of old buildings.

The EE scenario assumes a higher renovation rate than the BAU scenario and tougher standards for renovated buildings and new buildings. Existing standards are already relatively ambitious; therefore the additional reduction of

[24] Delivered heat demand including electricity for heating purposes. This is without conversion factors.

heat demand in the EE case is moderate. The figure below shows the development in the building stock distributed on new, renovated and old spaces in the residential sector[25].

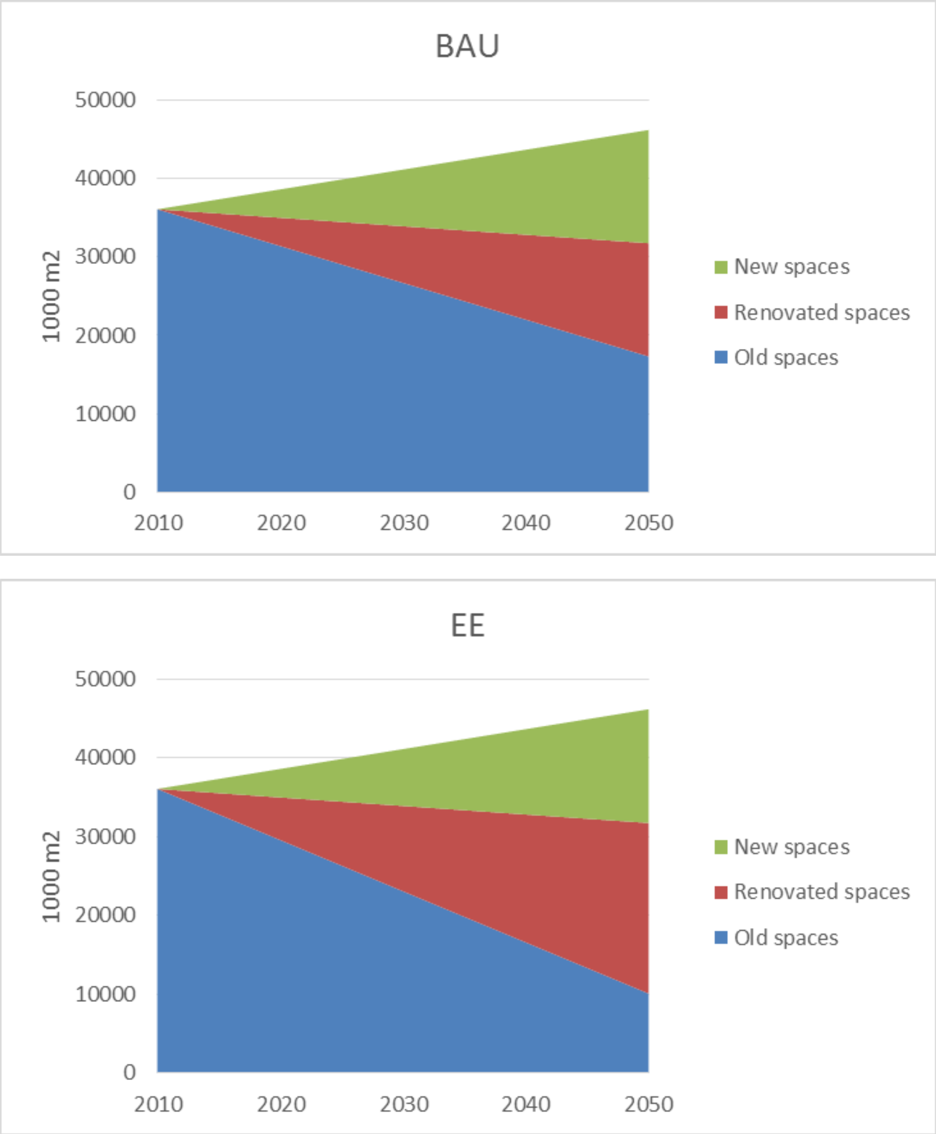


Figure 7: Development in heated m² in the residential sector distributed on new spaces (new buildings), renovated spaces (buildings that have undergone an energy renovation) and old spaces (existing building that have not undergone energy renovation).

As a result of the effort to renovate buildings the energy consumption – and the tough standards for new buildings – the demand for energy decreases in the BAU as well as in the EE scenario. In BAU the energy consumption declines

[25] It is clear from the graph that energy improvements in existing buildings are a challenge. In Denmark a knowledge centre for energy savings in buildings has been established with the main task to provide information about energy efficiency to installers. When an existing building is renovated or improved it is important that the building owner is informed about potential extra investments that can reduce the energy consumption. Installers can download 52 texts about energy savings from the centres home page.

gradually from around 35 PJ today to 23 PJ in 2050 (35% reduction) and in the EE scenario the demand drops to 19 PJ (46% reduction).

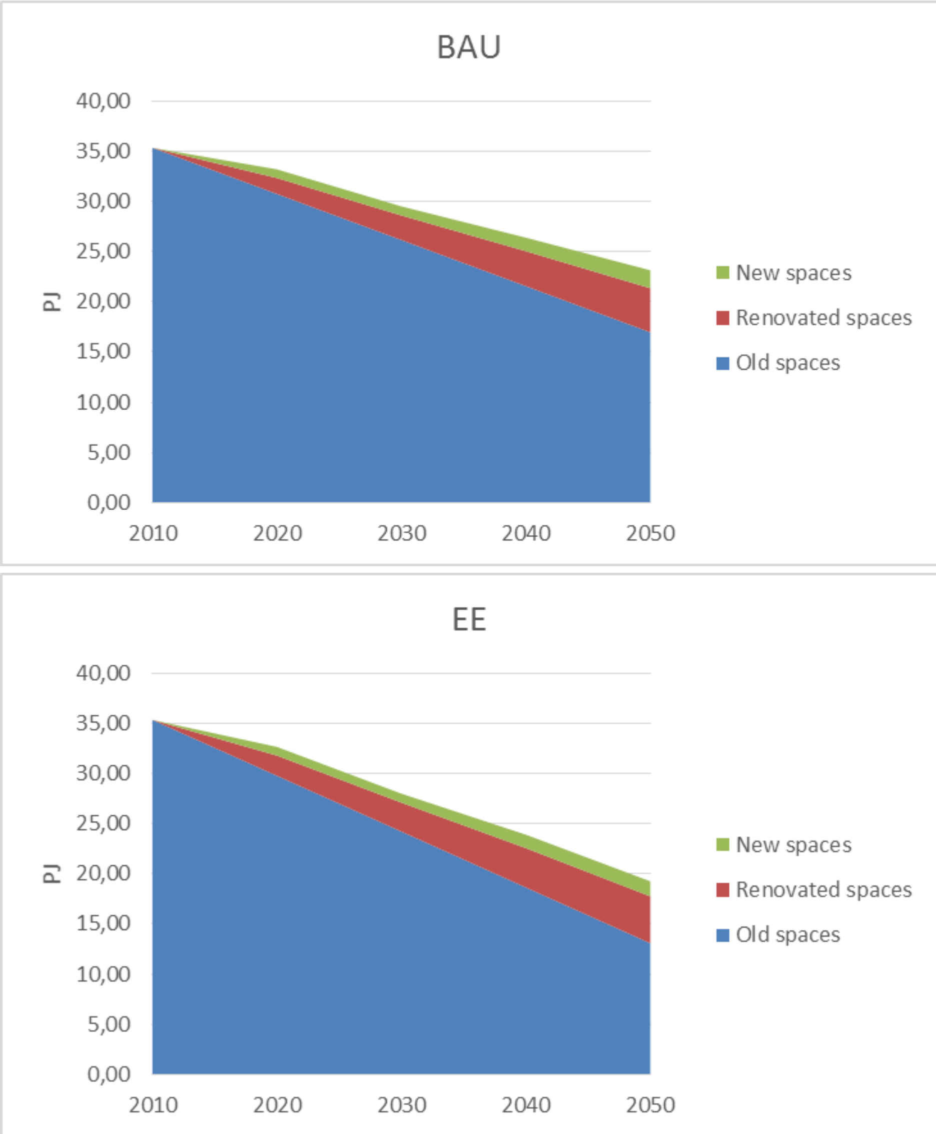


Figure 8: Development in energy delivered in the residential sector distributed on new spaces (new buildings), renovated spaces (buildings that have undergone an energy renovation) and old spaces (existing building that have not undergone energy renovation). . Note that electricity consumption is not included here.

It should be noted that the projection concerns the delivered heat to the buildings (not the heat losses of the buildings) as this methodology is in accordance with the Estonian building regulation. Part of the reduction in energy consumption can be attributed to change of heat supply to technologies with higher efficiencies, e.g. from boilers to heat pumps. The total heat losses in the residential sector are reduced by 27% per cent in BAU in 2050 compared to 2010 and by 37% in EE in 2050.

Energy sources for heating

The energy sources for heating in Estonia are dependent on the building type. Apartments, which constitute about 55% of the total residential building stock, are predominantly supplied by district heating, whereas single-family houses mainly are heated by wood-fired stoves and wood-pellets boilers and only to a smaller extent by natural gas and district heating.

In both the BAU and the EE efficiency scenario we expect the share of wood stoves to decrease in the future as a result of a gradual modernisation of the heating supply (people preferring technologies that require less labour and maintenance). Particularly electricity based heat pumps (various types) will increase their shares in its place. Heat pumps are also envisioned to play a key role in the heat supply of new buildings.

In the EE efficiency scenario we expect an increase in both district heating and heat pumps in the long term, also as means to conserve biomass for other purposes such as transport fuels. The EE scenario also assumes that natural gas for heating is phased out almost completely by 2050.

Cost of generating heat

The cost of supplying heat for a building is dependent on a number of circumstances such as:

- The specific heat demand of the building. Buildings with low energy demand will have relatively higher capital costs.
- The energy density of the area and the access or distance to district heating and natural gas infrastructure. In low energy density areas grid cost are relatively higher.
- The cost of delivering district heating depends on local circumstances: cost of generating heat, O&M costs, and grid losses.
- Access to ground to supply free heat if a ground based heating pump system
- Access to local biomass such as fire-wood

The following graphs compare the cost of supplying heat in block and a single family house today (Base) and in 2050 in the EE case.

The calculations depend on a number of assumptions:

- Heat losses in single family house is 54 GJ (i.e. 130 kWh/m^2 in 115 m2 house)

- Heat losses in apartment block is 1500 GJ (45 apartments*70 m2* 130 kWh/m)
- Technology data is based on the "Technology Data for Individual Heating Plants and Energy Transport" (Danish Energy Agency, 2012) adjusted by input from the expert groups.
- Cost of generating district heating is based on the average marginal heat generation price from Balmorel. We assume an average grid loss of 20 %.
- The calculations consider new heating installations (new district heating installation, new heat pump, new gas boiler etc).
- District heating grid costs is included in the capital cost of the district heating installation based on expected costs of connecting single-family houses (in a relatively energy dense area) and multi-storey buildings
- Natural gas grid cost is reflected in the price of gas. The Transmission tariff for natural gas is 0.0146 EUR/m3 (1.5 EUR/MWh). From 2020 the total transmission tariff is 4 EUR/MWh. Distribution (pressure equal to 16 bar and less) tariff is 0.0327 EUR/m3 (Eesti Gaas' tariff)
- Electricity transmission: 13 EUR/MWh[26]. Electricity distribution (including transmission): 55.6 EUR/MWh[27]. Total grid loss: 7%.
- 5% discount rate (real)

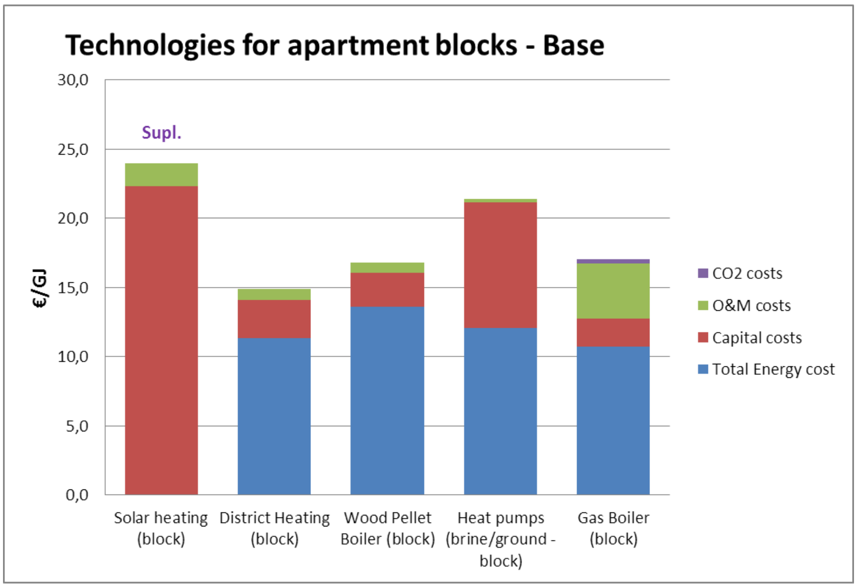
Some of the technologies in the comparison are not able to provide a share of heat service required, for example air-air heat pumps, which do not provide hot water and need to supplemented by electric heating in cold periods, solar heating, which mainly supply heat in the summer season, and wood-stoves which do not provide hot water.

The analyses indicate that today district heating is marginally less expensive than wood pellets and gas boilers for heatings apartments. By 2050 in the EE scenario this benefit is expected to improve as fuel prices increase and natural gas is penalised for its CO_2-emissions.

In single family houses a number of technologies are approximately equally competitive: gas boiler, wood pellet boiler, air-air heat pump, coal boiler, and wood-stove. District heating is slightly more expensive. By 2050 coal and gas are no longer competitive because of the increase in fuel and CO_2-prices. District heating becomes closer to being competitive with wood-pellets boilers

[26] Simple average of peak and non-peak transmission fee for a voltage of 110 kV (low-voltage side of a transformer) Prices obtained from http://elering.ee/price-list/
[27] Main service packages of Elektrilevi.

and wood-stoves. Brine-ground heat pumps remain relatively costly compared to the alternatives.



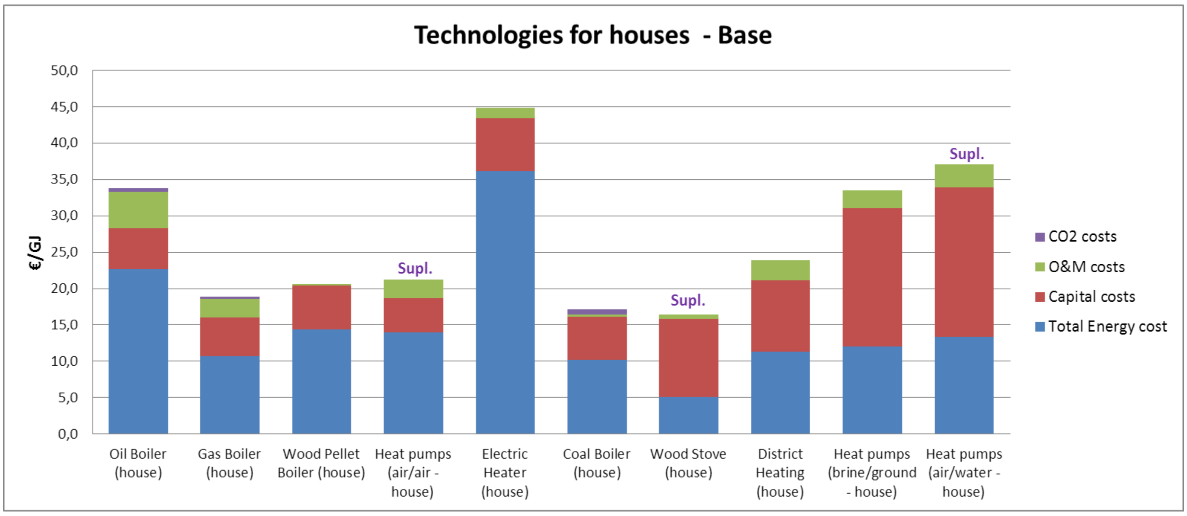
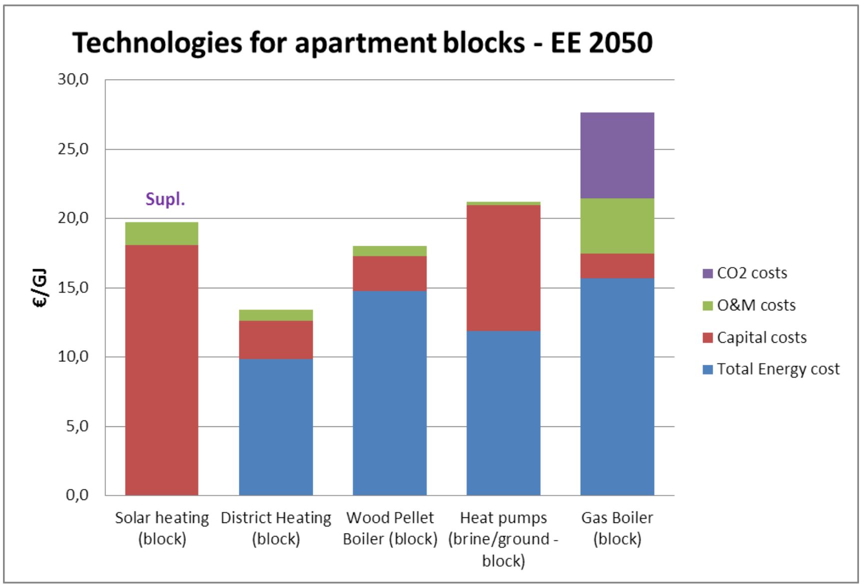


Figure 9: Levelised cost of different heating technologies in 2013. Cost of CO_2: 5 €/ton. The technologies labelled Supl. Is only covering a part of the total heat demand. The capital costs are divided on a smaller amounts of GJ.



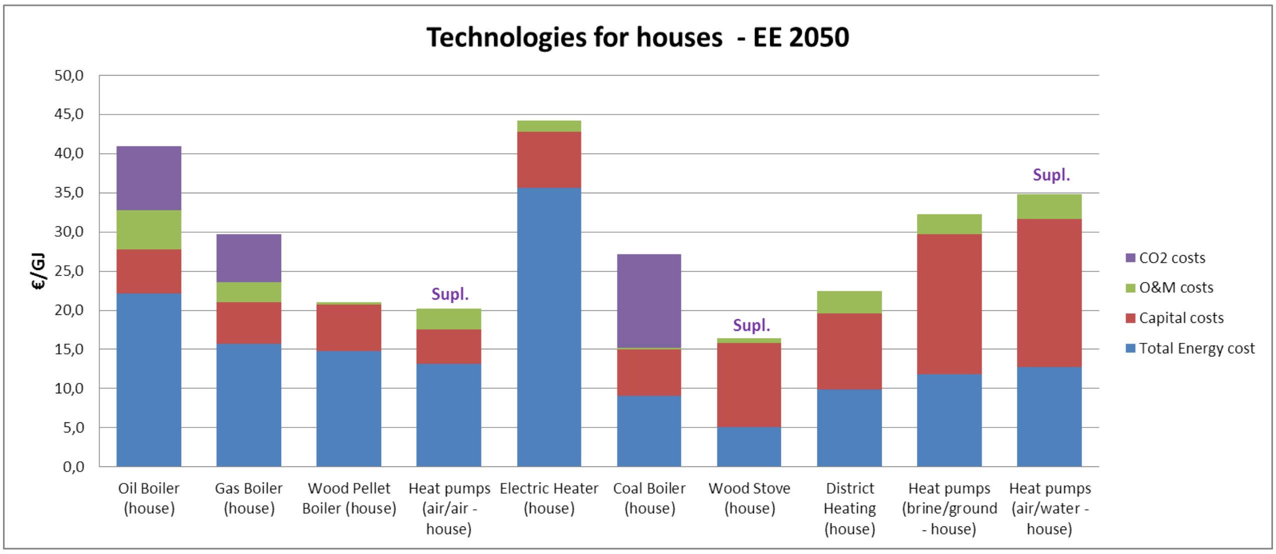


Figure 10: Levelised cost of different heating technologies in 2050 in the Energy Efficiency scenario Cost of CO2: 100 €/ton.

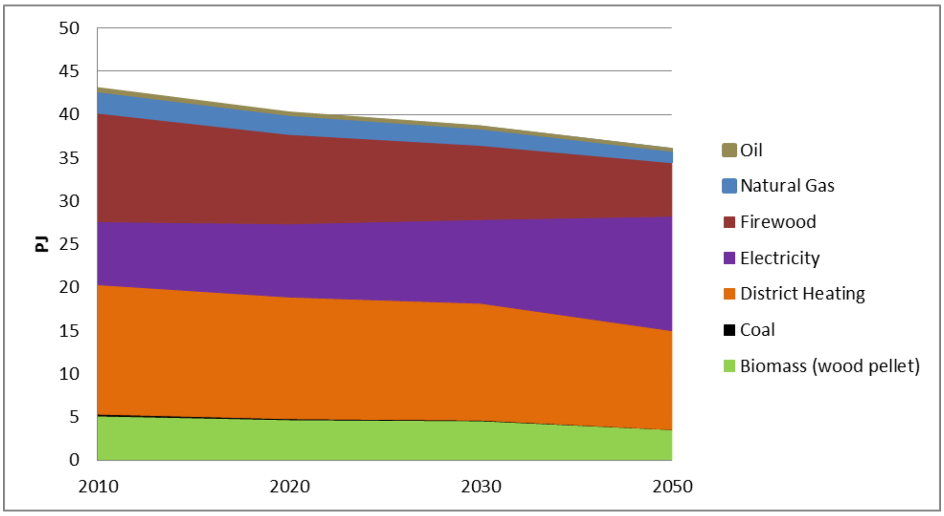


Figure 11: Development in energy consumption in the residential sector, <u>BAU scenario</u>. Note that this also includes electricity consumption.

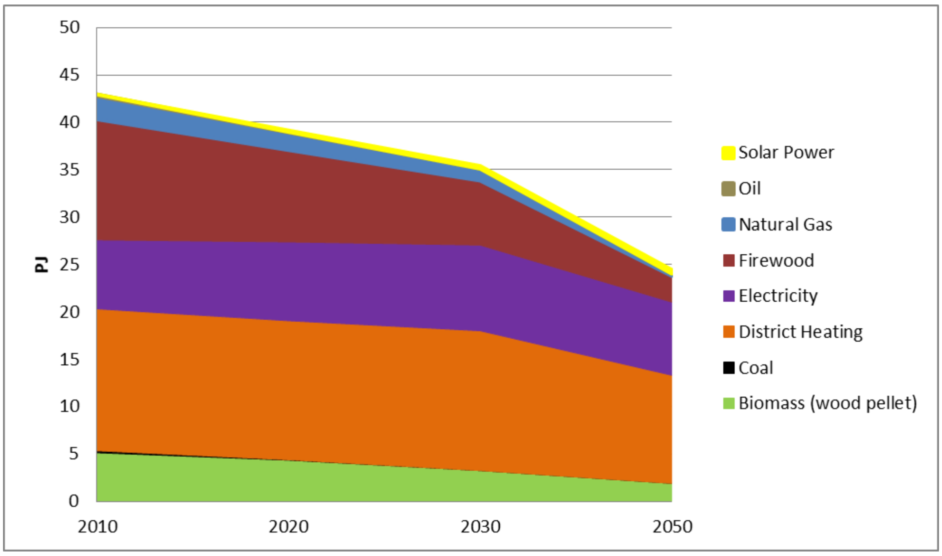


Figure 12: Development in energy consumption in the residential sector, <u>EE scenario</u>. Note that this also includes electricity consumption.

Tertiary sector

In the tertiary sector (trade and service) the heat is supplied mainly by district heating and natural gas. In the BAU scenario we foresee a decrease in both natural gas and district heating consumption as a result of energy savings being implemented. Moreover, electric heat pumps and district heating increases its share of heating compared to natural gas by the end of the period.

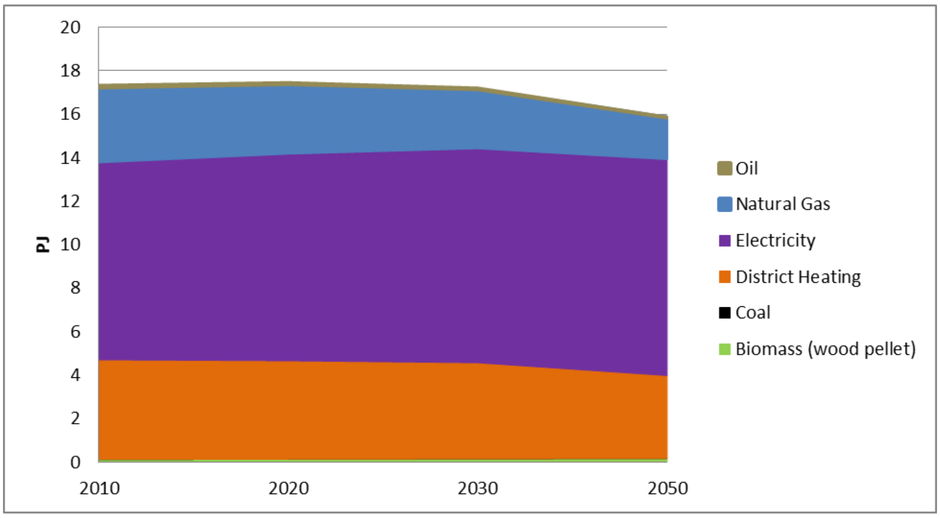


Figure 13: Development in energy consumption in the tertiary sector, BAU scenario.

In the EE scenario energy savings are more profound and the share of buildings heated by natural gas reaches close to zero by 2050. The electricity demand for non-heating purposes declines slightly whereas it increases in BAU.

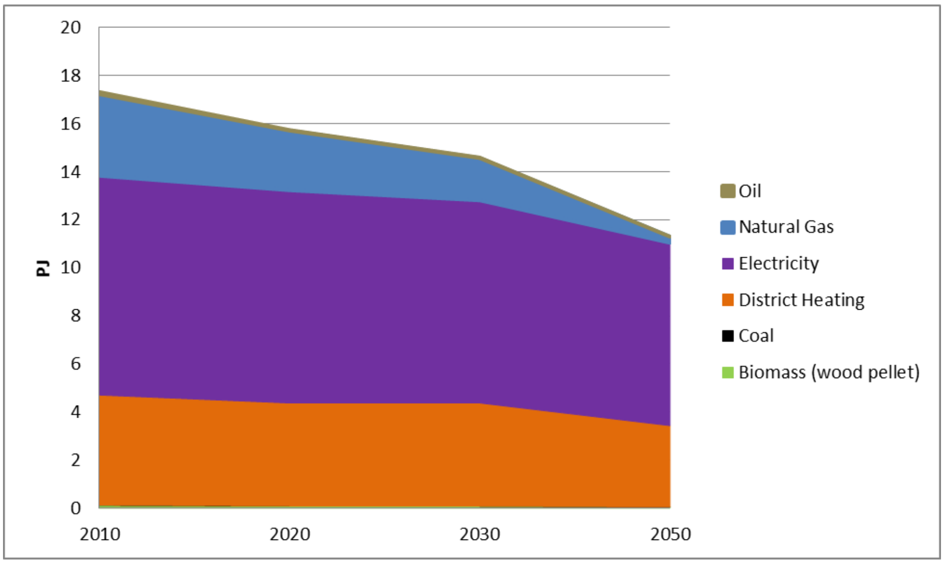


Figure 14: Development in energy consumption in the tertiary sector, EE scenario.

Industry

Forecasting how energy demand in the industrial sector will develop is associated with a higher level of uncertainty than any of the other sectors because it is very much dependent on, which type of industries will exist in Estonia.

The projection is based on the following assumptions:

- Increasing electrification – in agreement with developments in other countries.
- More energy savings (and/or low energy intensive industry) in EE scenario.
- Slight decrease in gas and oil consumption in the BAU scenario and continuous use of coal and oil shale.
- Coal is phased out in the EE scenario and natural gas and oil consumption significantly reduced.

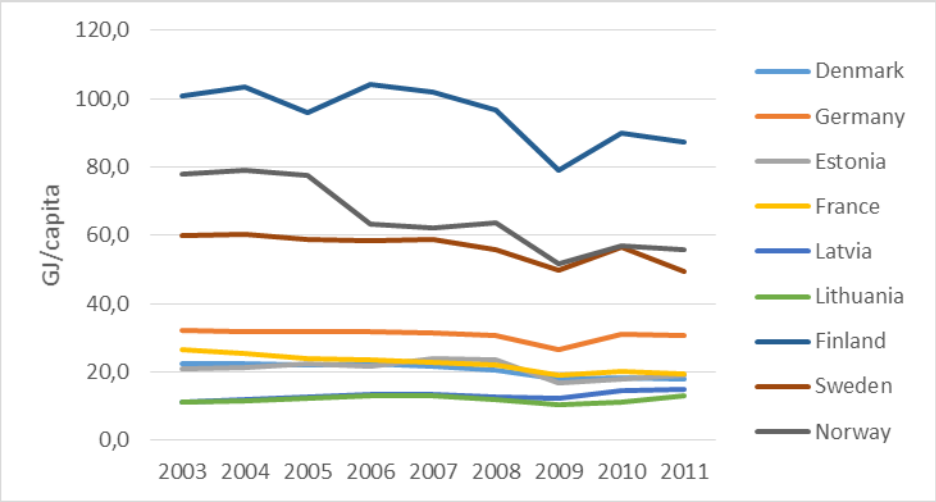


Figure 15: Energy consumption in the industrial sector per capita.

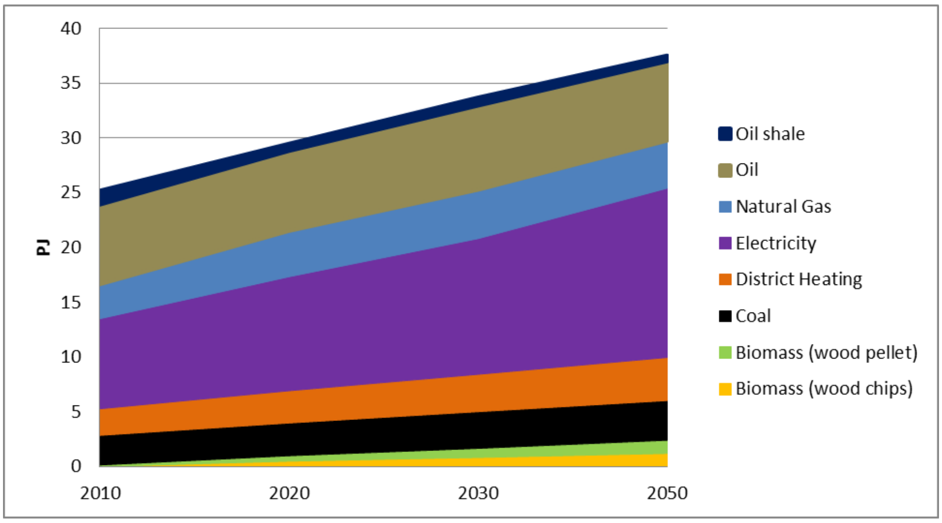


Figure 16: Development in energy consumption in the industrial sector, BAU scenario.

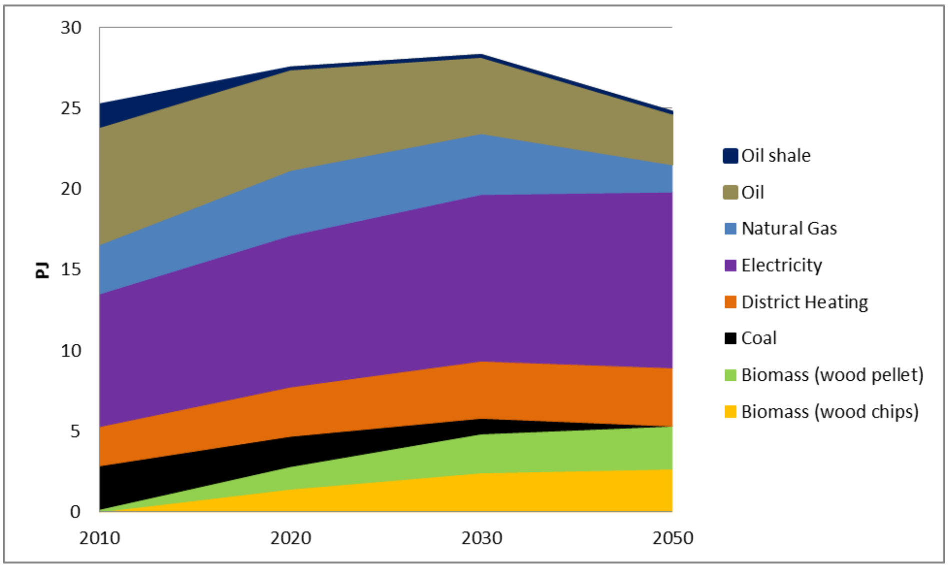


Figure 17: Development in energy consumption in the industrial sector, EE scenario. Transport sector

A number of factors affect the demand for energy in the transport sector, in particular:

- The demand for transport services expressed as personkilometers (pkm) for passenger transport and tonkilometer for freight transport.
- Means of transportation: car or bus, train or truck etc.
- Drivetrain technology: gasoline car or electric car, diesel train or electric train etc. including the efficiency of the respective technologies.

Today, the demand for passenger transport is approx. 10,000 pkm per capita in Estonia compared to just above 20,000 pkm in the USA, 14,000 pkm in Finland and just above 11,000 pkm in Denmark. In the BAU projection Estonia reach almost 16,000 pkm per capita in 2050 – reaching towards USA levels – whereas in the EE scenario transport demand stabilises at approximately slightly higher than in Denmark at 12,000 pkm per capita. Achieving the same level as in Denmark would require proactive physical planning and transport demand management strategies.

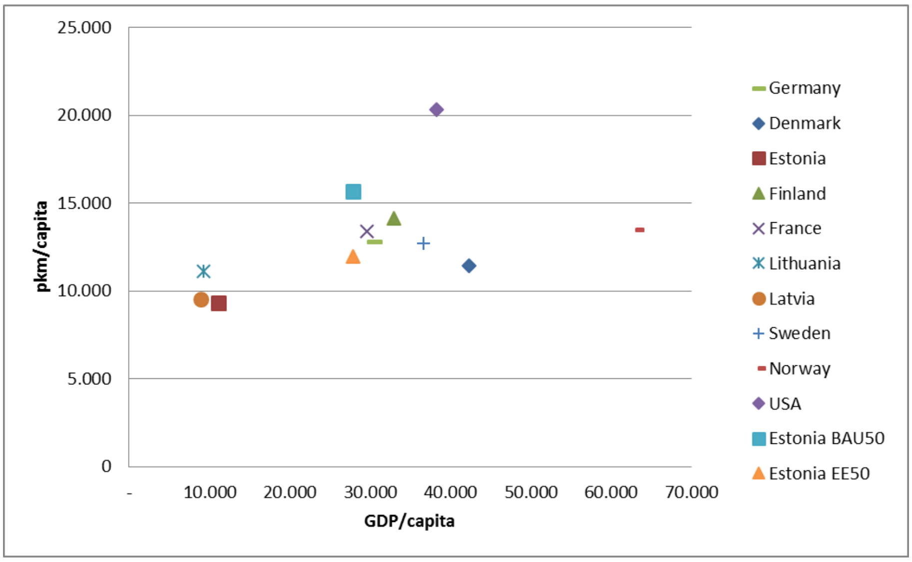


Figure 18: Passenger transport per capita (pkm/capita) in Estonia and selected other countries. The projected pkm/capita in BAU2050 and EE2050 are also shown in the graph.

In terms of freight transport, Estonia's demand is already quite high in 2010 compared to many European countries, but still well below USA levels. In the BAU development Estonia comes closer to USA levels whereas in the EE development the demand only increases slightly.

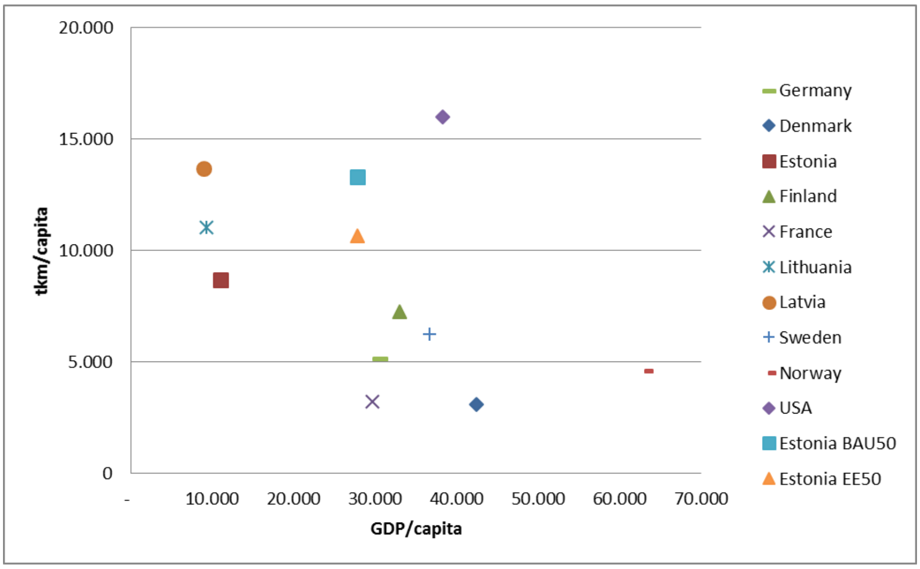


Figure 19: Freight transport per capita (tkm/capita) in Estonia and selected other countries. The projected tkm/capita in BAU2050 and EE2050 are also shown in the graph.

The BAU scenario development is based on the assumption that cars and trucks will increase their share of passenger transport and freight transport respectively. In the EE scenario on the other hand, train, tram and cycling increase their shares. Achieving this development would require strong national policies favouring public transportation and cycling through dedicated investments in and urban planning and possibly penalising private cars.

Over the next 5-10 years new transport technologies such as electric vehicles and natural gas vehicles are not expected to play a significantly role in any of the scenarios, but in the EE scenario policies are expected to be put in place that favour conventional cars with high energy efficiency. In the longer term – particularly beyond 2030 – electric vehicles (and other alternative technologies) are expected to play a key role in the private car segment. Within public transport, electric vehicles and particularly natural gas (or biogas) propelled cars could provide a noticeable contribution already around 2020-2025.

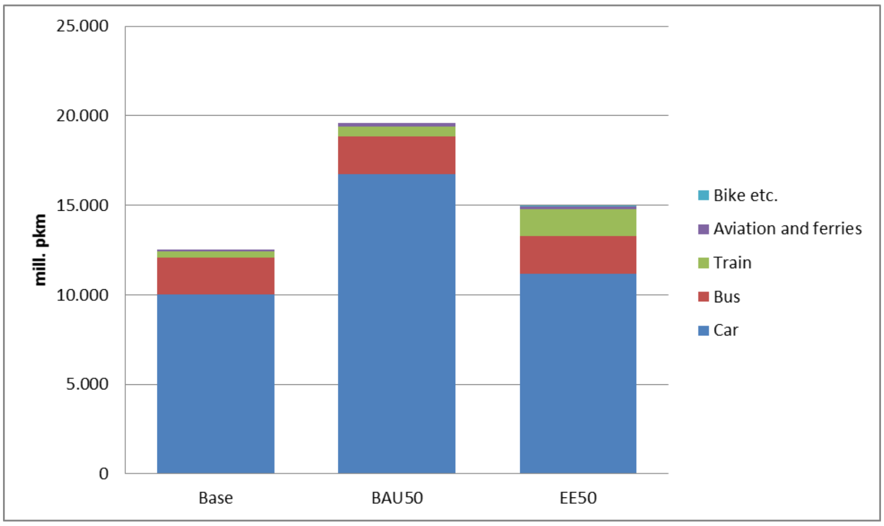


Figure 20: Distribution of passenger transport work today (base) and in the BAU 2050 and EE 2050 scenarios.

In the BAU scenario the demand for energy for transport purposes increases until 2030 and thereafter decreases slightly again. The decrease is particularly attributed to an assumption that conventional cars would become increasingly more energy efficient as a consequence of international regulation (EU requirements). Gasoline and diesel are the dominant fuels throughout the period.

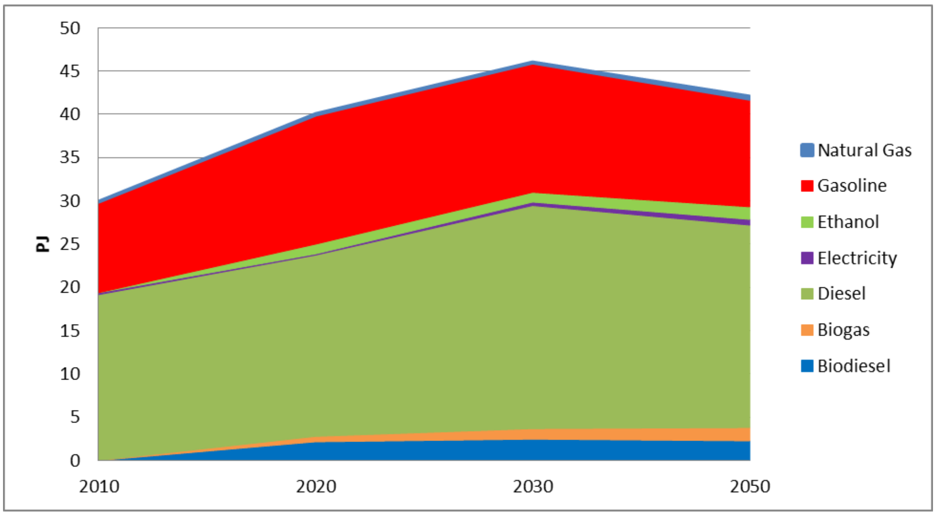


Figure 21: Development in energy consumption in the transport sector, BAU scenario.

In the EE scenario the demand for energy in the transport sector peaks already in 2020 and thereafter decreases rather significantly. The shift to electric vehicles in the longer term explains a large part of the decrease in energy demand as electric vehicles are around three times more energy efficient than cars with a combustion engine.

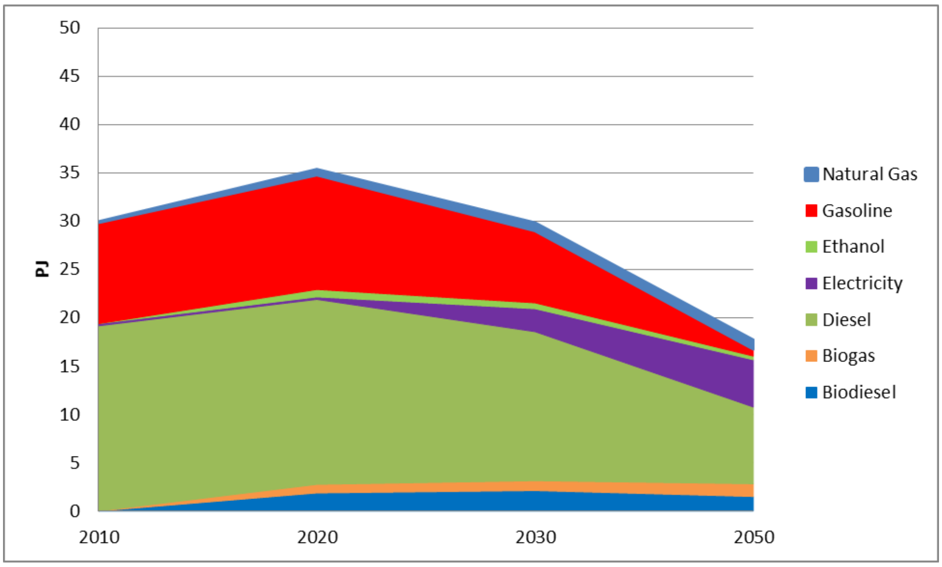


Figure 22: Development in energy consumption in the transport sector, EE scenario.

Electricity demand

Overall electricity demand increases in the BAU scenario from around 25 PJ to approx. 40 PJ by 2050. The increase is particularly strong within industrial sector and the residential sector.

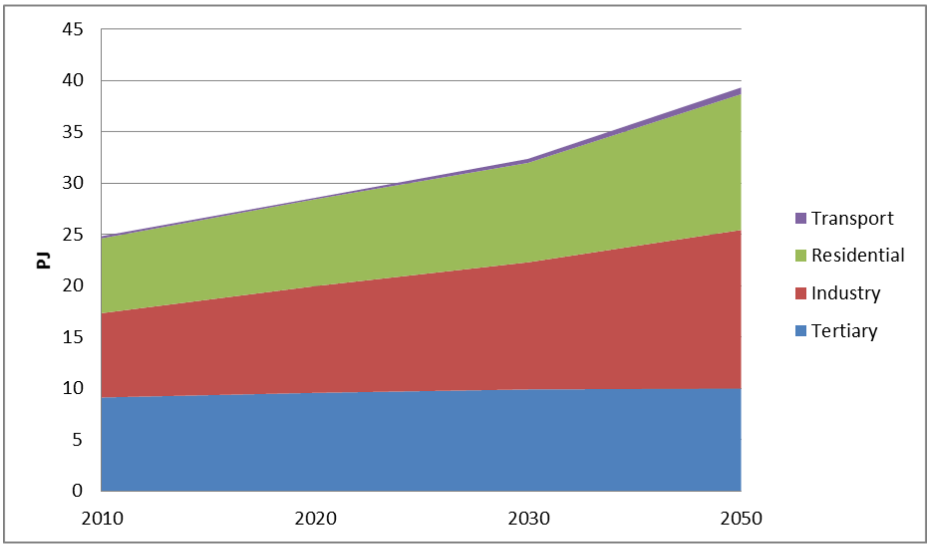


Figure 23: Development in electricity demand by sector, BAU scenario.

In the EE scenario the electricity demand within the sectors that traditionally consume electricity (residential, tertiary and industry) remains more or less stable, but the surging demand in the transport causes overall demand to increase to approx. 31 PJ.

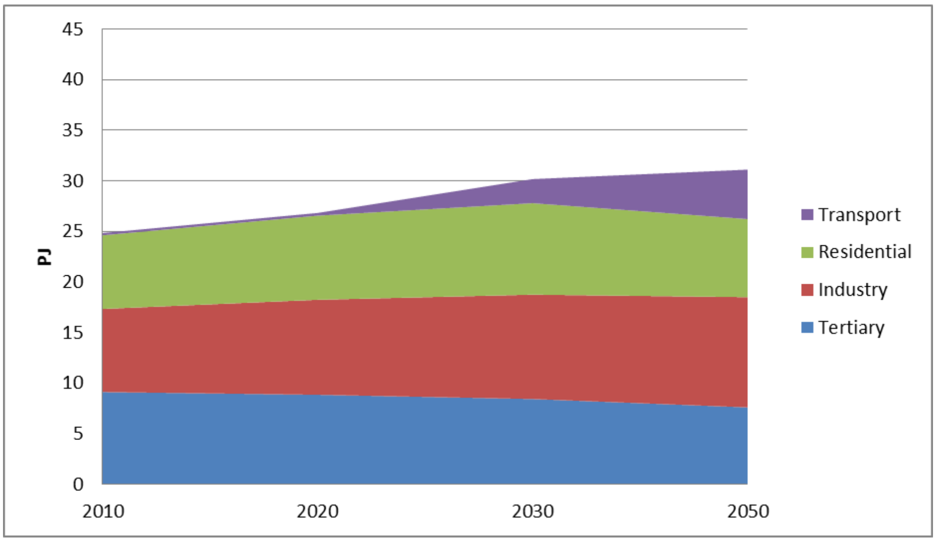


Figure 24: Development in electricity demand by sector, EE scenario.

The demand for district heating decreases in both the BAU and the EE scenario, but the decrease is slightly higher in the EE scenario due to more heat savings (despite of a higher share of district heating). In the short term towards 2030 the district heating demand is higher in the EE scenario due to increased share of district heating.

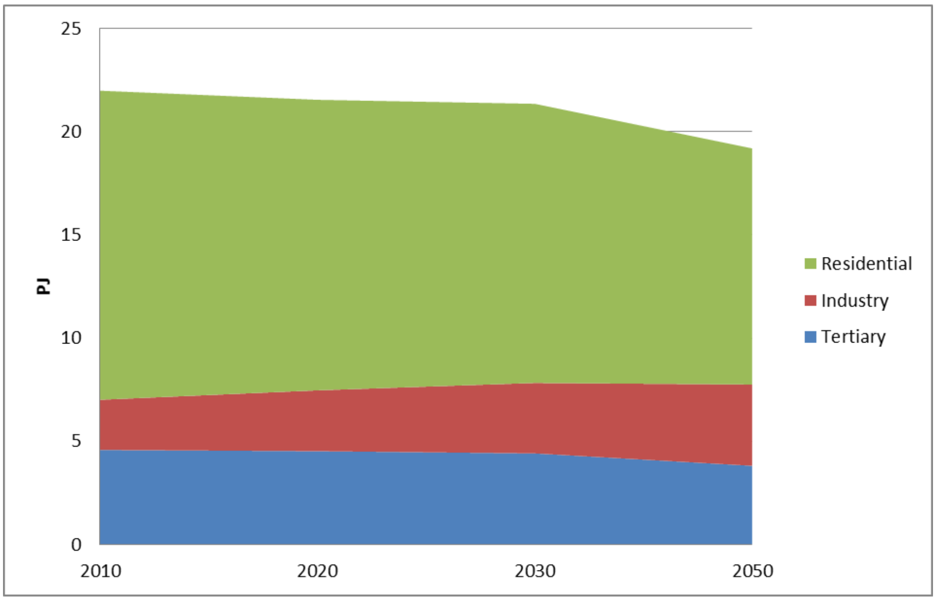


Figure 25: Development in district heating consumption by sector, BAU scenario.

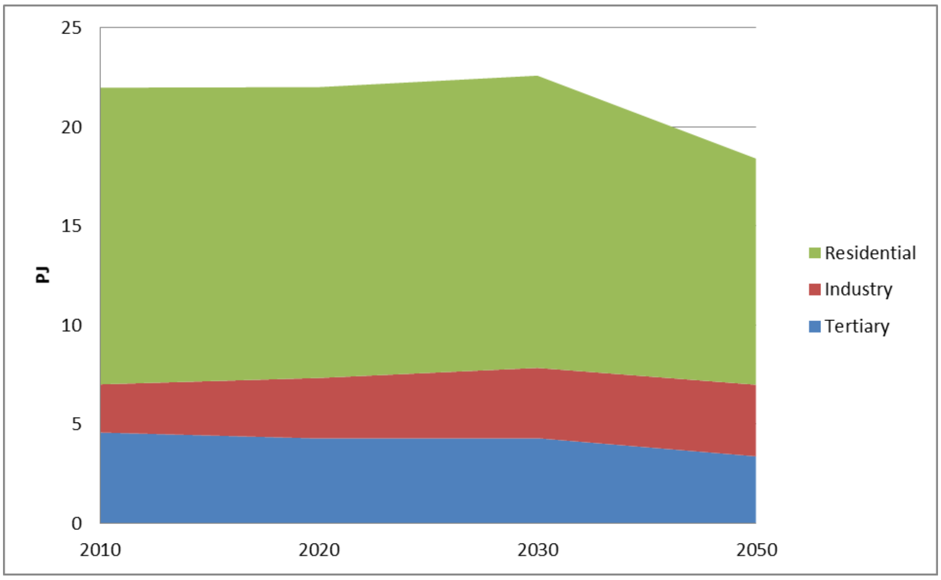


Figure 26: Development in district heating consumption by sector, EE scenario.

5 Designing energy scenarios

The future is uncertain and difficult to predict. In this project, scenarios are used to show the range of possible futures (international aspects) and also to illustrate the potential for shaping the future (the local decisions). The applied method can be called *input driven scenarios*.

In dialogue with the steering group and expert groups a number of topics have been identified that are of importance to the formulation of an Estonian long-term vision and strategy for the energy sector development. These are:

- The weight given to combat climate change,
- A rule to secure local electricity generation capacity in Estonia,
- National policy on the share of renewable energy in Estonia,
- The continued use of shale oil for electricity generation and
- The threat of carbon leakage to Russia.

Eight scenarios have been set up to analyse these topics. None of these individual scenarios is meant to predict the future. The scenarios are only intended to show the consequences of different potential developments. The energy demand is assumed to develop in the same manner for all supply scenarios except the renewable energy focus scenario and the CO_2 concern scenario, where higher energy efficiency improvements are assumed (see chapter 4).

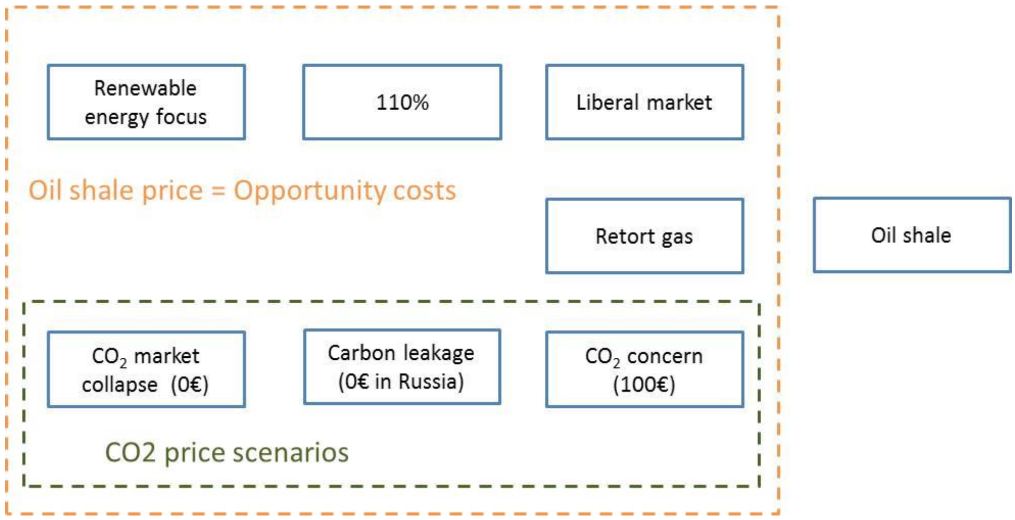


Figure 27: The eight modelled single track scenarios.

All EU countries have goals for renewable energy in 2020. For all other countries except Estonia the technology specific 2020 goals are taken from the national renewable energy actions plans (NREAP) as reported to the EU. For Estonia the model is free to decide how to fulfil the requirement of 25% renewable energy in 2020 in the most cost efficient way. This 2020 assumption is applied in all scenarios and is also set as a minimum RE requirement for the period beyond 2020 in the whole region.

Security of supply (110%)

In the 110% scenario the electricity generation capacity in Estonia is required must be 110% of the maximum hourly peak electricity demand in any given year. Intermittent generation, such as wind and solar, are not counted towards the 110 requirements Also, reserves and transmission lines are not counted. No similar requirements are made for the other countries in the model area.

Liberal market

The liberal market scenario is similar to the 110% scenario except that the 110% requirement for Estonia is not activated.

National RE focus

The renewable energy scenario is equal to the liberal market scenario, except national targets are set for the generation of heat and electricity based on renewable energy in Estonia in 2030 (50% RE of electricity and district heating demand) and 2050 (100% RE of electricity and district heating demand). In this scenario a lower energy demand is assumed resulting from energy efficiency improvements as described in chapter 4.

No new investments in fossil fuelled technologies are allowed in Estonia in this scenario, except existing oil shale power plants can be rebuilt to use coal.

Oil shale

The oil shale scenario is similar to the liberal market scenario, except that 7 Mt of oil shale (approx. 41 PJ fuel) is available at mining costs. This scenario can be understood as the case where the capacity of producing shale oil is limited to the currently decided refining capacity, which means the substitution price is not relevant.

Retort gas

In the retort gas scenario shale oil is produced instead of diesel on the refineries. In this process retort gas is a by-product and this gas can be utilised for e.g. electricity generation.

It is assumed that three units producing shale oil are commissioned by 2020 and in the period from 2020 to 2030 one unit comes online every second year giving a total of eight units by 2030. The entire oil shale resource of 20 Mt/year is utilised by these refineries in 2030 and each unit will be equipped with a gas motor utilising the retort gas with an electricity capacity of 90 MW. In 2030 the total electricity capacity of these eight units combined will be 720 MW. These units are assumed to run continually and the retort gas resource is assumed to have a cost of zero. In addition the assumptions from the liberal market scenario are used in this scenario.

CO_2 price scenarios

Two scenarios are used to describe variation in the CO_2 price. In the CO_2 market collapse scenario the CO_2 price is set to zero, while in the CO_2 concern scenario the CO_2 price is set to a value corresponding to the IEA's 450 scenario, reaching 34, 73 and 92 €/ton CO_2 in 2020, 2030 and 2035, respectively. The price in 2050 is set to 100 €/ton CO_2. Furthermore, in the CO_2 concern scenario a lower energy demand is assumed resulting from energy efficiency improvements.

Carbon leakage

In all scenarios except the carbon leakage scenario it is assumed that measures are in place, so that no CO_2 leakage takes place in relation to cross border electricity trade with Russia. This is modelled by assuming the same CO_2 price in Russia as in the EU. In the carbon leakage scenario a zero CO_2 price is used for Russia[28].

It should be noted that the current CO_2 price (7th June 2013) is 4 €/ton. This is much closer to the CO_2 price collapse scenario than to IEA's New Policy scenario (used in six of the eight scenarios).

An overview of the central parameters for each scenario can be found in the table below.

[28] See European Commission (2010) for a discussion of carbon leakage, including an analysis of carbon leakage and the security of supply in the Baltic States. Potential border measures are discussed, e.g. requiring that import from a country outside EU ETS should supply CO_2 quotas corresponding to the emission. See also Kisel (2011).

Name of scenario	Estonian energy demand	Estonian capacity constraint	Estonian RE generation 2030 / 2050	CO_2 price EUR/ton 2020 / 2030 /2050	Oil shale price after 2020
110%	BAU	110%	-	23 / 30 / 47	Substitution
Liberal market	BAU	-	-	23/ 30 / 47	Substitution
Oil shale	BAU	-	-	23/ 30 / 47	Mining costs for max 7Mt
Retort gas	BAU	-	-	23/ 30 / 47	Substitution. Retort gas is used for electricity generation
National renewable energy focus	EE	-	50% / 100% **	23/ 30 / 47	Substitution
CO_2 market collapse	BAU	110%	-	0 / 0 / 0	Substitution
Carbon leakage	BAU	110%	-	23 (0*) / 30(0*) / 47(0*)	Substitution
CO_2 concern	EE	110%	-	34 / 73 / 100	Substitution

Table 5: Central parameters for the scenarios. The two scenarios with reduced energy demand will be computed in two steps: with and without the reduced energy demand. In this way the impact of each step can be found.
** Zero in Russia. ** Of electricity and heat demand.*

Many parameters are held constant

In all scenarios the energy prices are expected to develop as predicted in the IEA's New Policy scenario (IEA, 2012). This is a simplification, which makes it easier to compare results across scenarios. In practise several mechanisms of feedback may exist, e.g. if the focus on reducing climate change is global, lower fossil fuel prices can be expected because of the massive interest in reducing CO_2 emissions leading to decreased demand for fossil fuels.

Also, technology costs are kept constant in all scenarios. In practise it is easy to understand that e.g. the cost of wind power and CCS would be influenced by the demand for these technologies. Such feedback is ignored in the scenarios.

Other important issues

In selecting the eight scenarios some discussions have been prioritised, while other important issues have not been included. The use of an electricity market design in Russia with a component of a capacity market can be very important for the flow of electricity between Russia and Estonia. On the Russian/Finnish border electricity flow to Finland has been reduced during peak hours after the introduction of the Russian capacity market. However, it has been decided not focus on the influence of capacity markets in this study.

It is difficult to predict the future design of both European and Russian electricity markets. In the simulations an electricity market similar to the current Nord Pool market is assumed in all years. This is a market where the price in each area is defined as the marginal cost of supplying electricity (called energy-only-market with marginal pricing)[29]. Investments in new capacity are expected to take place when the prices are sufficient to cover both operating and capital costs. This set-up is assumed to be relevant, also in 2030 and 2050.

Input data

A huge amount of input data is used in computing the scenarios. This includes fuel prices and CO_2 prices, as well as technology data for generation technologies and transmission lines. The input data are documented in a separate data report. Fuel and CO_2 prices are generally based on the New Policy scenario in the 2012 World Energy Outlook (IEA, 2012). Technology data (generation) are mainly based on data from a publication by the Danish Energy Agency (Danish Energy Agency and Energinet.dk, 2012) supplemented with Estonian cost assumption on a few technologies. Cost of transmission lines are based on (Ea Energy Analyses, 2012).

Understanding model results

The BALMOREL model represents a simplification of reality. Output is consistent and in most cases easy to understand. A major advantage is that all scenarios are computed with optimal results – so any difference can be attributed to model input, e.g. a price change or a rule included in one calculation.

However, it is important to understand some impacts of the simplifications:

- Results may be too smooth because the model finds optimal solutions. Market power, random variations, different future expectations and strategies may give more complex results.
- Tipping point: When one technology becomes more attractive than competing technologies, the model tend to shift 100% to the winning technology, e.g. when investing in new generation. In real life more friction may exist, due to companies' different strategies, different competences or other differences not included in the model.

[29] Other market models exist and are discussed in Europe, e.g. markets with a capacity market to attract new capacity (discussed in UK and France). Also more advanced models exist where the physical nature of the grid is taken into account in more details, as in nodal pricing models (discussed in Poland).

6 Electricity and district heating

The electricity system can be seen as a gigantic interconnected machine. The system must be in balance at all times and electricity markets are developing so this balance is achieved across national borders. District heating with combined heat and power (CHP) units are part of this big system. When one generator is increasing the output, another must reduce. E.g. an increase in power generation in Estonia may result in a reduction in Germany.

BALMOREL

BALMOREL is an open source model for analysing the electricity and combined heat and power system in an international perspective. It is highly versatile and may be applied for long-term planning as well as shorter term operational analysis. The model has, for example, been used in relation to the analyses of the Harku-Sindi-Riga 300 kV line and a project on wind power in Estonia[30].

The BALMOREL model has been used for analyses of for instance security of electricity supply, the role of demand response, hydrogen technologies, wind power development, the role of natural gas, development of international electricity markets, market power, heat transmission and pricing, expansion of electricity transmission, international markets for green certificates and emission trading, electric vehicles in the energy system, and environmental policy evaluation.

BALMOREL is a least cost dispatch power system model. It is a "fundamental model" based on a detailed technical representation of the existing power system; power and heat generation units as well as the most important bottlenecks in the overall transmission grid. The main result is a least cost optimisation of the production pattern of all power units. The model, which was originally developed with a focus on the countries in the Baltic region, is particularly strong in modelling the combined heat and power system. Only district heating systems are considered. For individual heating, see next chapter.

For this project the model area covers the Baltic States, the Nordic countries, Germany, Poland and North-West Russia. Each of these consists of one to four electricity price areas so that in total 23 prices areas are included. All demand and generation are allocated to a specific price area. Belarus is included, but only as a transit country. No demand or generation in Belarus are included in the model. The price areas and the initial connections between them are

[30] Economic and technical research of the Harku-Sindi-Riga 330 kV line (2009) and Wind power in Estonia (2010)

shown in Figure 28. In this initial set-up the Baltic States are only indirectly connected to Poland and Germany. However, planned transmissions lines between Sweden, Lithuania and Poland will change this in the short term.

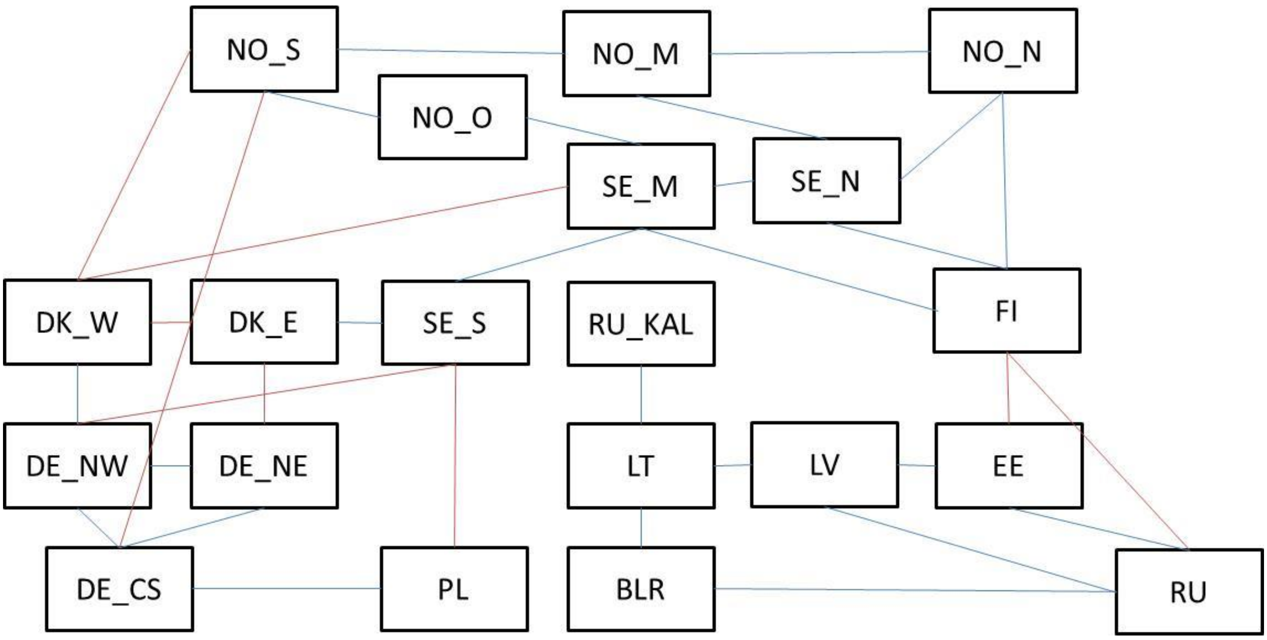


Figure 28: Price areas in BALMOREL. The lines indicate the transmission lines in 2012. Red lines are DC connections.

Investments

In addition to simulating the dispatch of generation units, the model allows investments to be made in different new generation units (coal, gas, wind, PV, biomass, oil shale, nuclear, CCS) as well as in new interconnectors. However, certain constraints are placed on coal, nuclear and CCS investments as well as grid capacity investments.

It is our experience that constraints on grid connections are necessary to obtain realistic investment suggestions from the model. Therefore, for example, a limit is imposed on the potential to expand grid connections within each five year period. This limit is 1,000 MW on sea cables and 3,000 MW for grid reinforcement on land – except in Germany where the limit is 6,000 MW. These limitations are introduced to ensure a gradual development of the grid in the region. The model only considers transmission capacity between the above electricity price areas.

The BALMOREL model is myopic in its investment approach, in the sense that it does not explicitly consider revenues beyond the year of installation. This means that investments are undertaken in a given year if the annual revenue requirement (ARR) in that year is satisfied by the market. Since lead times for obtaining e.g. planning permission and environmental approval may be up to 5-10 years the model essentially operates with a foresight of that length.

A balanced risk and reward characteristic of the market is assumed, which means that the same ARR is applied to all technologies, specifically 0.12, which is equivalent to 10% internal rate for 20 years. This rate should reflect an investor's perspective.

In practice, this rate is contingent to the risks and rewards of the market, which may be different from technology to technology. For instance, unless there is a possibility to hedge the risk without too high risk premium, capital intensive investments such as wind or nuclear power investments may be more risk prone. Hedging could be achieved via feed-in tariffs, power purchase agreements or a competitive market for forwards/futures on electricity, etc.

Net present value

To sum up the results for the entire simulation period the net present value is presented. A 5% interest rate is used for this purpose. The interest rate is assumed to reflect the societal perspective. For the society there are fewer risks than for the private investor. This calls for a lower interest rate.

Time resolution

The base year is 2012[31]. In the period 2020-2030 the analyses are carried out with two year intervals and in the period 2030-2050 in five year intervals (see Figure 29).

[31] Model results for 2012 ares computed by the Balmorel model and should therefore not be considered as realised historic generation.

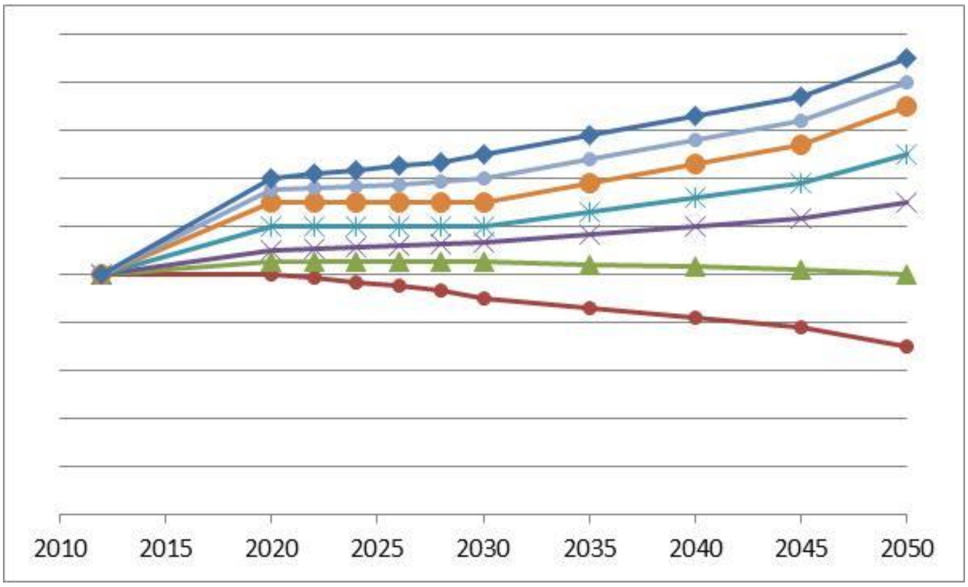


Figure 29: Symbolic presentation of the year used for BALMOREL modelling. 2012 is the historical year and this is the same for all scenarios. Next calculation is for 2020 and here the model is allowed to invest in generation capacity. From 2026 the model can also invest in transmission capacity.

The model will be operated at 12x6 time steps per year. This gives 72 steps per year, which is much less than the 8,760 (hourly) steps that are used for operational analyses. However, 72 steps per year are appropriate for a long-term scenario study. The time aggregation of the model ensures that critical hours, e.g. peak demand or hours with high or low wind power generation, are considered by the model.

Economic analysis

BALMOREL is also capable of reflecting political framework conditions such as taxes, quotas and subsidies, and to assess the economic consequences for different stakeholder groups such consumers, producers, grid owners, countries or the region as a whole. In this study taxes and subsidies are not analysed. The result of the CO_2 quota system is described as input in form of CO_2 costs.

Economic consequences are described for consumers, generators and TSO for each country.

Because the focus is the long term, existing tariffs are not included. It is assumed that future tariffs will ideally reflect the marginal cost of supplying electricity and district heating. Today the Estonian regulation requires that no fixed tariff is paid by consumers of district heating and that the tariff should be the same for all end-users. This is far from cost-reflective for the operation of district heating.

Levelised cost of electricity

The model computes optimal invest in new generation based on a least cost approach. This optimisation is carried out based on the framework conditions the model has been given. The figures below show the levelised costs of energy applying the framework assumptions used in the model for 2020 (CO_2-price of 22 euros/ton). It can be seen that biomass is attractive, especially in CHP plants. After 2020, when the CO2 price increases wind power will be the most attractive technology for electricity generation. It should also be noted that the balance of cost between coal and natural gas based generation is very close. Relatively small changes in the price difference between these two fuels can therefore make natural gas more attractive than coal.

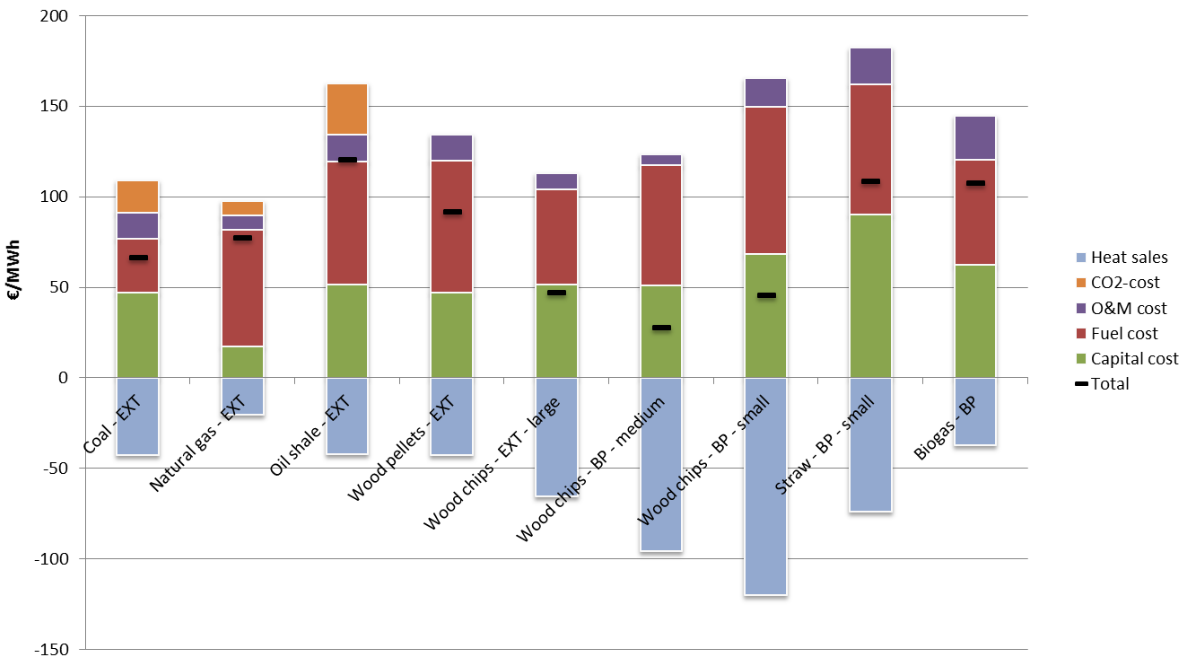


Figure 30: Levelised cost of energy for CHP plants in 2020 with a CO_2 price of 22 EUR/ton. 6000 full load hours assumed.

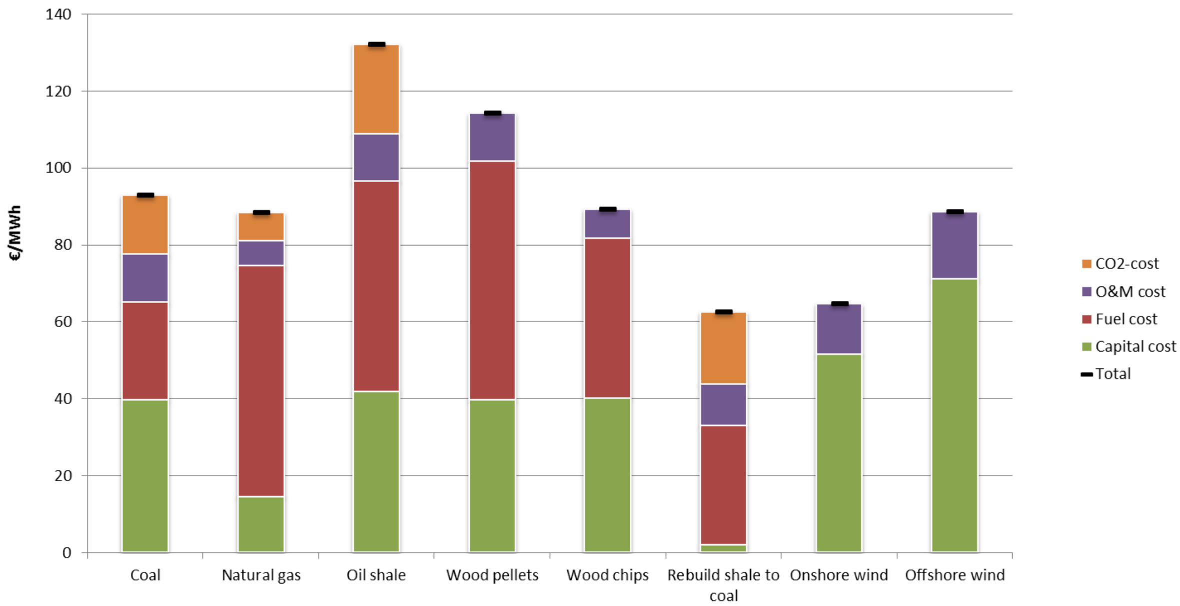


Figure 31: Levelised cost of energy for condensing plants and wind turbines in 2020 with a CO_2 price of 22 EUR/ton. 6000 full load hours assumed.

Results – model area

Each scenario creates a large amount of results. The detailed results, including generation, emission, prices and investments, are presented in a separate appendix to this report t. In this section only a few central observations are presented.

Figure 32 illustrates the fuel-mix in electricity generation in 2030 in the liberal scenario. The graph also illustrates the main drivers for the electricity market: The different resources and generation technologies in the different countries, e.g. hydro in Norway, wind in Denmark, and coal in Poland etc. Without such difference there would be less need for transmission lines.

The volume of coal is decreasing and wind power is increasing as the CO_2 price is increasing in the three scenarios with zero, medium and high CO_2 price (see Figure 33). In the CO_2 concern scenario natural gas acts as an important bridging technology from coal to renewable and CCS.

RE beyond 2020 goals

The EU goals for 2020 motivate expansion of renewable energy throughout the model area. The development of PV is practically the same in all scenarios: 25,706 MW PV are expected in 2020. This investment is motivated by EU 2020 goals. The 2020 requirements are assumed to exist for the entire period 2020-2050, and this motivates the re-investment in PV at the end of the life time of the first round of investment. No commercial investments in PV take place after 2020.

The expansion of wind power is dependent on the CO_2 price (see Table 6). In the period 2022- 2030 the investments in wind power is increased with a factor 14, when comparing the CO_2 collapse and the CO_2 concern scenarios. In the CO_2 concern scenario the investments in wind take a step up in 2026 – the year where the model is allowed to invest in new transmission lines.

MW	2020	2022-2030
CO_2 collapse	24,100	2,600
Liberal	27,700	16,500
CO_2 concern	37,800	36,400

Table 6: MW investment in wind power in three scenarios with low, medium and high CO_2 price.

Except for Estonia the 2020 goals are implemented as indicated in the NREAP reports to the EU on a technology specific level. For Estonia the model does not invest with the purpose to fulfil the 25% EU renewable energy requirement. The goal is achieved by planned wind power (before 2020) and by biomass.

In Lithuania 60% of the annual electricity generation in 2030 comes from wind power (see Figure 32).

Also the amount of biomass used is sensitive to the CO_2 price.

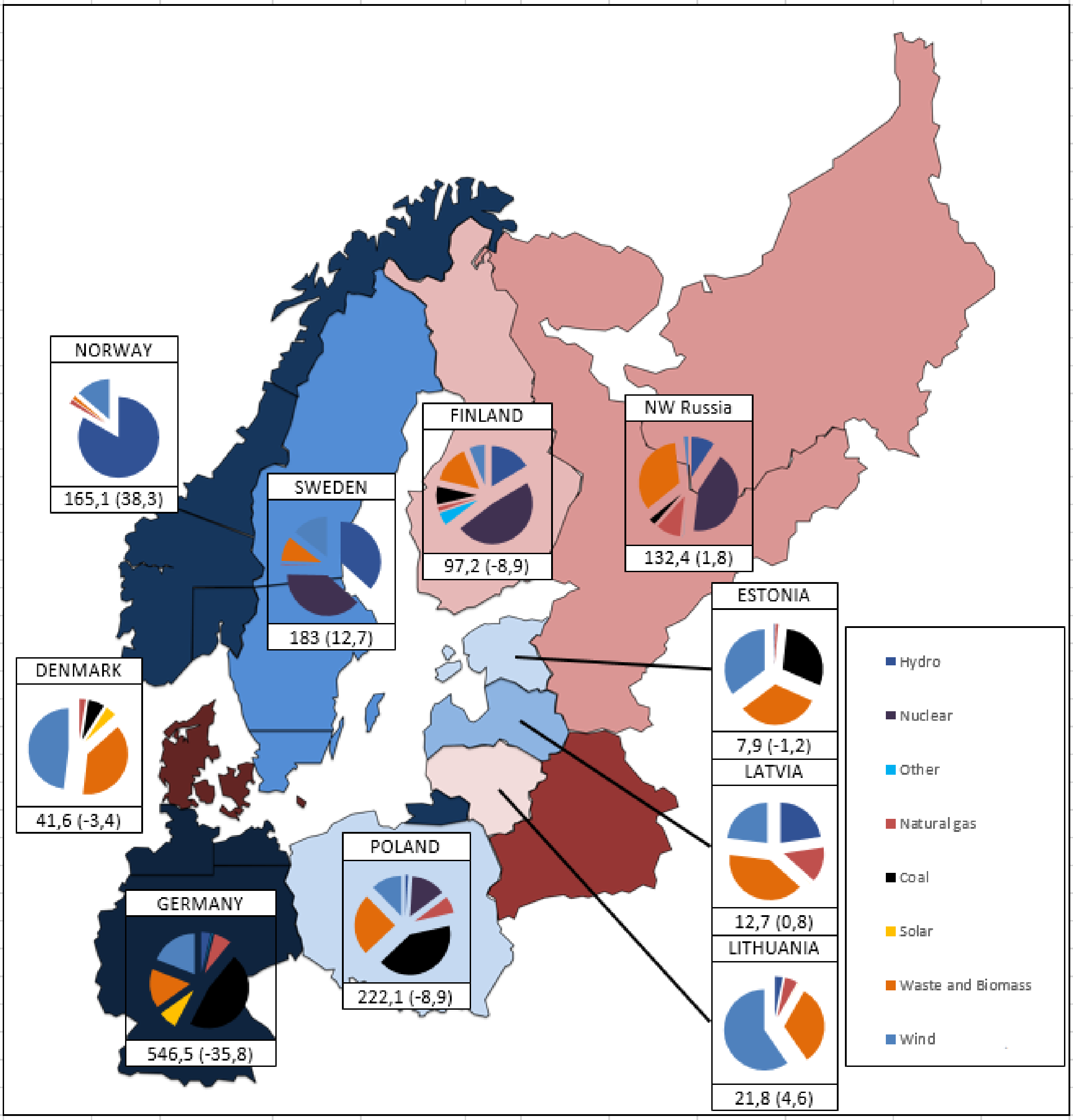


Figure 32: Electricity generation in 2030, liberal scenario. Values indicate national generation (and export) in TWh.

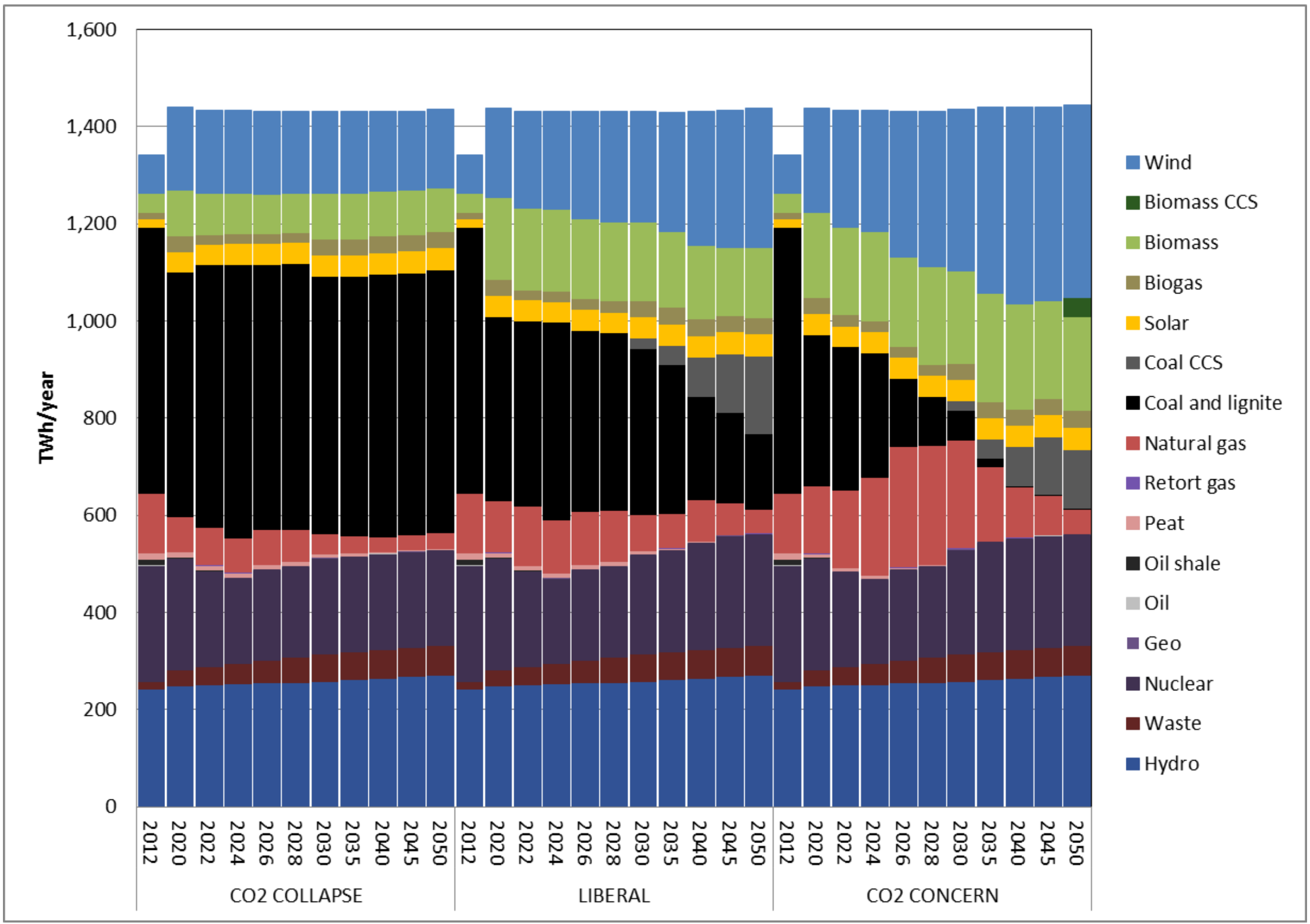


Figure 33: Electricity generation in the model area in three scenarios with low, medium and high CO_2 price. Please note for this and the following figures: The time scale starts with 2012 and then 2020. After 2020 it shows two years steps until 2030 and 5 years steps thereafter.

CCS attractive

The model is allowed to invest in CCS from 2030. With the assumed costs and efficiencies of CCS the model invest in 20,000 MW CCS from 2030 to 2050 in all scenarios, except in the CO2 collapse scenario. In the CO_2 concern scenario the CCS capacity is 15,000 MW coal CCS and 5,000 MW wood pellet CCS (resulting in negative CO_2 emission). In the other scenarios it is coal CCS.

When CCS becomes attractive it will influences the power flow and motivates new transmission investments between areas with CCS and areas without this possibility (because of lack of adequate sites, which is the case for e.g. Estonia). It must be stressed that the assumed costs of CCS are very uncertain. We have used a cost estimate of a new power plant with CCS to be 3 M€/MW$_{electricity}$ and 9% loss of efficiency. Variable cost for operation and maintenance is expected to be 18 €/MWh$_{electricity}$. The investment is 50% higher than for a plant without CCS and the O&M costs are seven times higher.

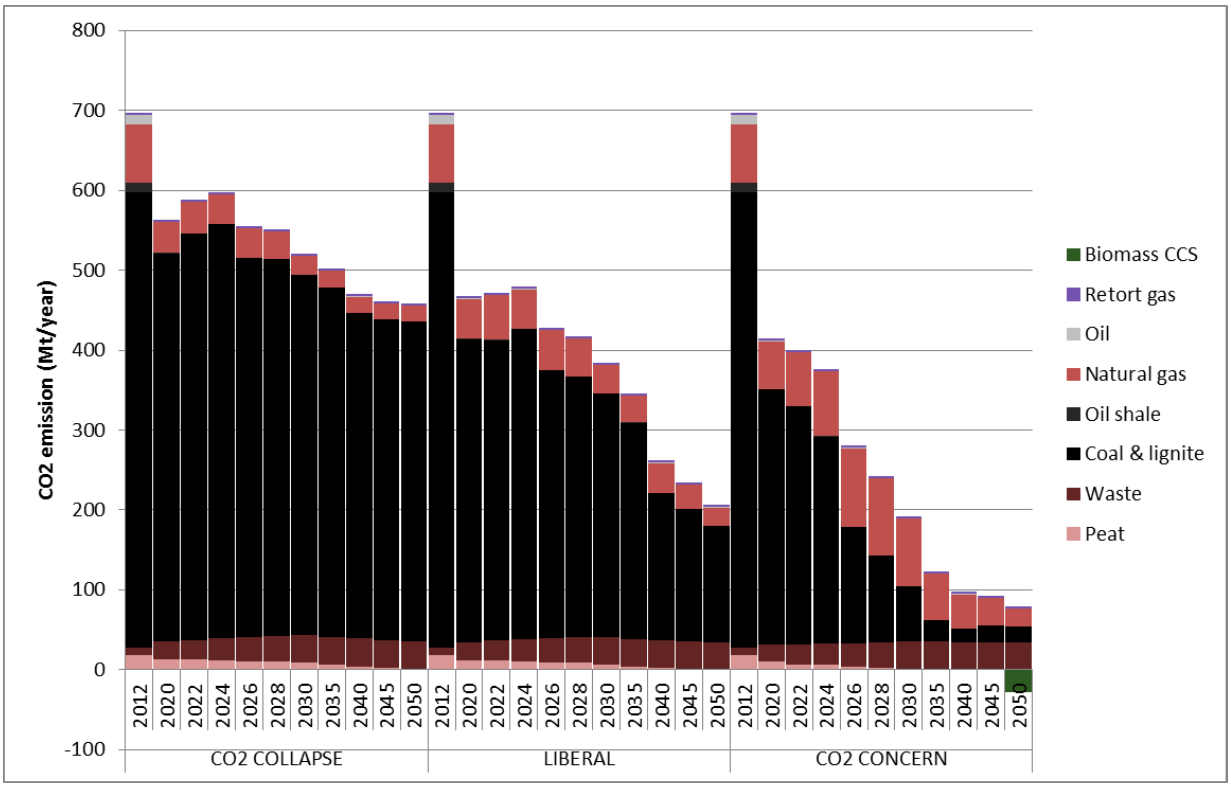


Figure 34: CO_2 emissions in model area in three scenarios with low, medium and high CO_2 price.

The resulting CO_2 emission in the model area starts at 700 Mt in 2012, and is reduced to 200 Mt in 2050 in the liberal scenario. In the CO_2 collapse scenario the emission is also reduced, but only to 450 Mt. In the CO_2 concern scenario the emission is reduced to 50 Mt in 2050.

EU Road maps for 2050 take the starting point on limiting the atmospheric warming to 2°C. This translates into 80-95% reduction of greenhouse gasses by 2050 compared to 1990[32]. The electricity and district heating sectors are expected to be almost CO_2 neutral in this road map. It is only the CO_2 concern scenario (with a 100 €/t CO_2 price in 2050) that follows such a development.

The steep reduction in CO_2 emission from 2012 to 2020 is due to the EU 2020 goals, but also due to the optimal investment in new generation from 2020. A model run with the liberal scenario without the 2020 goals indicates 79% of the reduction from 2012 to 2020 is related to the optimal investments in generation. The rest is due to the 2020 goals for renewable energy[33].

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[32] See: European Commission (2013).

[33] When the model is allowed to invest it is easy to compare two scenarios. Both scenarios are optimal and any difference is due to the parameter that has been changed. However, comparing 2012 and 2020 can be confusing because the model is not allowed to invest in 2012. Therefore such comparison should be done with caution. Model based investments are a central feature in this study. However, it is clear that real life is less optimal than the model world.

Results – Estonia

Electricity generation in Estonia can be seen in Figure 35. In all scenarios (except the oil shale scenario) the use of oil shale is minimised in 2020 and thereafter. Coal and wood chips are introduced to replace the oil shale.

In the liberal scenario wind power increases from 10% of local generation in 2020 to 32% in 2030 and 61% in 2050. The model is only investing in onshore wind power. The wind power capacities are 313 MW, 987 MW and 1,710 MW in 2020, 2030 and 2050, repsectively. In a previous wind power study (Ea Energy Analyses, 2010) similar amounts of wind power have been studied and the results indicate that some curtailment must take place, e.g. 1% with 1,000 MW. However, this result is for 2020. The additional interconnectors in 2050 will help integrate the large amount of wind power. Please see Figure 35.

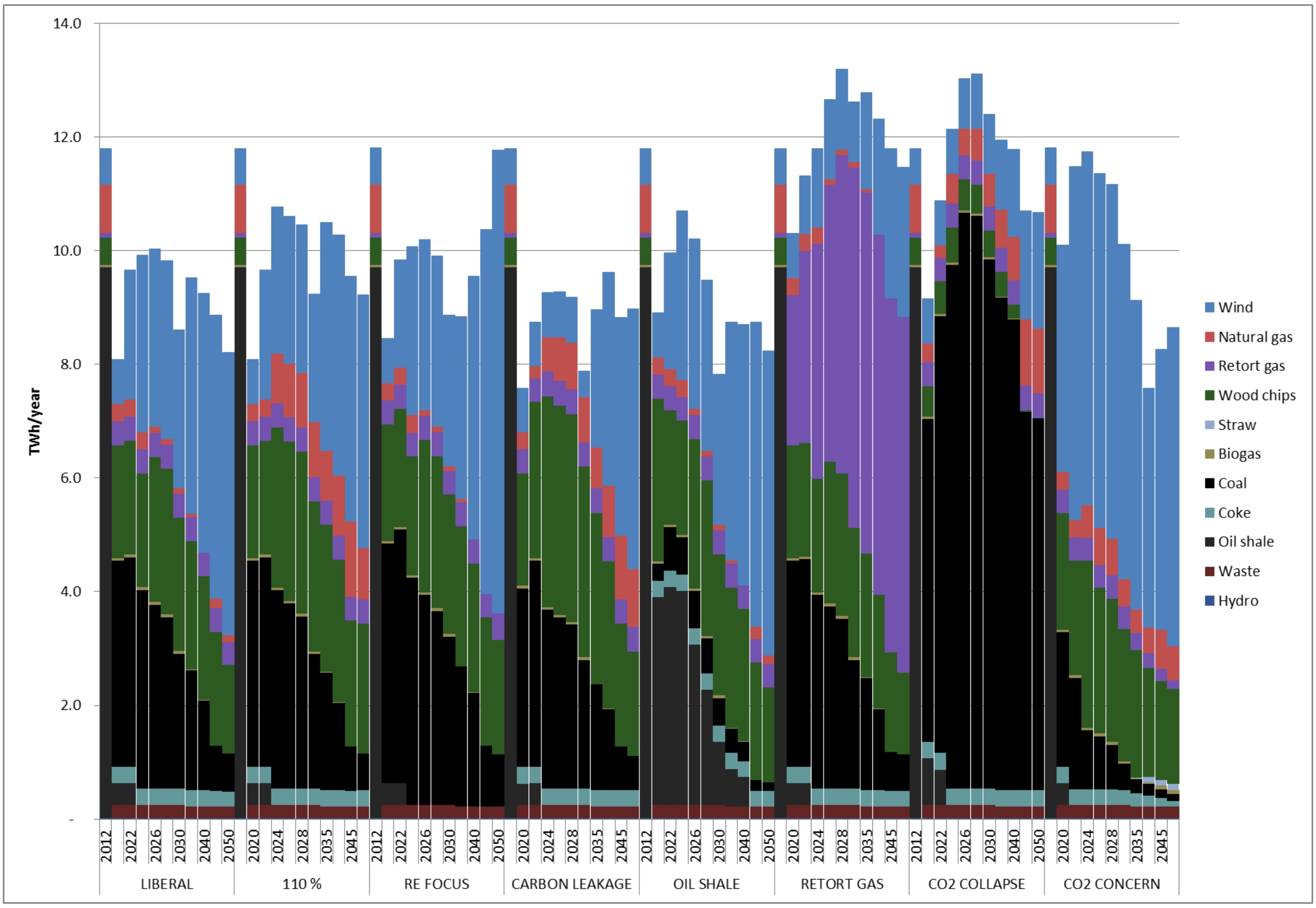

Figure 35: Electricity generation in Estonia in the eight scenarios.

Electricity export

The Estonian electricity demand is 8.5 TWh in 2020 and increasing to 11.6 TWh in 2050. The local generation of electricity is sold on the (international) market. Figure 36 shows the net exchange of electricity from Estonia. Comparing the 110% and the liberal scenarios it can be seen that the extra local capacity in the 110% scenario reduces the import. The RE focus scenario generally leads to increased export, which is caused by decreased inland demand and the RE generation requirement that leads to increased investments in Estonian generation capacity.

In the retort gas scenario significant exports takes place (as expected, since the retort gas is supplied at no costs). In the CO_2 collapse scenario a significant coal based export takes place in 2030. This coal based export is facilitated by a ban on new coal power plants in Sweden, Norway and Denmark, which dramatically decreases the electricity generation in these countries in this scenario. This generally increases coal based electricity generation in all other countries, as this is the most competitive fuel when no cost of CO_2 is applied. In 2050 CCS and nuclear power in the surrounding system leads to Estonian import. It is unclear how these technologies will develop, which means there is some uncertainty in relation to this result.

The country specific yearly electricity export balance in Figure 37 shows how Estonia exchanges electricity with the neighbouring countries, which are interconnected to Estonia. In all scenarios Estonia is importing power from Finland, which is transit power from Norway and Sweden, which both have large exports due to expansion of renewables, hydro power and Swedish nuclear power. The connection to Latvia is used for export while the same is the case for the interconnector to Russia. In the carbon leakage scenario, where the CO_2-price in Russia is set to zero, significant imports from Russia take place.

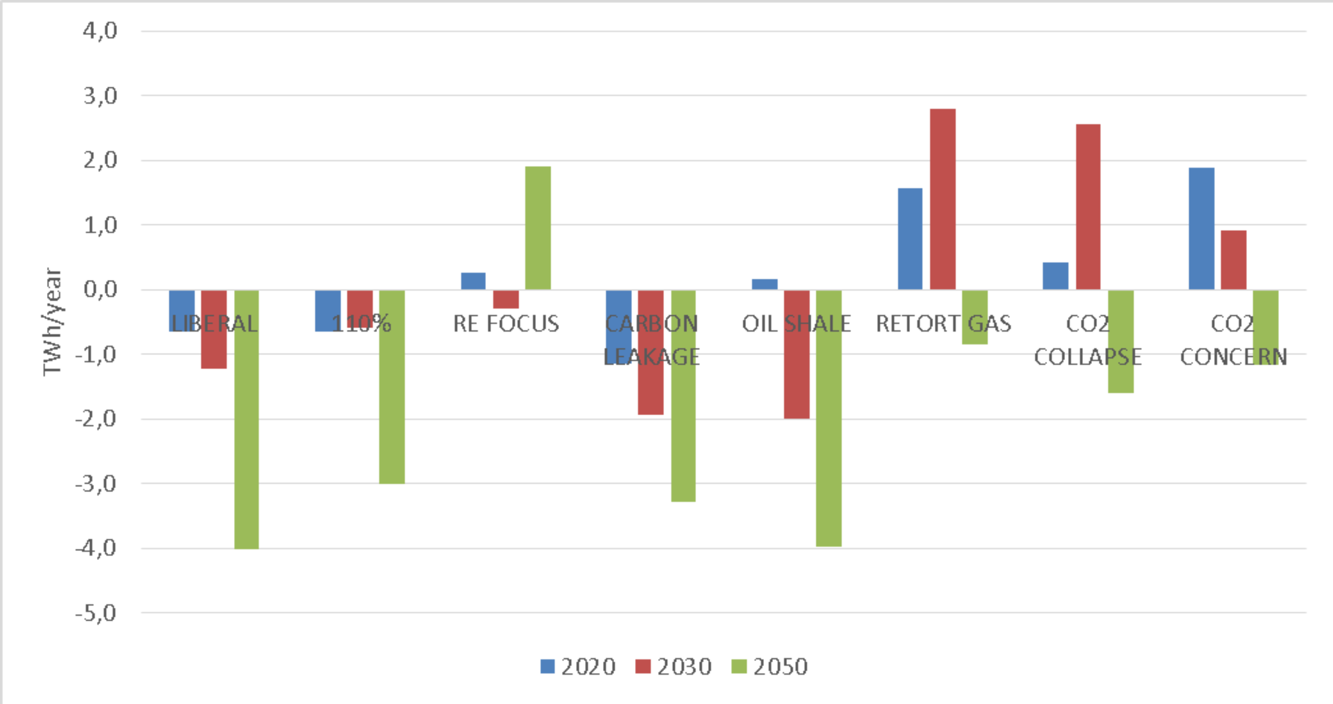

Figure 36: Estonian electricity export balance in all eight scenarios for 2020, 2030 and 2050 (TWh/year). Positive numbers are export of electricity.

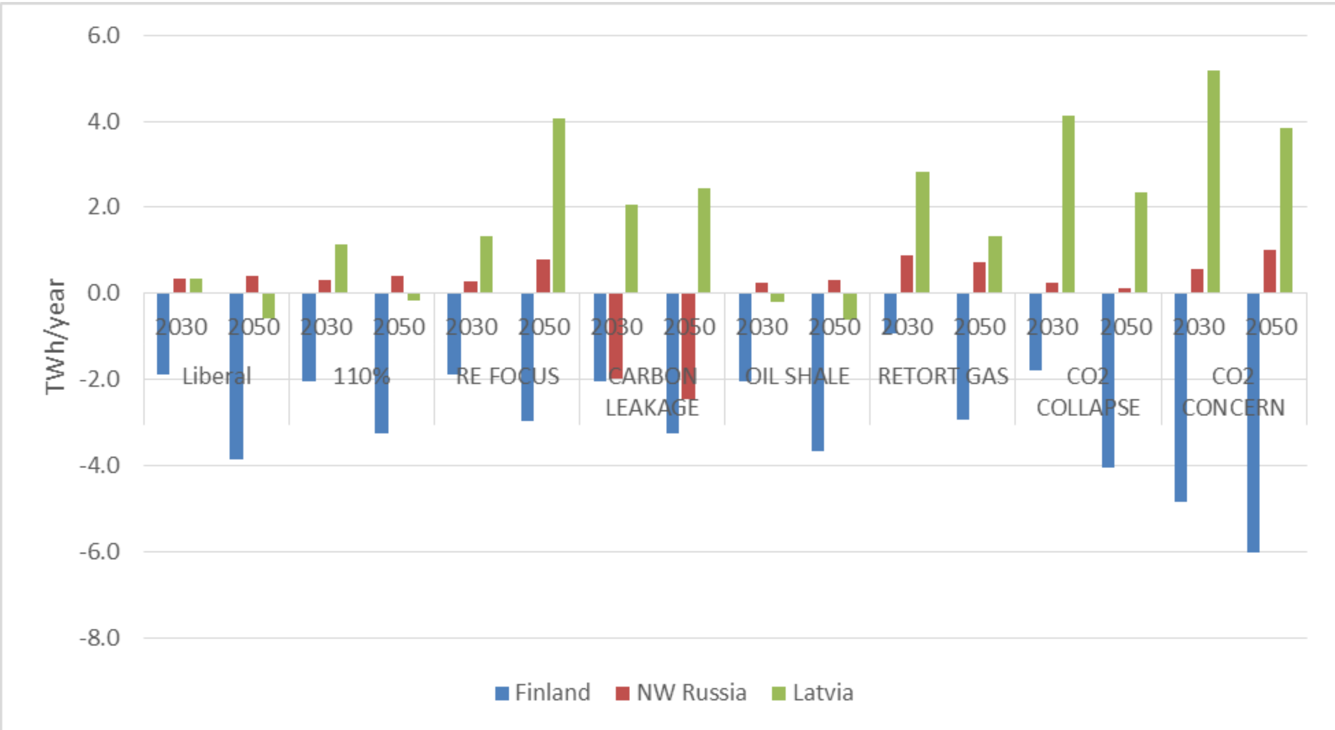

Figure 37: Estonian country specific electricity export balance in all eight scenarios for 2030 and 2050 (TWh/year). Positive number are export of electricity.

CO₂ emissions

The pricing for oil shale in accordance to its substitution price results in reduction of CO_2 emission from the district heating and power sector. See Figure 38. It should be noted that while the use of oil shale is reduced in the electricity and district heating sector, the total oil shale mined may be unchanged (20 Mt/year) because of the increased use of oil shale for producing shale oil. The CO_2 emissions from the shale oil refineries is 3.9 Mt per year in the period from 2020 to 2050. See chapter 7 for the development in total emissions.

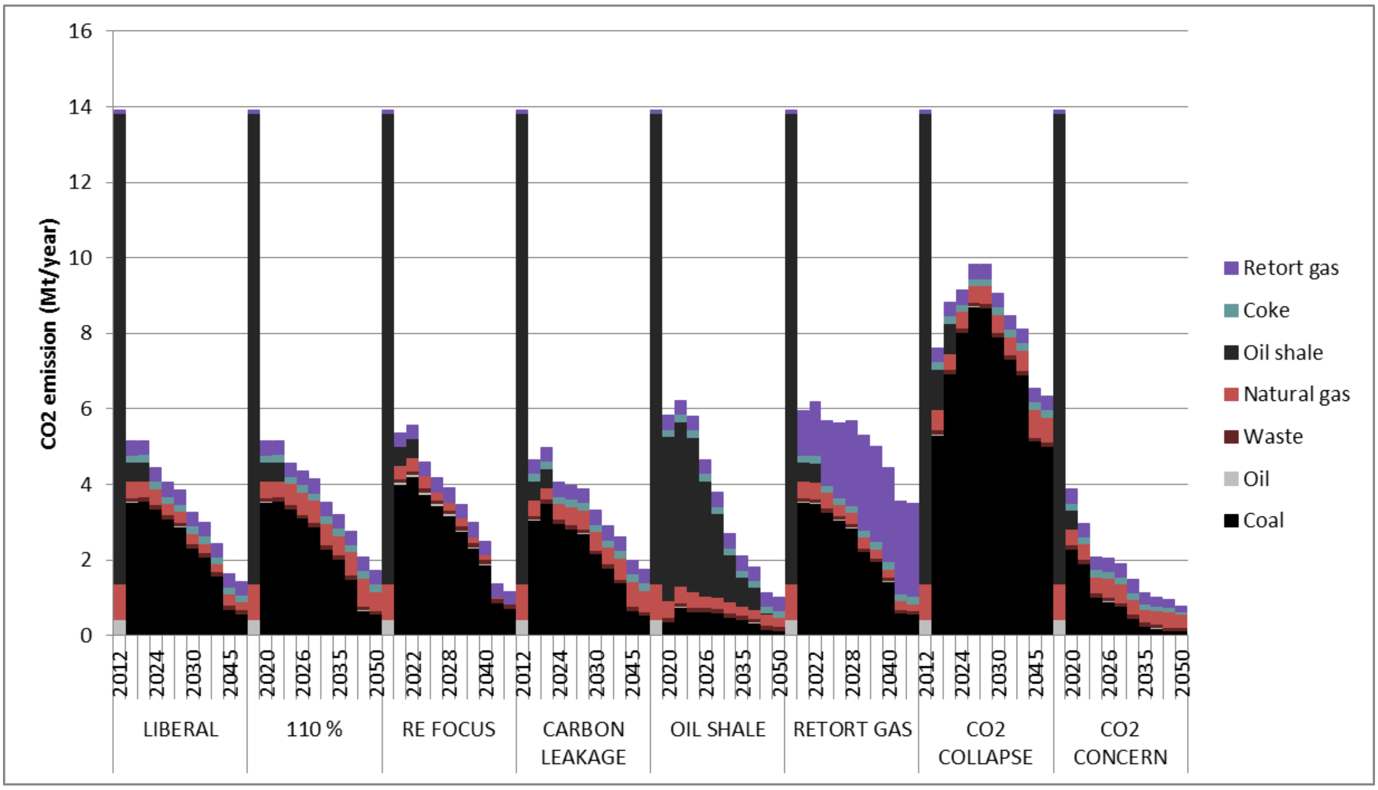

Figure 38: Total CO_2 emission in Estonia in the eight scenarios.

Investments in new generation capacity

The Estonian 2020 renewable energy goals are reached without subsidies in all scenarios except the CO_2 collapse scenario. The goals are reached by commercial investments and operation. Note that this result is simulated under optimal electricity market condition. This also means the power price includes all costs, which in the longer term is long run marginal costs. In the CO_2 collapse scenario a shadow price of 6 €/MWh is needed to reach the renewable energy goal in 2020. The 2020 goal is maintained for the rest of the simulation period at a shadow price of 12.5 €/MWh in 2030 and 10 €/MWh in 2050.

Investment in significant amounts of wind power in Estonia takes place during 2022-2024 (800 MW) and 2035-2045 (1,710 MW).

The 110% rule that secures local capacity to cover Estonian peak electricity consumption has impact from 2024 and forward. Mainly natural gas based turbines are introduced to fulfil the capacity requirement (e.g. 600 MW in 2030). The extra investment in Estonia is reducing investment in other countries. In 2020 and 2022 commercial investment takes place in Estonia – independent of the 110% rule. See Figure 43.

Estonia has historically been exporting electricity produced from the local oil shale resources. In the modelled scenarios (except in the oil shale scenario) oil shale is priced according to its substitution price. The substitution price is much higher than the mining costs, indicating that the resource should be used for producing shale oil for export – and not electricity. Existing oil shale based power plants are not used intensively after 2020 and no re-investments in new oil shale based power plants take place. Investment in rebuilding 660 MW existing oil shale plants[34] to coal takes place in 2020 (in the liberal, 110%, RE focus, carbon leakage and retort gas scenarios).

In the retort gas scenario it is assumed that three units producing shale oil are commissioned by 2020 and in the period from 2020 to 2030 one unit comes online every second year giving a total of eight units by 2030. These units have a total electricity capacity of 720 MW and will run continually towards 2050. These investments are not shown in the graph below as they are not carried out by the models investment module, but are included in all other results.

[34] The model is allowed to rebuild the Narva 8, 11 and Auvere units. These are the three newest oil shale plants.

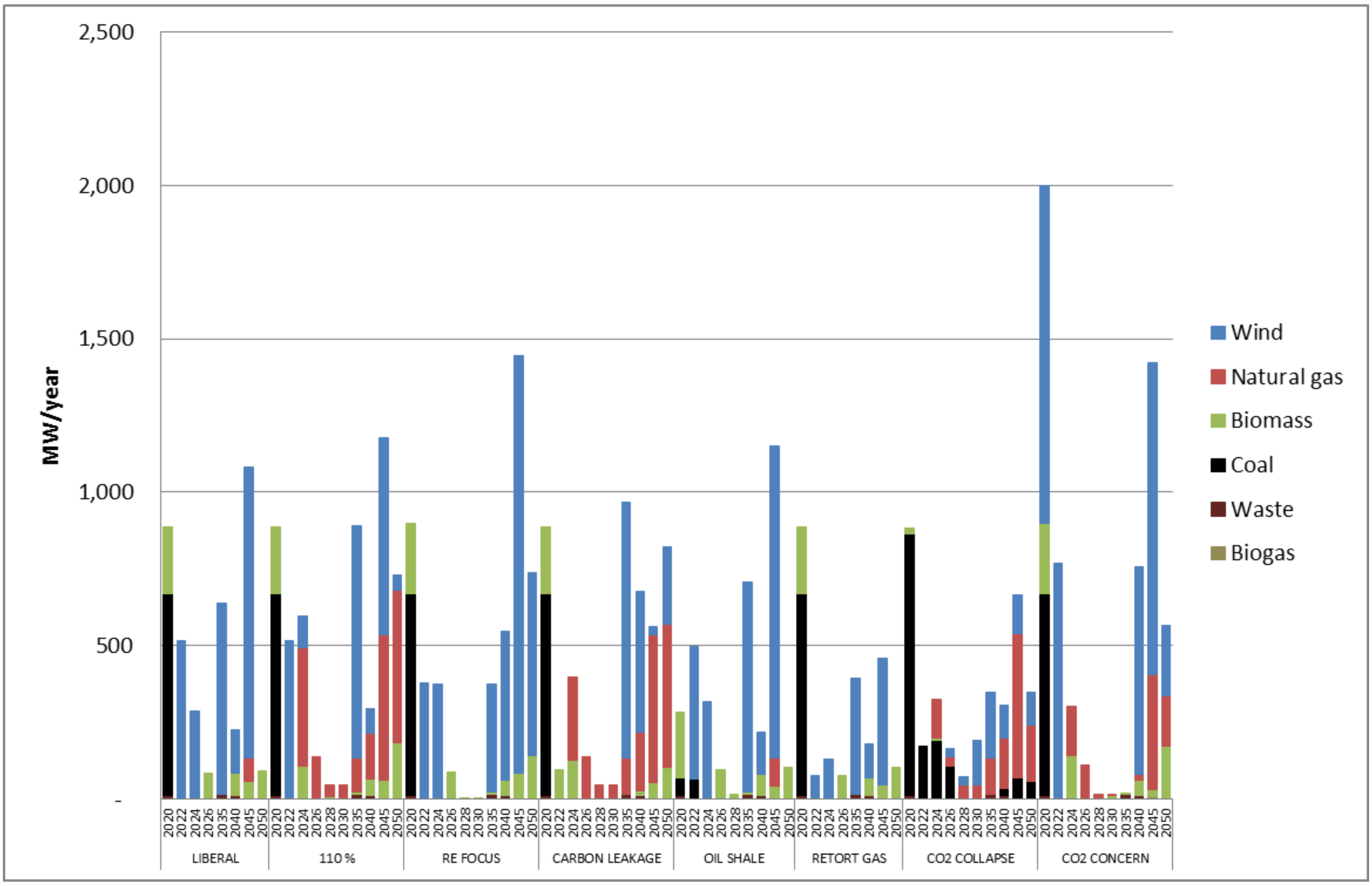

Figure 39: Investment in electricity generation capacity in Estonia. In the Liberal and Retort gas scenarios there are no model investments in 2028 and 2030.

District heating

The use on wood chips is more than doubled from 2012 to 2020 in all scenarios, except in the CO_2 collapse scenario). The model invests in more CHP: The electricity CHP capacity is increasing from 484 MW in 2012 to 717 MW in 2020. This results in an increase in the share of CHP of the total district heat delivered from 50% in 2012 to 69% 2020. This percentage remains at approx. 70% towards 2050. In the longer term (around year 2035) large scale heat pumps become an economic solution for district heating and the model invests in 40 large scale heat pumps.

The prognosis for district heating indicates a reduction in total demand. However, the prognosis is uncertain. District heating is the basis for the CHP generation and the possibilities for increasing the demand (e.g. by connecting more buildings) should be studied.

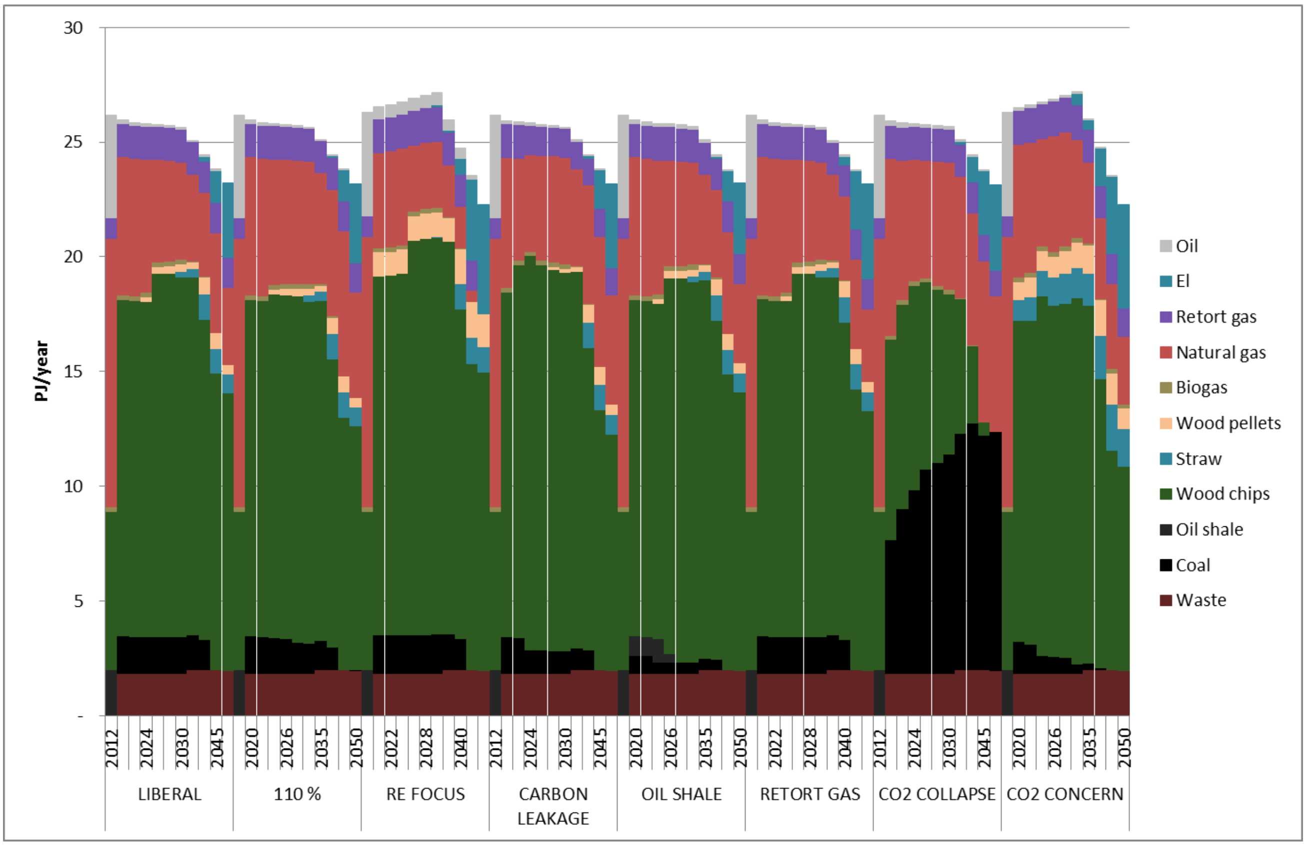

Figure 40: District heating generation in Estonia in the eight scenarios (PJ/year) (El = central heat pumps).

In Figure 41 the development in Estonian fuel consumption is shown. The significant decrease between 2012 and 2020 is a result of the shift from less effective oil shale plants to more efficient generation. Wind power will also contribute to a higher share of the generation.

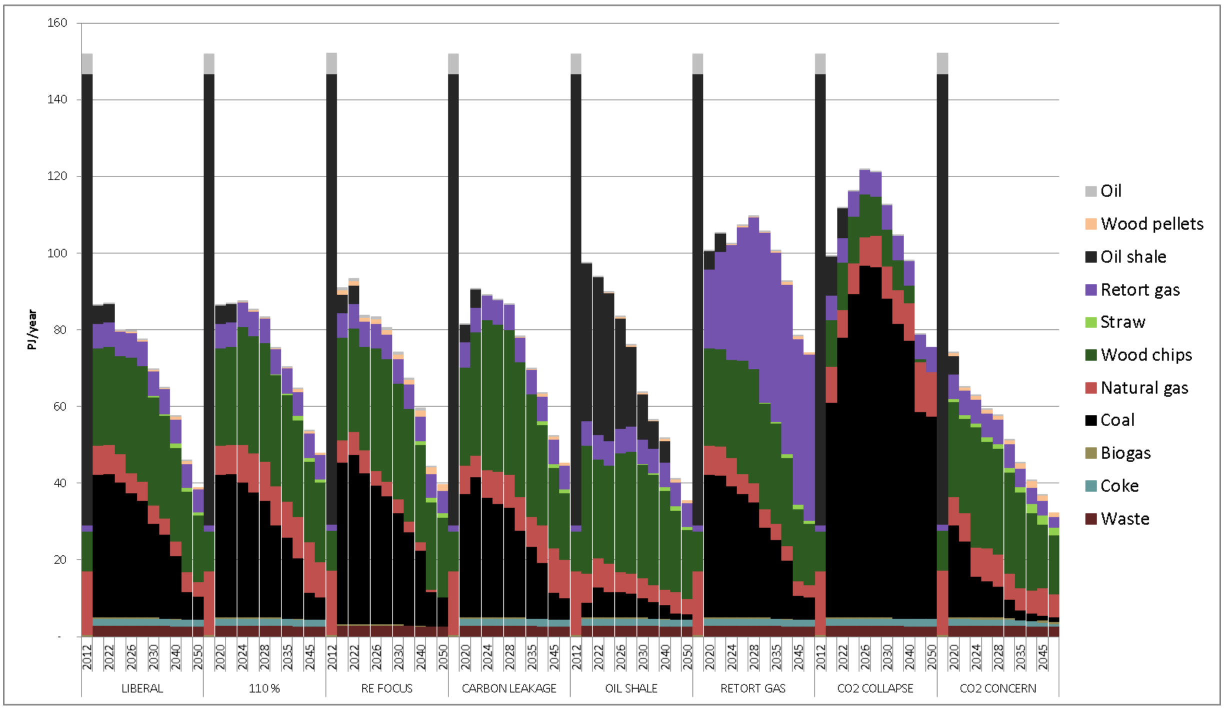

Figure 41: Total fuel consumption in Estonia in all eight scenarios (PJ/year).

The total million ton of oil shale consumed for electricity and district heating generation is illustrated in Figure 42 below. Only in the oil shale scenario a substantial part of the oil shale resource is used for electricity and district heating generation after 2012.

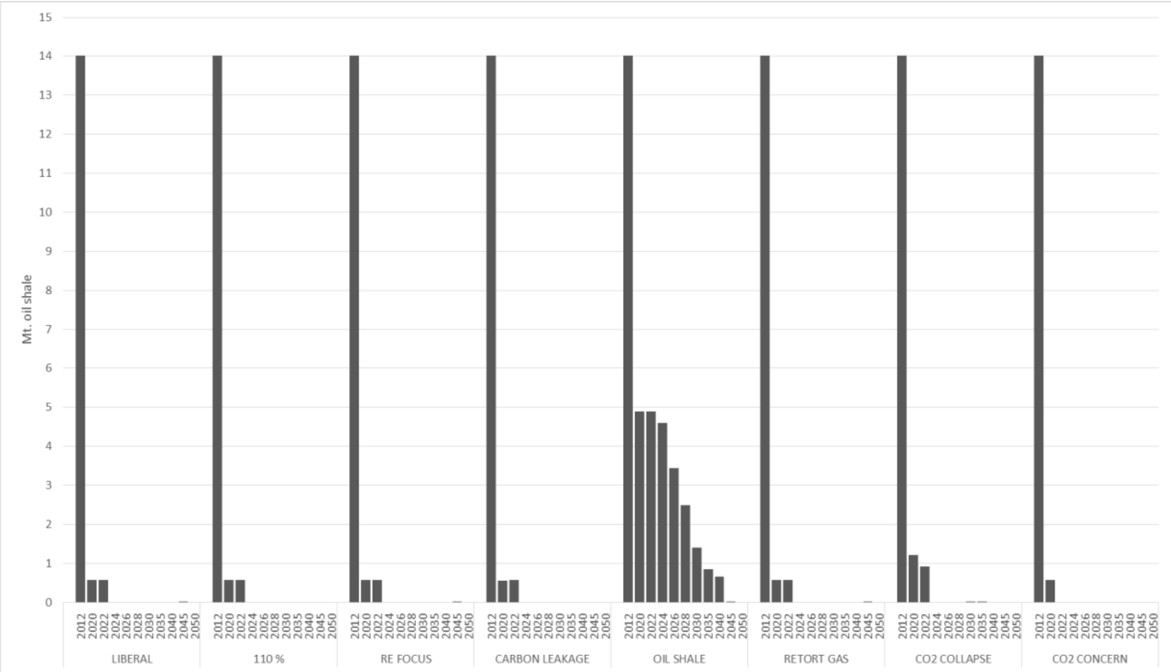

Figure 42: Total million ton of oil shale for electricity and district heating generation in all scenarios.

Figure 43 and Table 7 show how the 110% electricity capacity requirement is met in the 110% scenario. The main conclusion is that natural gas generation will be deployed to meet this requirement in the most cost efficient way. The 110% requirement decreases the development of wind power, since intermittent technologies, e.g. wind, do not count towards meeting this requirement.

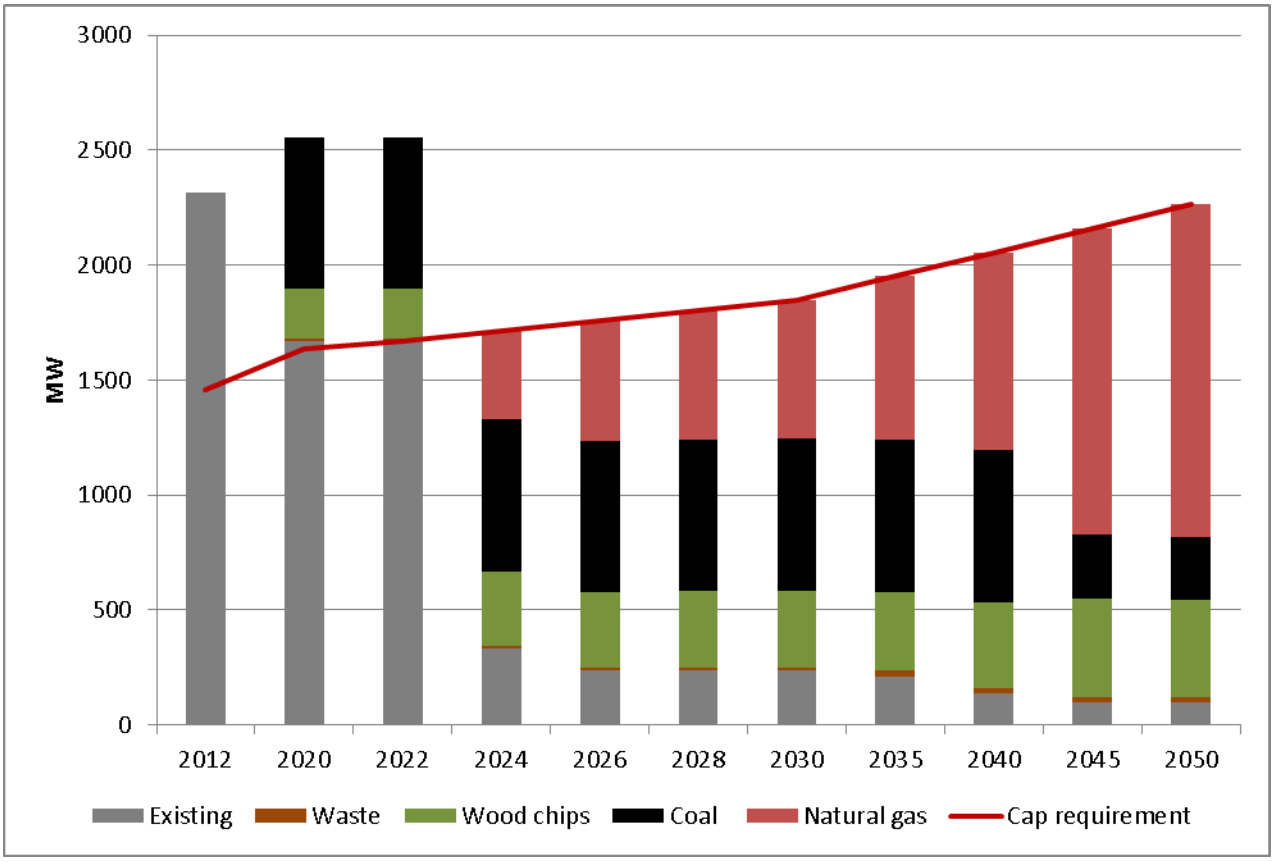

Figure 43: Illustration of how the 110% capacity requirement is met in the 110% scenario.

MW	Biomass	Natural gas	Wind	Total	Total
	Estonia	Estonia	Estonia	Estonia	Other countries
2024-2030	+48	+497	-288	+257	+30
2035-2050	+79	+1,278	-179	+1,179	-38
Total	**+127**	**+1,776**	**-467**	**+1,436**	**-8**

Table 7: Extra investments due to the 110% requirement. The table shows the difference in investment between the 110% and the liberal market scenario.

Coal attractive in Estonia

Coal prices and relatively low rebuilding cost[35] make coal based power generation attractive in all of the scenarios in Estonia, except the CO_2 concern scenario. In Estonia coal is replacing oil shale. This is done by rebuilding the three newest oil shale plants to coal. This takes place in 2020 – the first year where investment is possible. In the oil shale scenario only one of the blocks is rebuilt to coal. Due the lower oil shale price in this scenario it is more attractive to continue operation using oil shale than rebuilding to coal. Only the three newest and most efficient oil shale units can be rebuild to coal, so these units will also be the most attractive units for oil shale usage. Rebuilding a power

[35] Capital costs of rebuilding existing oil shale plants to coal is set to 100.000 EUR/MWel.

plant is less costly than building a new power plant. Since the plants retain their relatively low efficiency, new coal power plants would be more competitive than these units[36].

The use of coal continues until 2030. From 2030 to 2050 the increasing CO_2 prices are reducing the use of coal. In general the result is increased import of electricity to Estonia.

The use of coal is different in the two CO_2 scenarios: In the CO_2 collapse scenario coal is delivering more than 90% of the generation. In the CO_2 concern scenario the use of coal is strong in the start, but this is diminished in 2028.

Results – Electricity prices

Electricity prices are defined as the marginal cost of supplying electricity in each price area. This corresponds to the way that the spot price in calculated on Nord Pool. In Figure 44 it can be seen how the electricity prices in the liberal scenario vary between 60 and 80 €/MWh across countries[37].

For Estonia little variation is found across the scenarios. Typical values throughout the simulation period is 65-70 €/MWh. Only the CO_2 market collapse results in a significantly different electricity price. In this scenario the price is 20% lower. In the CO_2 concern scenario the electricity price is marginally higher. See Figure 45.

[36] The rebuilt oil shale power plants have a condensing efficiency of maximum 36% while new coal power plants have an efficiency of up to 49%.
[37] In Sweden the low price in2024 is driven by wind power investments. From 2026 the model is allowed to invest in transmission and the price is normalised.

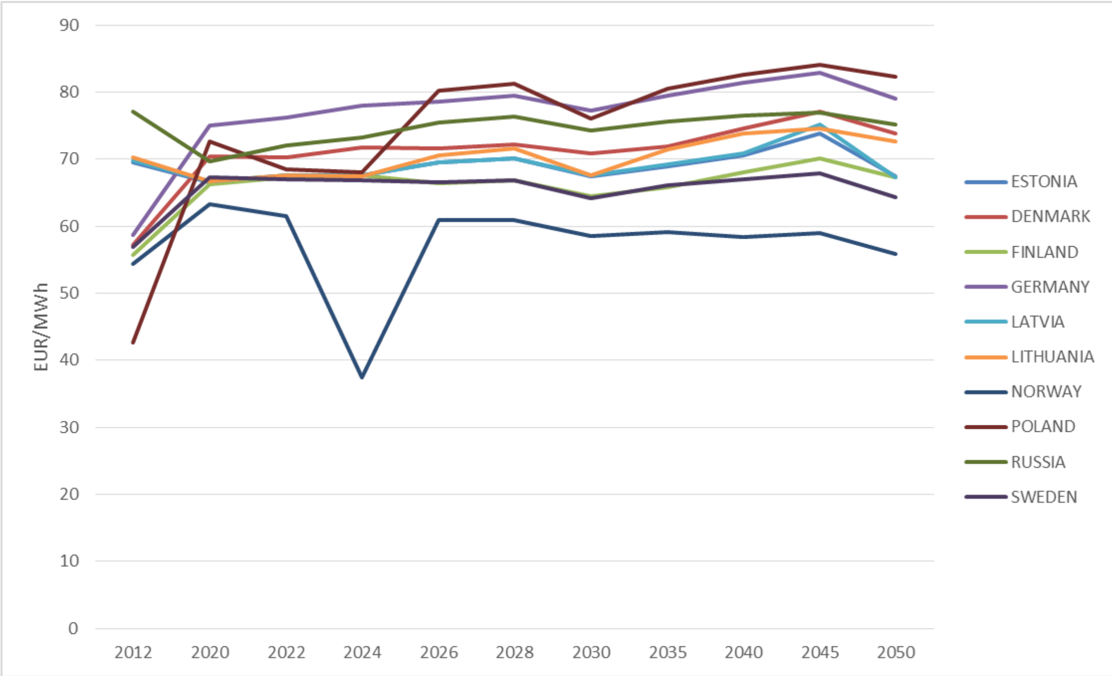

Figure 44: Wholesale electricity prices. All countries in the model, liberal scenario. Yearly average.

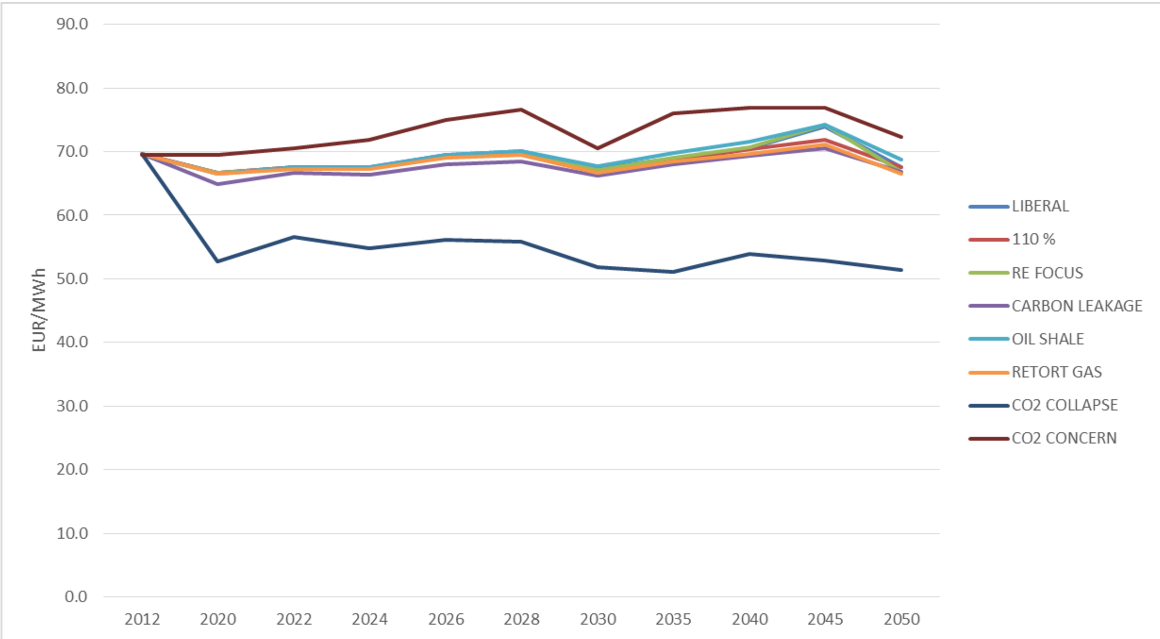

Figure 45: Wholesale Estonian electricity prices in all scenarios. Yearly average..

The electricity price in the two figures above is the average yearly prices. This price is calculated on the basis of the average of different price areas of the given country as well the 72 time steps each year is divided into in the model. The Russian electricity price e.g. also includes Kaliningrad. This means that it is not possible from the yearly average price figure to see the direction of the electricity flow, as this will be determined on the basis of the price of the specific price area as well as the time step. It can e.g. be seen that the Russian electricity price generally is the third highest even though Russia in some years exports electricity. This is illustrated in the figure below where the electricity price per time step in 2020 in the Liberal market scenario is shown.

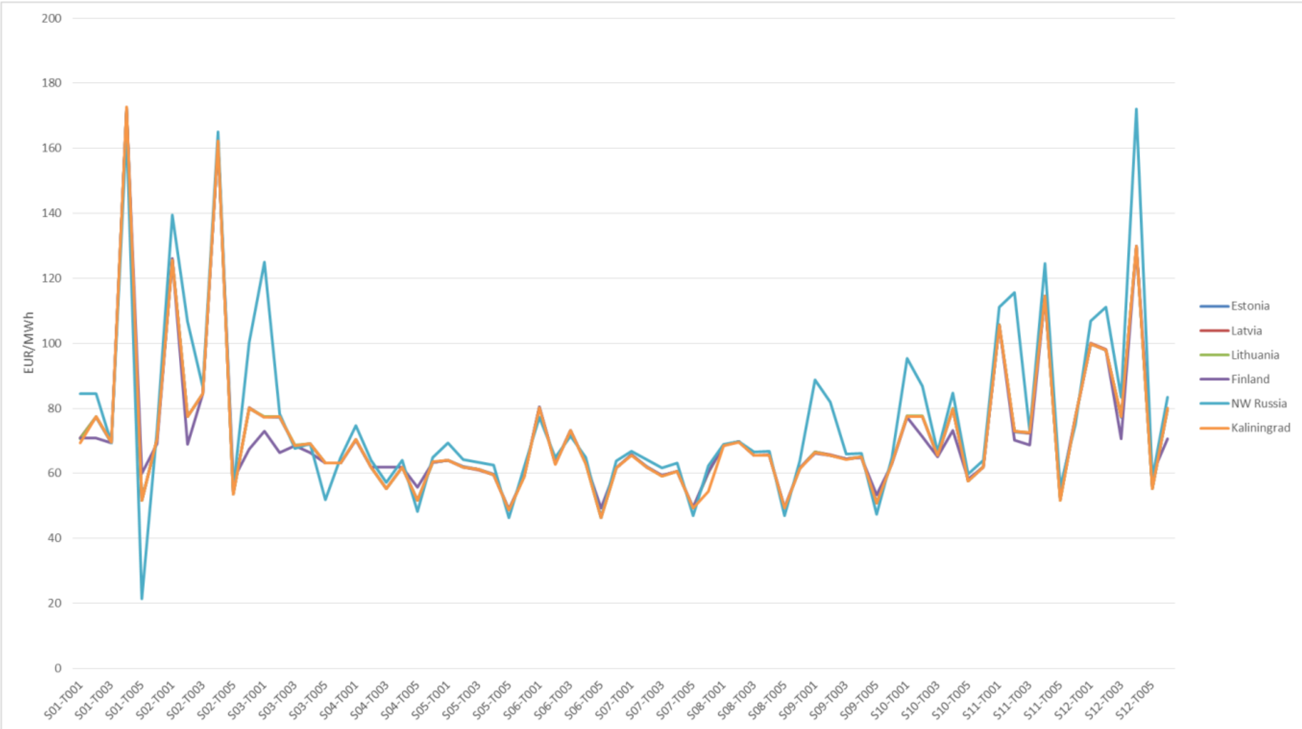

Figure 46: Wholesale electricity prices in the Liberal market scenario in 2020 (EUR/MWh). The prices are not weighted by the length of the individual time step.

Results – Investments in transmission

Until 2025 the expansion of transmission is based on planned investments. From 2026 the model can invest in new transmission capacity[38]. Results are shown in Figure 47, Table 8 and Table 9. The net present value of the investment in transmission lines is 6,877 M€ in the liberal scenario.

The investment in new transmission capacity depends strongly on the CO_2 price. In the CO_2 collapse scenario less than 2,000 MW are invested between 2026 and 2030. The value is more than five times higher in the liberal scenario

[38] The model can investment in generation already from 2020 and the consequences of first allowing investment in transmission from 2026 has been studied. The overall result is that the consequences are limited. If investment in transmission was allowed from 2020 the model would increase the investment in wind power in Norway. An interest rate of 10% and 20 years payback time is assumed for investments in new transmission capacity. This is a higher interest rate than what normally would be applied in feasibility studies for these connections. This is chosen to account for the external barriers, e.g. public

and more than 20 times higher in the CO_2 concern scenario. The need for transmission is among other things motivated by the expansion of wind power. In the CO_2 collapse, liberal and CO_2 concern scenarios the share of wind power in 2030 is 12%, 16% and 23%, respectively. An increasing CO_2 price is also changing the competitiveness of existing power plants.

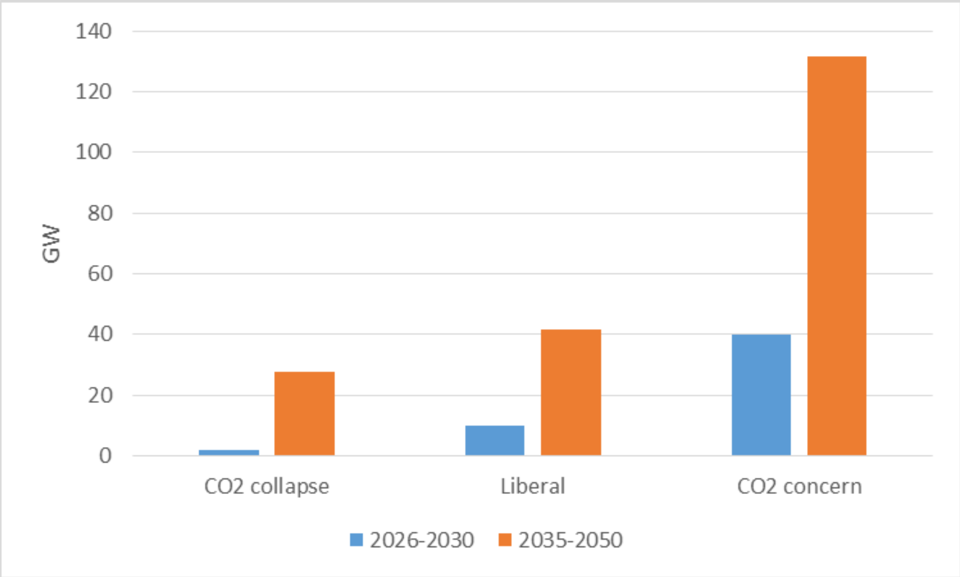

Figure 47: Investment in transmission capacity in three scenarios with low, medium and high CO_2 price. Entire model area. The value is the sum of all new capacity between price areas. Please note, that the model has 23 price areas and in the starting year the sum of existing transmission capacity is 92 GW distributed on 33 interconnectors.

Until 2030

In most of the scenarios the new transmission lines are not connected to Estonia. In the CO_2 concern scenario the model invests in a (small) expansion of the capacity to Finland. This can be seen as evidence of the fact that the planned investments in transmission will cover the needs seen from an Estonian perspective.

2026-2030	LIBERAL	110%	RE FOCUS	CARBON LEAKAGE	OIL SHALE	RETORT GAS	CO_2 COL-LAPSE	CO_2 CON-CERN
FINLAND								
ESTONIA								458
GERMANY								
DENMARK								2,874
GERMANY								12,209
NORWAY								
DENMARK	396	397	400	400	400	393	136	1,200
FINLAND								1,200
GERMANY								400
NORWAY	1,154	1,137	1,140	1,124	1,169	1,160	18	1,694
POLAND								
GERMANY	3,106	3,306	3,102	3,632	3,321	3,120	757	7,200
LITHUANIA	949	984	963	1,897	1,192	853		3,462
RUSSIA								
POLAND	1,035	1,063	1,059	1,471	1,135	1,010		1,651
SWEDEN								
DENMARK				96				800
FINLAND								709
GERMANY	978	921	958	446	810	946	541	2,000
LITHUANIA								915
NORWAY	1,521	1,659	1,652	2003	1,345	1,507	409	1,730
POLAND	800	800	800	838	800	800		1,200
Total	9,939	10,267	10,074	11,907	10,173	9,788	1,860	39,702

Table 8: Model based investment in transmission, 2026-2030, MW. All capacities can serve both directions. When the same country is mentioned twice, e.g.: Norway-Norway, the line in connecting different price areas within the country in question.

2035-2050	LIBERAL	110%	RE FOCUS	CARBON LEAKAGE	OIL SHALE	RETORT GAS	CO_2 COL-LAPSE	CO_2 CON-CERN
FINLAND								
ESTONIA	12				187		179	1,330
GERMANY								
DENMARK	64	37	37		62		493	3,453
GERMANY								41,551
LITHUANIA								
LATVIA	106				148			309
NORWAY								
DENMARK	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,428
FINLAND	182	12	197		362	79	1,132	4,000
GERMANY							2,719	4,000
NORWAY	275	265	345	164	268	345	358	3,674
POLAND								
GERMANY	19,293	19,414	19,279	19,500	19,238	19,511	7,226	24,000
LITHUANIA	1,705	1,355	1,229	1,870	1,794	1,266		9,844
RUSSIA								
POLAND	1,524	1,413	1,413	2,023	1,488	1,503	78	2,023
SWEDEN								
DENMARK	2,466	2,577	2,543	3,062	2,356	2,954	5,126	4,237
FINLAND								1,477
GERMANY	1,638	1,513	1,639	1,186	1,577	1,578	1,075	6,000
LITHUANIA	115	162	6	122	132	156	1,290	3,990
NORWAY	5,944	6,102	5,953	6,351	5,825	5,934	2,605	8,678
POLAND	3,940	3,935	3,986	4,000	3,852	3,942	1,413	4,000
SWEDEN								3,159
Total	41,266	40,786	40,626	42,278	41,288	41,269	27,695	130,154

Table 9: Model based investment in transmission. 2035-2050, MW. All capacities can serve both directions. When the same country is mentioned twice, e.g.: Norway-Norway, the line in connecting different price areas within the country in question.

2030-2050

In the period from 2030 to 2050 the investment in transmission is accelerated. In most scenarios the total of new capacity is between 40,000 and 42,000 MW. In the CO_2 concern scenario the investment is a factor three higher. In the CO_2 collapse scenario there is less need for new capacity. Only minor capacities are connecting to Estonia.

The planned connections to and from Estonia (realised before 2022) seem to be sufficient for a long time as only new lines are built in the oil shale and CO_2 collapse scenario.

Results – District heating

In 2012 the capacity of CHP plants is 802 MW_{heat}. Investment in CHP capacity increases to 1258 MW_{heat} in 2020. As a result the share of CHP generated heat in the district heating system increases from 50% in 2012 to 69% in 2030. From 2040 investment in heat pumps starts and large heat pumps supply 1-14% of the heating in district heating systems at the end of the simulation period.

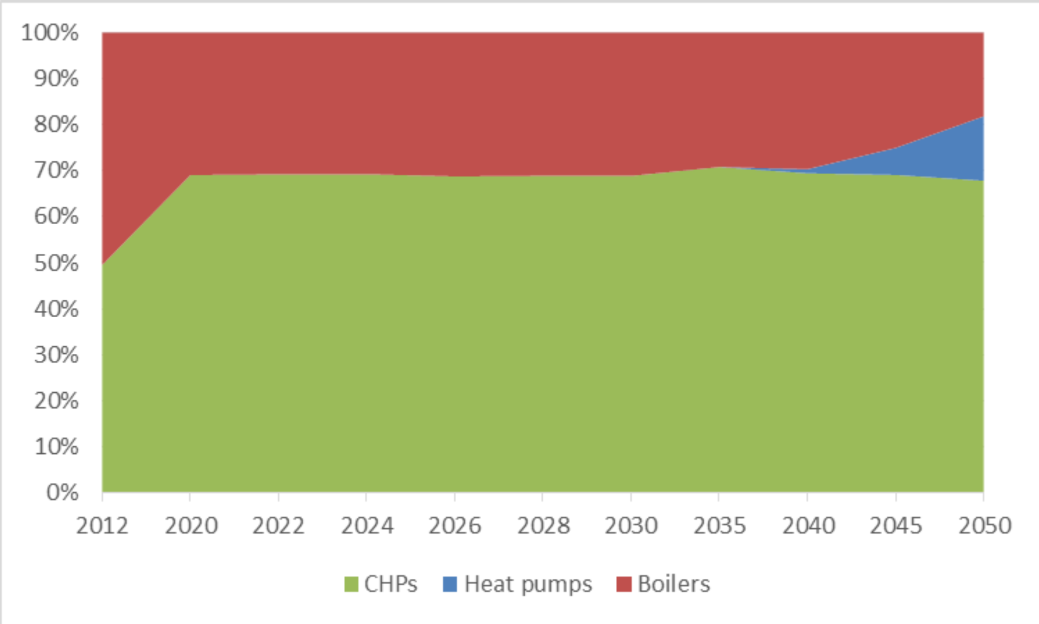

Figure 48: Division of CHPs, heat pumps and boilers in district heating. Liberal scenario.

Heat storage

Heat storage is a simple technology that basically is a large hot water steel tank. If it is used efficiently, it can allow the CHP plants to operate when the electricity price is high even without a heat demand. The storages also allow the CHP plants to reduce the peak demand generation on boilers, since storages can be filled before the demand peaks. The use of heat storage, e.g. in the form of steel tanks is not common in Estonia today. However, the model makes significant investments in heat storages, especially in the RE focus scenario where there are no cheap options to supply peak load in the long term and the value of moving heat production increases. In the liberal market scenario a total of 20 GWh of heat storage is included during the simulation period, with 7 GWh in 2020.

The investment in heat storage seems to be a very robust solution. The investments are very similar in the different scenarios. See Figure 49. The costs of heat storages applied in this study is 210 € per m^3 and their efficiency is 95%.

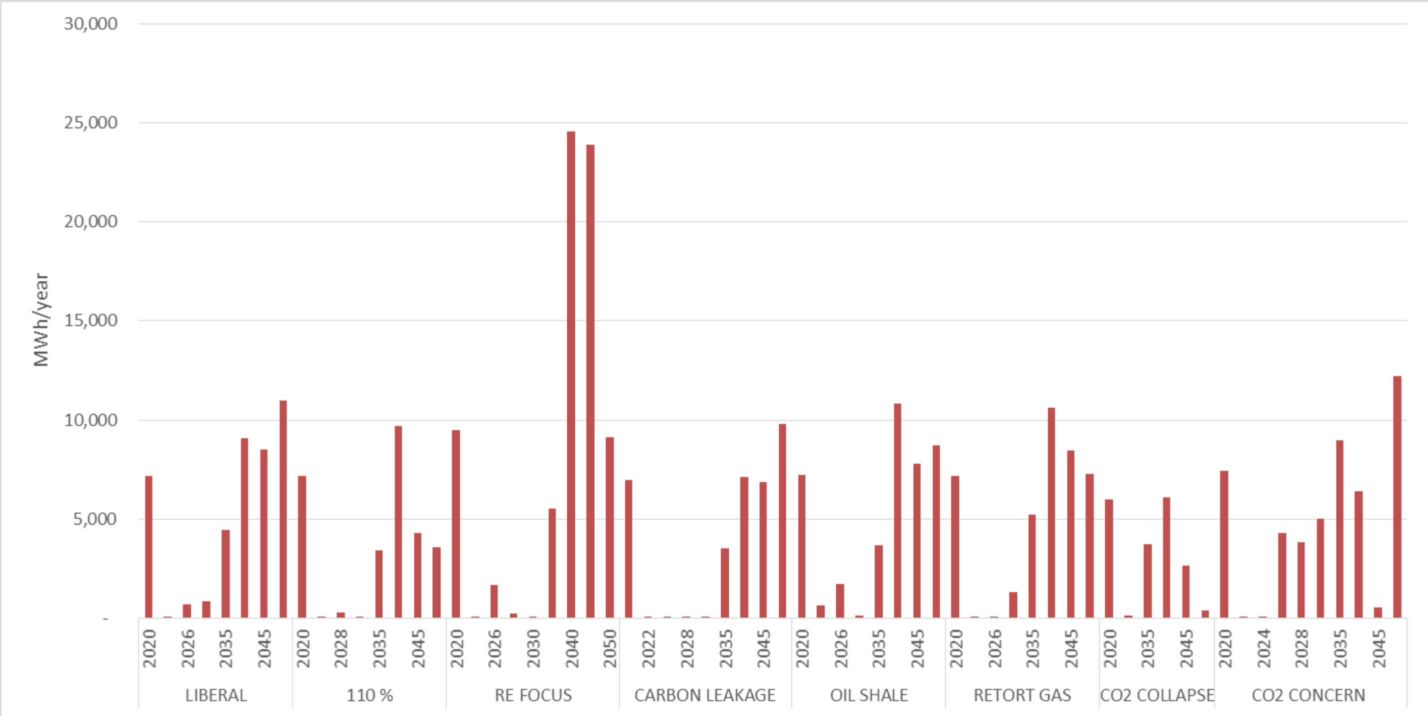

Figure 49: Investments in heat storages in Estonia (MWh/year).

Results – Economy

In this section the economy for the stakeholders is shown as the net present value (5%) over the entire simulation period until 2050. As can be seen from Table 5 the oil shale, the retort gas and the renewable energy scenarios can be directly compared with the liberal scenario, while CO_2 collapse, Carbon leakage and CO_2 concern can be directly compared with the 110% scenario.

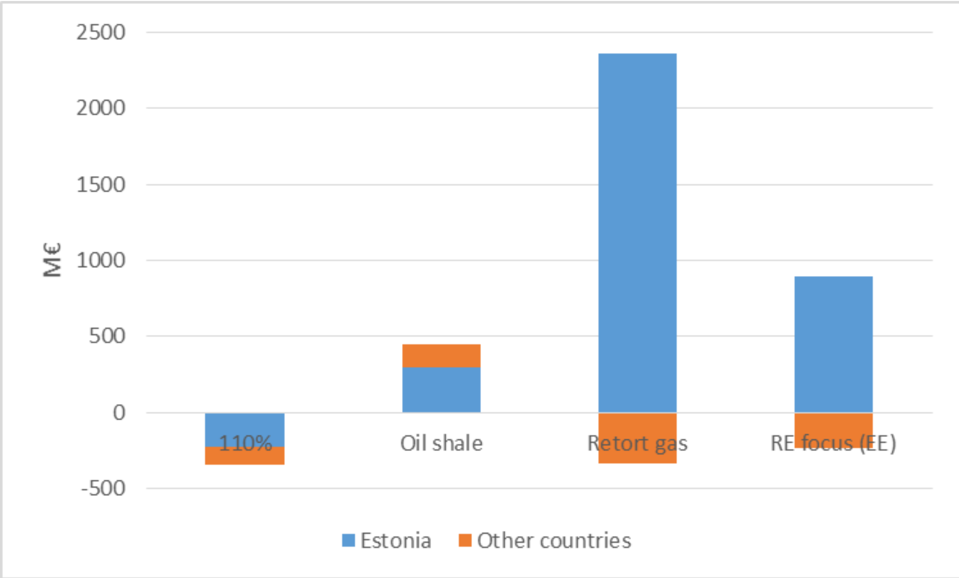

Figure 50: The overall economic impact of four scenarios compared to the liberal scenario.

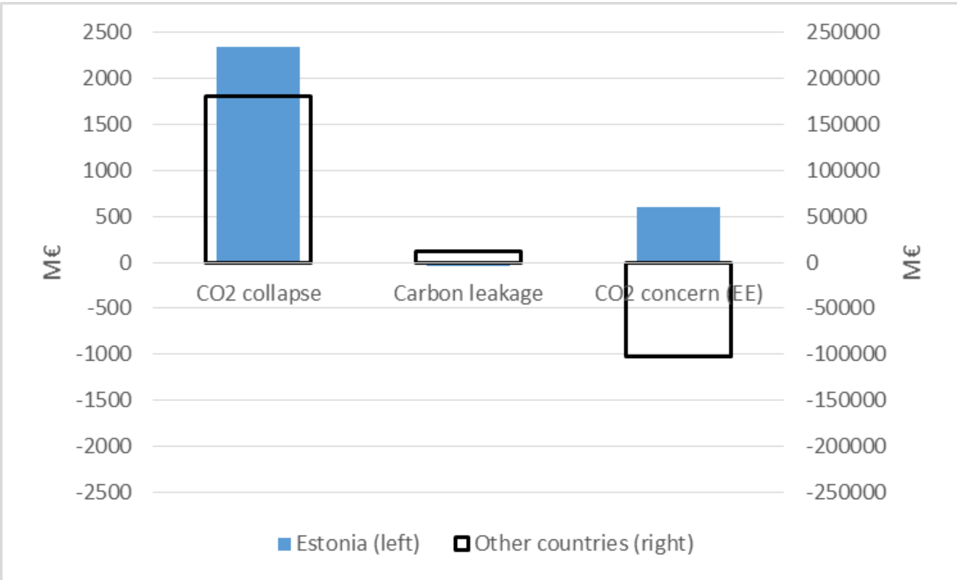

Figure 51. The overall economic impact of three scenarios compared with the 110% scenario.

Understanding the economy tables

The *consumer surplus* is easy to interpret when the energy demand is kept constant. In these cases the value is simply a result of a change in energy price. The *TSO profit* is the change in congestion rents (when price difference exists between price areas).

When the values for generators and consumers are practically equal, but with different signs, it is typically due to the impact of a changed electricity price. E.g. see the values for the Nordic area and for Germany/Poland in the top part of Table 14. If there are differences between the two values it is because of an altered generation.

The TSO profit includes two components: Congestion rents are included as an income. The congestion rents are the price difference in price times the flow over congested lines. Investments in new transmission lines are included as costs.

Table 10 shows the economy of having an Estonian 110% requirement. Only the difference relative to the liberal market is shown. For the entire model area the 110% requirement costs 346 M€. For Estonia the total cost is 227 M€[39]. The extra local capacity results in lower prices, which is a benefit for consumers.

For the generators the total loss of 566 M€ (net present value) consist of extra investments and fixed costs of 236 M€, and 330 M€ in reduced income (extra fuel and CO_2 cost minus extra revenues). If it is assumed that the generators would need a subsidy of 566 M€, this would correspond to 6 €/MWh collected from all Estonian electricity demand in the period 2024 to 2050.

(Mio. euro)	ESTONIA	LATVIA	LITHUANIA	RUSSIA	NORDIC	GERMANY & POLAND	TOTAL
			110%				
Generator profits:	-566	-96	-111	49	-600	-192	-1,516
Consumer surplus:	351	32	16	-18	639	333	1,352
TSO profit:	-12	7	-2	12	-117	-69	-181
Socio economic benefit:	**-227**	**-57**	**-98**	**43**	**-78**	**72**	**-346**

Table 10: Economic consequences of the 110% scenario compared to the liberal market.

[39] Note that if year 2024 was used as base year – the first year that the rule has consequences – then the net present values would be double.

The total undiscounted costs of the 110% requirement has been calculated to a cost of approximate 1000 M€ for the entire model area. This is the costs for all years in the period 2012-2050.

Table 11 shows the economic results for the CO_2 concern scenario compared to the 110% scenario. The results are shown in two steps. In the first step the CO_2 price is increased and this results in extra costs in Estonia of 437 M€. Reducing the energy consumption as described in the energy efficiency scenario is such a benefit that it outweighs the initial costs (benefit of 596 M€ with high CO_2 price and low energy consumption in Estonia). However, it should be remembered that the cost of achieving the lower energy consumption (investments and the cost of the political instruments) is not included in figures presented in the table.

(Mio. euro)	ESTONIA	LATVIA	LITHUANIA	RUSSIA	NORDIC	GERMANY & POLAND	TOTAL
			CO_2 concern				
Generator profits:	587	1,052	3,204	12,945	21,695	24,723	64,207
Consumer surplus:	-1,148	-1,366	-2,272	-16,934	-29,581	-123,118	-174,420
TSO profit:	124	117	-345	195	6,526	833	7,449
Socio economic benefit:	-437	-197	587	-3,794	-1,360	-97,562	-102,764
			Impact of EE				
Generator profits:	121	-33	40	-274	358	-242	-28
Consumer surplus:	911	22	29	237	-387	253	1,065
TSO profit:	0	-6	9	16	4	-27	-4
Socio economic benefit:	1,033	-16	78	-21	-25	-15	1,033
			CO_2 concern (EE)				
Generator profits:	709	1,020	3244	12,671	22,054	24,482	64,179
Consumer surplus:	-237	-1,344	-2,243	-16,697	-29,968	-122,865	-173,354
TSO profit:	124	111	-336	210	6,529	806	7,445
Socio economic benefit:	596	-214	665	-3,815	-1,385	-97,577	-101,731

Table 11: The CO_2 concern scenario compared to the 110% scenario. First step (top) is the scenario with the high CO_2 price, but with BAU development in the energy consumption. The lowest part shows the same simulation, but with reduced energy demand in Estonia. The difference between these two simulations is shown in the middle of the table.

Table 12 shows the CO_2 collapse and the carbon leakage scenarios compared to the 110% scenario. The Carbon leakage scenario (where the CO_2 price in Russia is set to 0 €/ton) create – as expected – a huge benefit for Russia. The impact on Estonia (as a whole) is limited to a 44 M€ loss. However, significant losses are placed on Estonian generators.

The CO_2 collapse scenario – where the CO_2 price is set to zero – is a benefit for all countries. First of all the electricity price is reduced with positive benefits to consumers. Estonia is the only country where the generators benefit from the change. This is due to the CO_2 intensity of the Estonian electricity generating sector due to the oil shale based plants.

In the CO_2 collapse scenario it requires extra focus to fulfil the renewable energy targets for 2020-2050. The shadow price is 9 €/MWh in average (2020-2050). This can be understood as the tariff on all Estonian electricity that is needed for subsidies to reach the target. In all other scenarios the CO_2 price is sufficient to fulfil the renewable energy target by commercial investments.

(Mio. euro)	ESTONIA	LATVIA	LITHUANIA	RUSSIA	NORDIC	GERMANY & POLAND	TOTAL
			CO_2 collapse				
Generator profits:	113	-1,705	-2,752	-21,737	-87,066	-50,741	-163,888
Consumer surplus:	2,199	2,768	4,172	30,722	95,026	210,702	345,589
TSO profit:	32	-59	50	4	1,264	-503	788
Socio economic benefit:	2,344	1,004	1,470	8,989	9,224	159,458	182,489
			Carbon leakage				
Generator profits:	-411	-476	-421	-18,864	-3,962	-1,509	-25,643
Consumer surplus:	279	234	153	29,696	3,633	2,895	36,890
TSO profit:	89	144	-219	961	266	-37	1,204
Socio economic benefit:	-44	-98	-486	11,793	-64	1,349	12,450

Table 12: The CO_2 collapse and the carbon leakage scenarios compared to the 110% scenario.

Table 13 shows the oil shale and the retort gas scenarios compared to the liberal scenario. Both scenarios describe the impact of supplying cheap fuel to the electricity sector. For the retort gas scenario the cost of the gas is not included. As expected both scenarios result in significant profit for the Estonian generators.

In the oil shale scenario oil shale will be used for a longer period than in the liberal scenario. However, even in the oil shale scenario the use of oil shale is reduced to 41 PJ in 2020 and 12 PJ in 2030 (compared with 118 PJ in 2012).

The retort gas scenario assumes an increasing use of retort gas from 2 PJ in 2012 to 21 PJ in 2020 and 44 PJ in 2030.

(Mio. euro)	ESTONIA	LATVIA	LITHUANIA	RUSSIA	NORDIC	GERMANY & POLAND	TOTAL
			Oil shale				
Generator profits:	359	-42	67	-258	-1,321	114	-1,080
Consumer surplus:	-69	-53	-39	263	1,459	78	1,637
TSO profit:	5	-6	9	0	-87	-33	-112
Socio economic benefit:	295	-101	37	6	51	159	446
			Retort gas				
Generator profits:	2,285	-202	-139	-177	-1,529	-609	-371
Consumer surplus:	84	70	35	150	1,524	743	2,606
TSO profit:	-10	22	-26	-9	-123	-62	-209
Socio economic benefit:	2,360	-111	-130	-36	-128	72	2,026

Table 13: The oil shale and the retort gas scenarios compared to the liberal scenario.

Table 14 shows the result for the renewable energy scenario. This is done in two steps so that the impact for the lower energy consumption can be seen clearly.

Note that the requirements for renewable energy are strongest at the end of the simulation period (2050) and the impact is significantly reduced in the computation of the net present value. 1 € in 2012 is equal to 6.4 € in 2050 when using 5% real p.a. as interest rate.

Already from 2020 the requirements of not investing in fossil fuel based generation change the scenario – compared to the liberal market.

The requirement has a total costs of 135 M€ for the model area. However, for Estonia there is a net benefit of 62 M€.

When the renewable energy target in Estonia is applied there will be an extra costs for the entire system. This cost will not necessarily be located in Estonia, but somewhere in the system. The RE requirement in Estonia will also change the investment pattern in the other countries in the system. Additional RE investments will normally increase the capital costs and decrease consumer prices and the balance between these are decided by the interest rate. When we run the model we use a 10% interest rate and 20 years payback time. When we evaluate the stakeholder economy we use 5 % and 20 years - these 5 % results in a positive economic result for Estonia. If we apply a 10 % interest rate in the stakeholder economy the positive economy for Estonia will be changed to a cost of 45 M€. This is due to the investments in the RE scenario has higher capital costs, which will take place in the last part of the period, with a 10 % interest rate, will have less importance for the net present value. A general result from the study, when you look at the other scenarios, is that the majority of the RE investments are competitive even without a RE target as they are facilitated by the CO_2 price. Therefore the difference in costs between the liberal market scenario and the RE scenario will be at the end of the period towards 2050 when the model takes the final steps to reach the 100 % target. The costs at this point in time will have less importance in a net present value calculation.

The net impact of the lower energy consumption is similar to what was found in the CO_2 concern scenario.

(Mio. euro)	ESTONIA	LATVIA	LITHUANIA	RUSSIA	NORDIC	GERMANY & POLAND	TOTAL
			RE focus				
Generator profits:	-779	-152	29	-9	77	-32	-866
Consumer surplus:	840	2	-3	0	-71	-38	730
TSO profit:	1	3	1	3	-9	2	1
Socio economic benefit:	62	-147	27	-6	-3	-68	-135
			+EE				
Generator profits:	3	-25	-86	-160	-574	-221	-1,063
Consumer surplus:	836	26	19	187	586	337	1,991
TSO profit:	-5	-12	-10	24	-52	-78	-133
Socio economic benefit:	834	-11	-78	52	-40	38	795
			RE focus (EE)				
Generator profits:	-776	-177	-58	-169	-497	-253	-1,929
Consumer surplus:	1,676	28	16	187	515	298	2,721
TSO profit:	-4	-10	-9	27	-61	-76	-132
Socio economic benefit:	896	-158	-51	45	-43	-30	660

Table 14: The renewable energy scenario compared to the liberal scenario. First step (top) shows the impact of the renewable energy requirement in Estonia. The second step shows the impact of lower energy demand. Finally, step three shows the impact of renewable energy requirement and lower energy demand combined.

Profitability of investments

BALMOREL is myopic in its investment approach, which means that it does not consider revenues beyond the year of installation. Investments are undertaken in a given year if the annual revenue requirement in that year is satisfied by the market. This also means that the investments are not necessarily profitable beyond the year of installation. To check the investments carried out in Estonia it has been analysed if the investments are also profitable in the long term with an interest rate of 5%. Includes in this analysis is fixed and variable O&M, fuel, CO_2 and capital costs as well as district heating and electricity sales.

The analysis indicated that all investments in biomass CHPs are profitable in all years of operation. Wind power is also profitable. The rebuilding of the

Narva oil shale plants to coal is generally profitable. However, especially the Auvere unit generates this profit, while Narva 8 and 11 are only profitable in the first 5-10 years of operation.

Sensitivity analysis

The figures below illustrate the result of a set of simple sensitivity analyses. The simulations have been fixed in 2030 and for this year a number of parameter variations are made. No new investments are allowed in these simulations. The parameters are changed for the entire model area except for consumption, which only is changed in Estonia. The investment until 2030 is fixed. The impact of these variation on CO_2 emission and electricity generation in Estonia is computed. In the appendix results for all scenarios are to be found.

The table below show in which steps the parameters variations are performed while Figure 52, Figure 53 and Figure 54 show the results of the analyses.

	Biomass/natural gas/coal/oil/CO_2	Shale	Demand
Step 1	-50%	-75%	-25%
Step 2	-37.5%	-56.25%	-18.75%
Step 3	-25%	-37.5%	-12.5%
Step 4	-12.5%	-18.75%	-6.25%
Step 5	+12.5%	+18.75%	+6.25%
Step 6	+25%	+37.5%	+12.5%
Step 7	+37.5%	+56.25%	+18.75%
Step 8	+50%	+75%	+25%

Table 15: The different steps in the parameters variations. "+25%"does for example indicate the parameter is increased by 25%.

For the liberal scenario the parameter variations do not have any practical impact on the oil and oil shale. The reason for this is that these fuels are not used in 2030. Existing oil shale plants are either decommissioned before 2030 or rebuilt to coal. The Estonian generation is sensitive with respect to changes in fuel and CO_2 prices. Higher biomass and natural gas price increase the generation in Estonia, while increased coal price or CO_2 price results in lower Estonian generation. The impact is determined by the available capacity inside and outside Estonia, and since majority of the available capacity in Estonia is coal power plants their generation will increase with decreased coal price or increased natural gas prices. A reduced natural gas price will reduce the Estonian generation, as these plants are mainly found outside Estonia in this scenario.

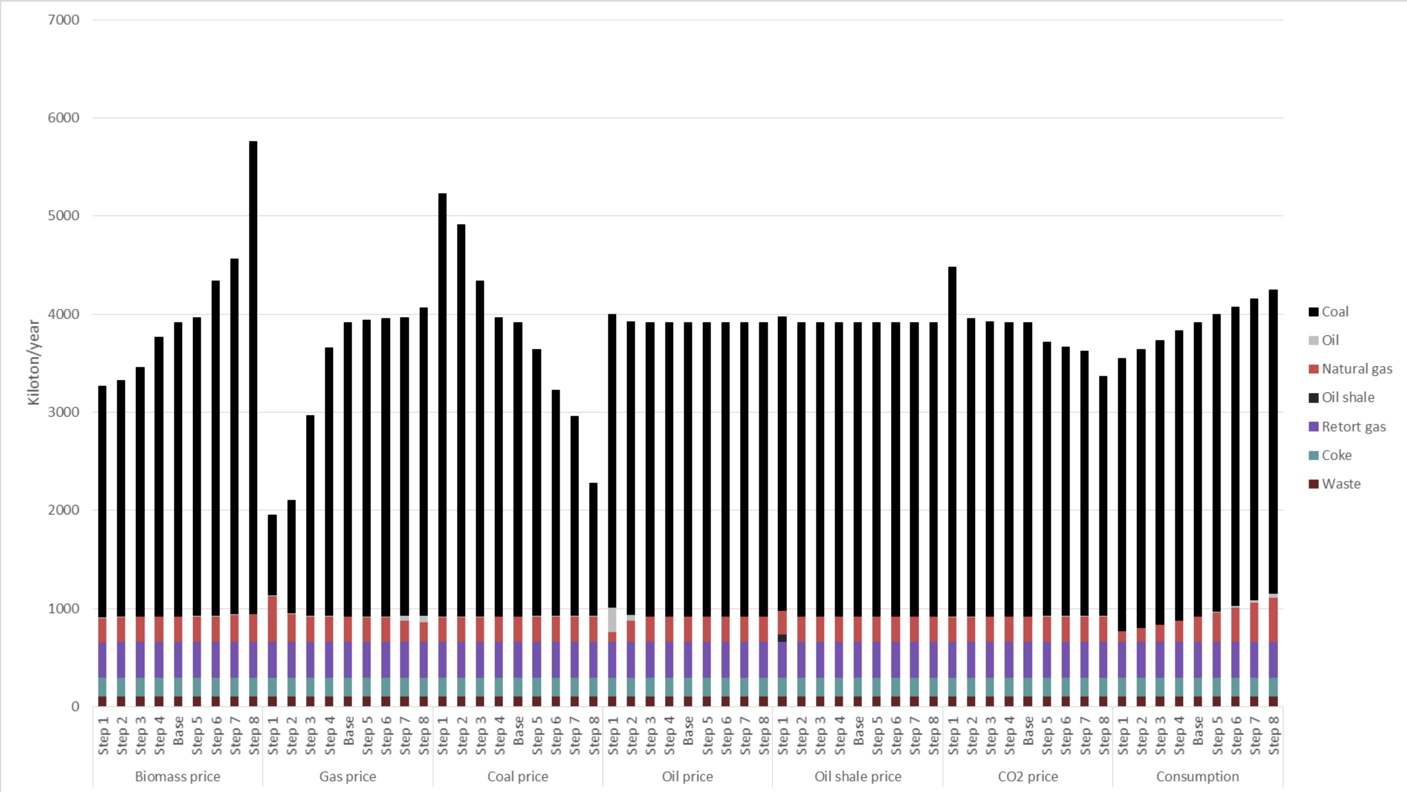

Figure 52: Estonian CO_2 emission in 2030 when fuel and CO_2 prices are de- and increased. Liberal scenario. "Base" indicates no change in parameter variation and is therefore the same in all variations.

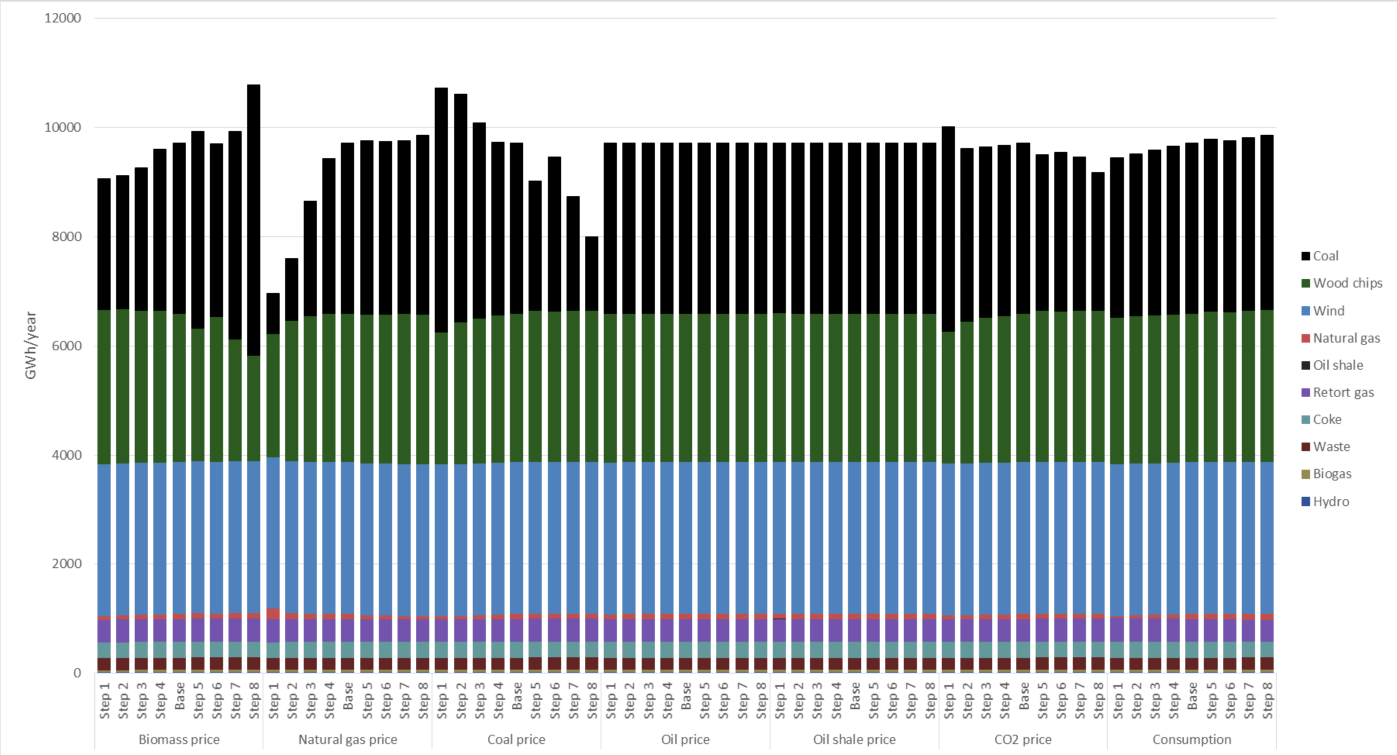

Figure 53: Estonian electricity generation in 2030 when fuel and CO_2 prices are de- and increased. Liberal scenario. "Base" indicates no change in parameter variation and is therefore the same in all variations.

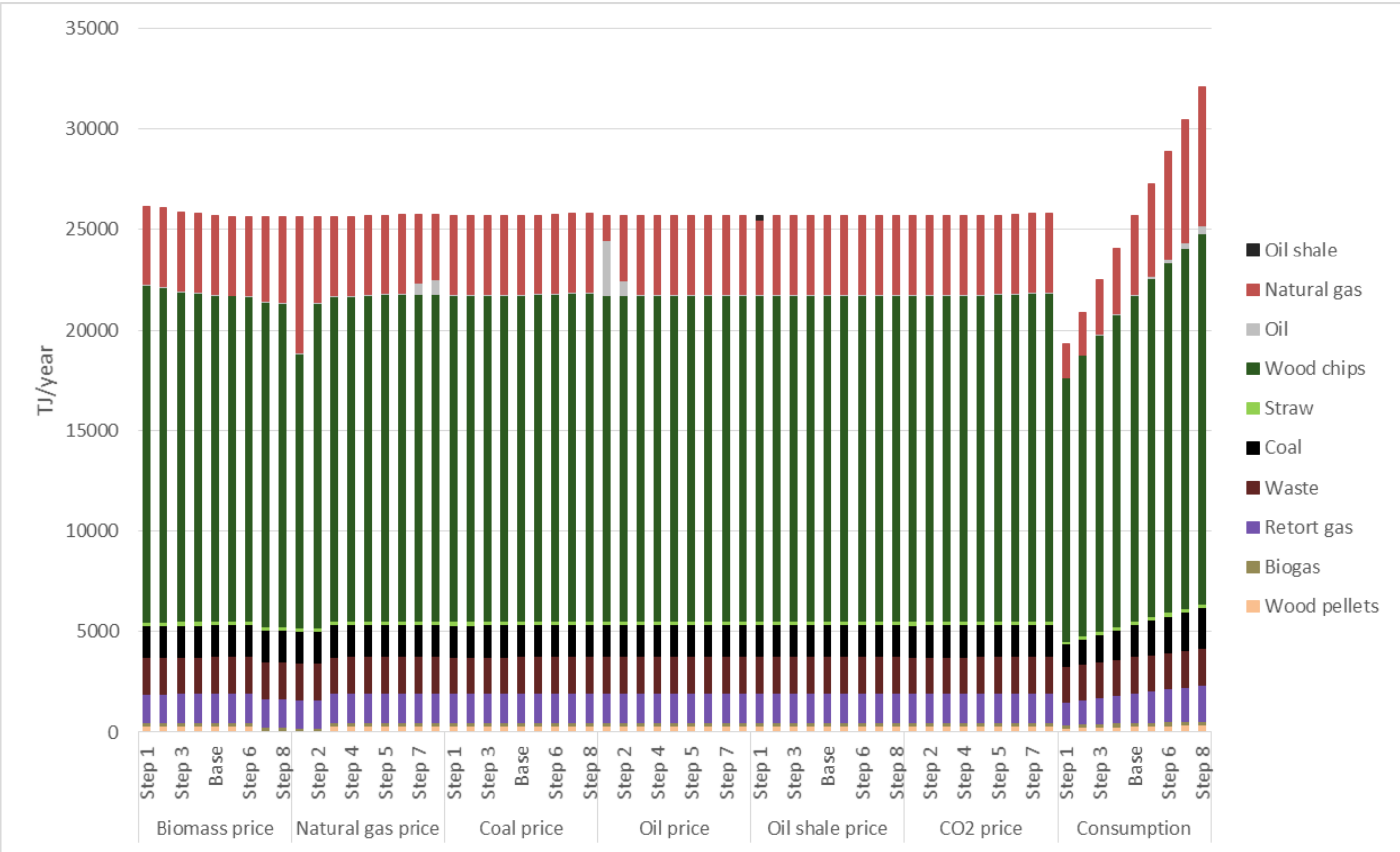

Figure 54: Estonian heat generation in 2030 when demand, fuel and CO_2 prices are de- and in-creased. Liberal scenario. "Base" indicates no change in parameter variation and is therefore the same in all variations.

7 The complete picture

Energy consumption for electricity generation and district heating is modelled in BALMOREL, while energy consumption for individual heating, transport and industry is modelled in STREAM. Below the development for the entire energy sector is shown. The chapter focuses on three of the scenarios: liberal market, CO_2-collaps and CO_2-concern.

Note that the losses associated with the production of shale oil is included in the graphs, while the export of diesel is not included. This approach is similar to how e.g. industrial production is typically treated. The CO_2 emission resulting from the shale oil production is substantial.

In the long term total energy consumption decrease in all three scenarios but most notably in the CO_2-concern and only slightly in the CO_2-collapse scenario. In all three scenarios fuel consumption is reduced dramatically in the power sector as the oil shale is prioritised for shale oil production. On the other hand a new energy consumption is introduced here due to the 30% conversionen losses associated with the processing of oil shale (termed oil shale diesel in the graphs). The production of shale oil is assumed to remain constant in all three scenarios throughout the period and likewise the energy losses.

In the both liberal scenario and particularly the CO_2-concern scenario the share of wind power increased markedly over time, and since wind power per definition produces electricity at 100 % efficiency this contributes considerable to reducing gross energy demand. The increasing share of combined heat and power in the heat supply as well as the gradual introduction of new state of the art power plants with high electric efficiencies also contribute to the reduction of energy demand.

Moreover, in the CO_2 concern scenario final energy demand decreases as this scenario builds on the energy efficiency scenario for the demand side, which assumes significant reductions in the demand for heating, electricity and transport fuels.

Coal plays an important role throughout the period in the CO_2-collapse scenario, whereas its contribution is marginal in the CO_2-concern scenario, which relies heavily on renewables (when ignoring the energy losses from shale oil production).

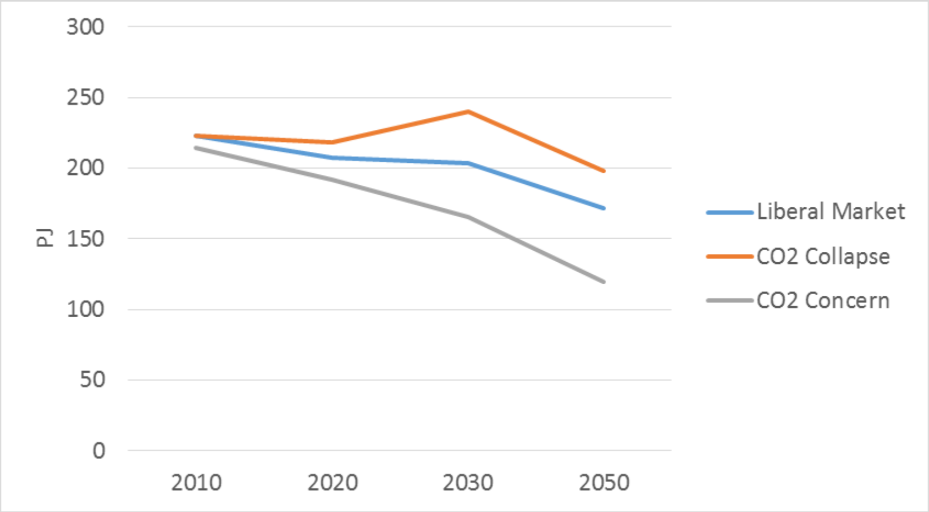

Figure 55: Total energy consumption for three scenarios (gross energy demand).

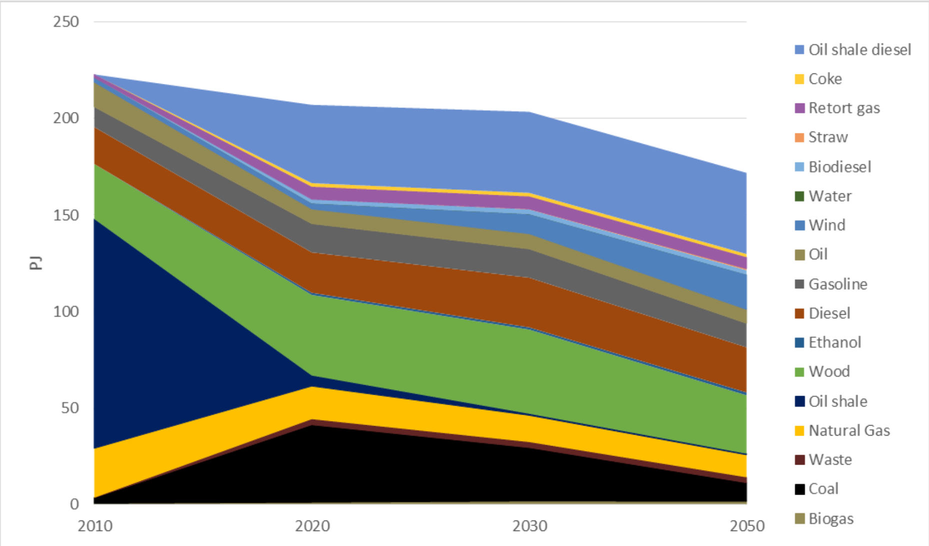

Figure 56: Total energy consumption in BAU liberal market scenario (gross energy demand).

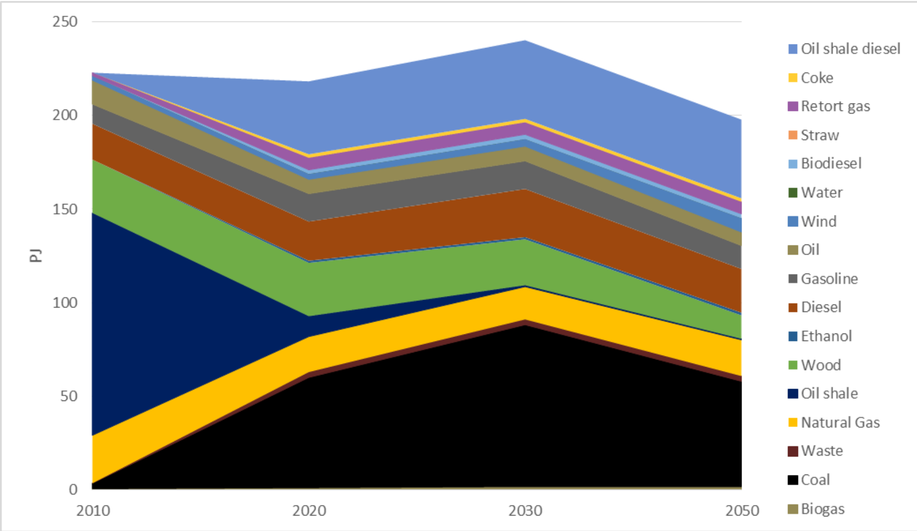

Figure 57: Total energy consumption in BAU CO_2 collapse scenario (gross energy demand).

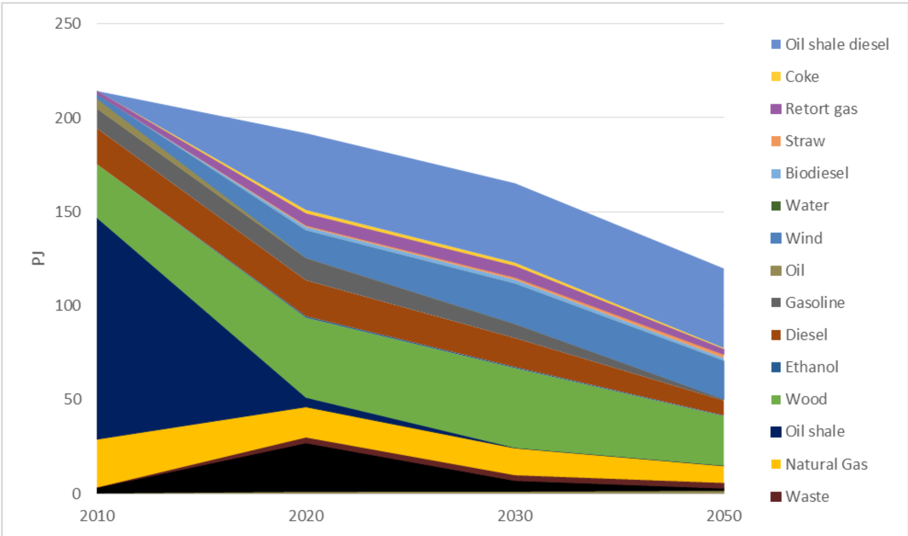

Figure 58: Total energy consumption in EE CO_2 concern scenario.

The emissions of CO_2 in the scenario reflect the composition of the gross energy demand. In the long-term emissions are reduces in all three scenarios as the amount of fossil fuels decrease. Today CO_2-emissions from the combustion of oil shale are very dominant and the new utilisation of oil shale reduces emissions in all scenarios towards 2020.

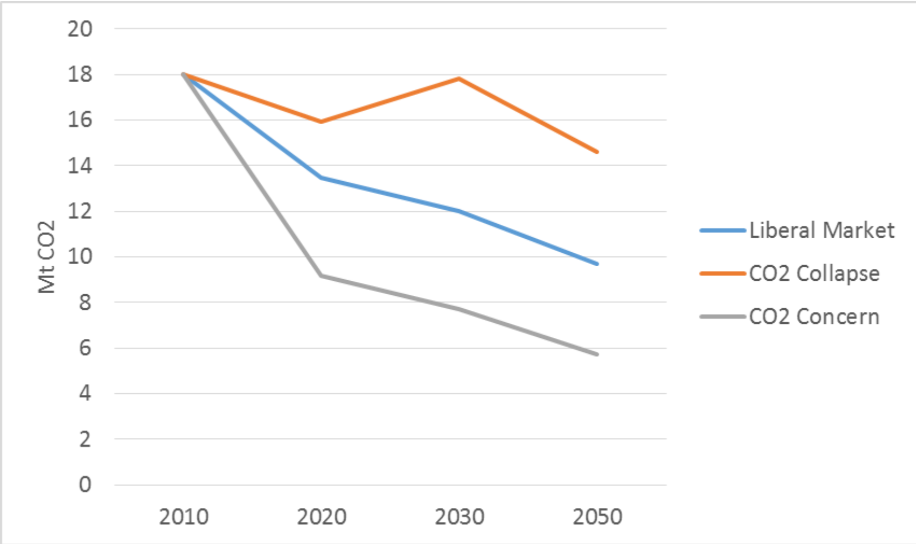

Figure 59: Total CO_2 emission for three scenarios.

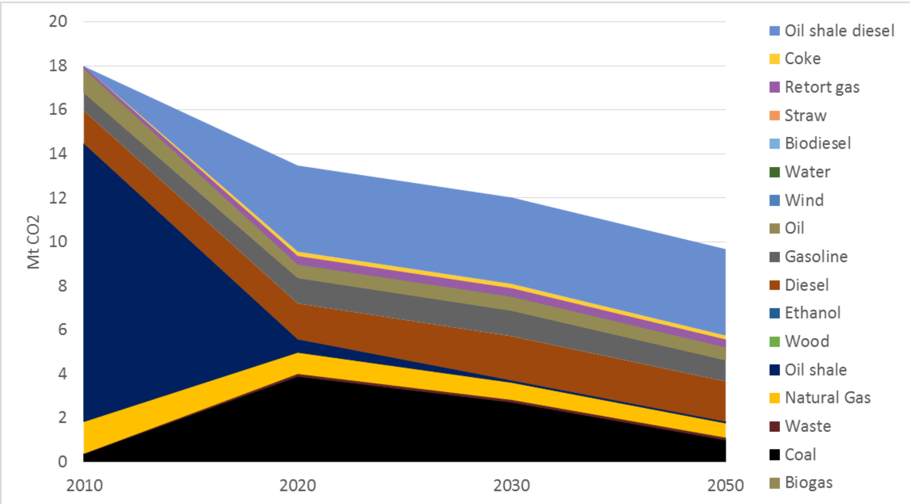

Figure 60: Total CO_2 emission in the BAU liberal market scenario.

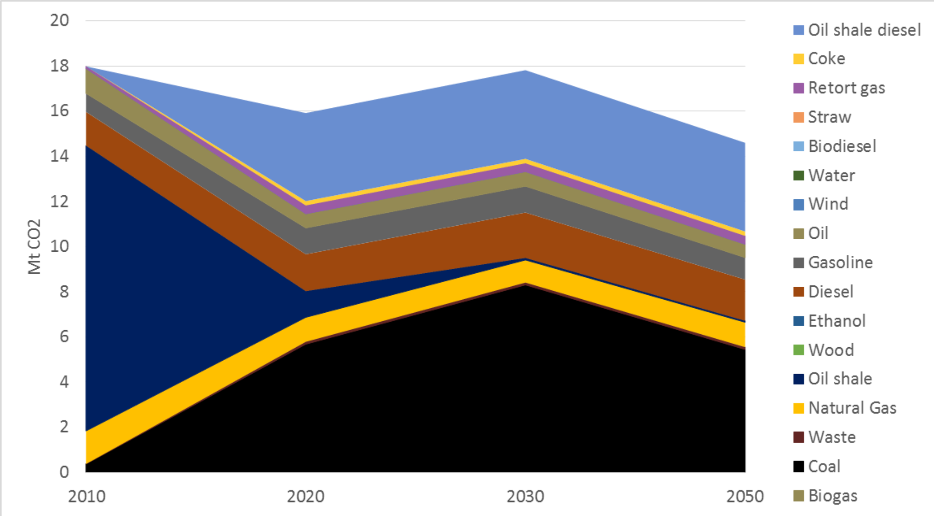

Figure 61: Total CO_2 emission in the BAU CO_2 collapse scenario.

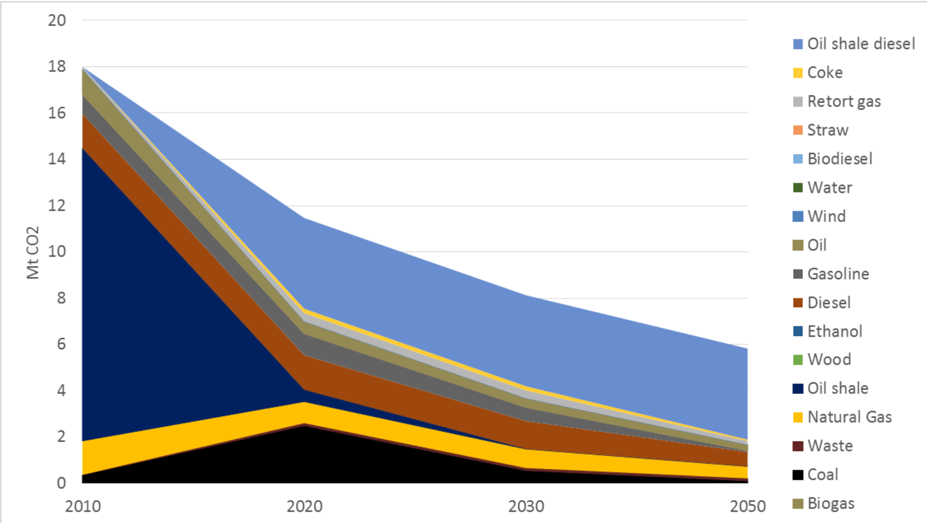

Figure 62: Total CO_2 emission in the EE CO_2 concern scenario.

The share of renewable energy in total energy consumption is illustrated in the figure below. In 2012 the share is calculated to 14 %, which increases to 24.5 % in 2020 in the liberal market scenario. This is close to the Estonian EU target of 25% in 2020. In the longer perspective towards 2030 and 2050 the share increases to more than 30 % in the liberal market scenario. In the CO_2 collapse scenario the share decreases to 14% in 2050, while in the CO_2 concern scenario the share increases to 45% in 2050.

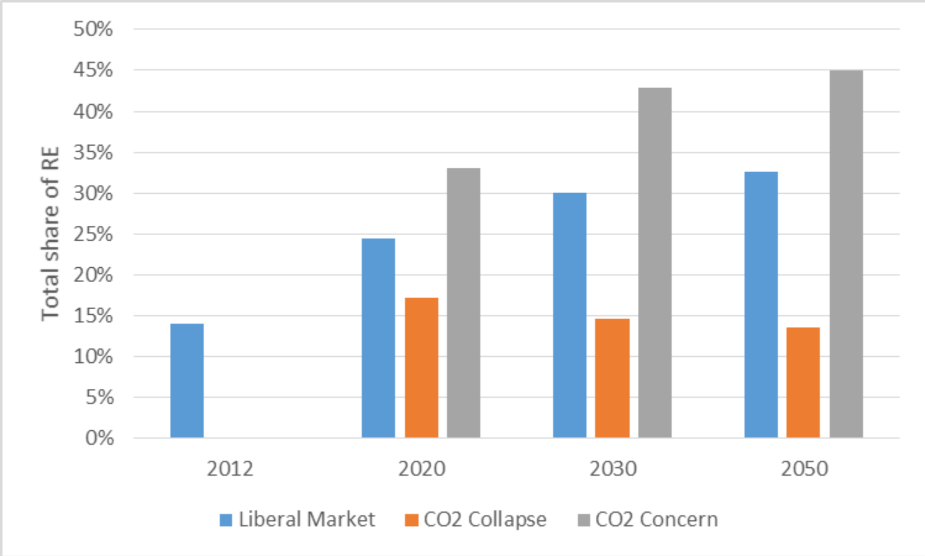

Figure 63: Share of renewable energy of total Estonian energy consumption.

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