north european power perspectives

Executive summary

NEPP mid-term report

May 2012

The NEPP mid-term report

The purpose of this report is to present some of the analyses, results and conclusions that have emerged during the first half of the NEPP project. The analyses and results are presented in short chapters dealing with different aspects of the development of the European energy systems. The Nordic/North European region and the electricity system are focus areas.

The findings are also presented as “twelve statements” that summarize these analyses and results in a way that also provides a summary of the research carried out during the first half of the project. Some of the twelve statements are the key results referred to above, while other statements are hypotheses based on the analyses carried out so far in the project. These hypotheses will be further analysed in the second half of the project.

The NEPP Research Group:

- KTH, Electric Power Systems
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Read more about the project: *www.nepp.se*

1. TWELVE EARLY STATEMENTS

This research report contains analyses and results form the project North European Power Perspectives (NEPP). The purpose of the report is to present some of the key results and conclusions that have emerged during the first half of the project.

The findings are presented as twelve statements that summarize these results in a way that also provides a summary of the research carried out during the first half of the project. Some of the statements are the key results and conclusions referred to above, while other statements are hypotheses based on the analyses carried out so far in the project. These hypotheses will be further analysed in the second half of the project.
Since the project is only halfway to completion, all results and conclusions, as well as the hypotheses, must be regarded as preliminary. All results, conclusions, and hypotheses will be further studied in the second half of the project.

RESTRUCTURING THE ENERGY AND ELECTRICITY SYSTEMS BY 2050 IS A CONSIDERABLE CHALLENGE

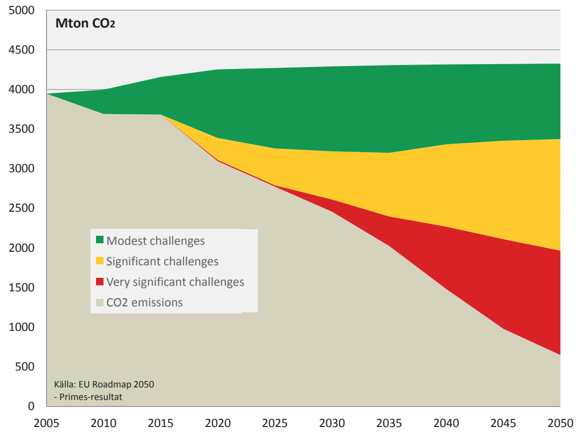
1

Our project has developed a new methodology, based on the scorecard principle, for evaluating the difficulties in restructuring the electricity and energy systems by the year 2050. The methodology has been used to evaluate the difficulties in meeting the goals set out by the European Commission in its Energy Roadmap 2050, and has also been applied to our four NEPP scenarios. Both the Roadmap and all NEPP scenarios assume very large reductions in greenhouse gas emissions. Three possible conclusions from our evaluation are:

- The challenges are so great that the likelihood of fully reaching all targets is low.
- All scenarios and roadmaps are more or less equally challenging.
- The challenges ahead (2012 to 2050) are far greater than the difficulties that were encountered during the period 1970-2012.

Some of the proposed measures are very uncertain

One of the significant challenges facing the EU is the introduction of Carbon Capture and Storage (CCS) and the development of CO_2-infrastructure, i.e. sites suitable for the long-term storage of CO_2. CCS has not been applied at large scale anywhere in the EU, and public acceptance for the technology seems to be very low. Whether CCS is available at large scale in the next 20-30 years is therefore highly uncertain.



Reduction in carbon emissions according to the Scorecard, in the EU roadmap - Diversified supply technologies scenario.

It is also highly uncertain if the system will deliver the necessary generation capacity and transmission infrastructure required for an electricity sector dominated by intermittent renewables. Equally uncertain is the Roadmap's ambition to electrify the transport sector, as it entails replacing nearly all vehicles and building a new electric transportation infrastructure from scratch. Many of the underlying technologies are close to the point where they become commercially feasible, but it is important to realize that the challenges in electrifying the transport sector by the year 2050 are very significant.

2 NEW POLICY INSTRUMENTS WILL BE NECESSARY, AND THEY NEED TO BE MORE POWERFUL THAN THE ONES IN USE TODAY

In the remainder of the project the scorecard methodology will be further developed to refine the analyses of the challenges in restructuring the electricity and energy systems. A further goal is to develop the methodology so that it can also be used to shed light on what government policies related to the restructuring of the energy system will look like in the future, provided that the restructuring is fully carried out.

One NEPP hypotheses – which will be further analysed during the second half of the project – is that current policy instruments are inadequate for the challenges ahead. The current set of policies may be adequate for some of the minor challenges, but to overcome the major challenges new and more forceful policy instruments will be required. For instance, it is highly unlikely that CCS will be introduced on a large scale without new and powerful government policies.

Using an extended version of the scorecard methodology, we hope that we will be able to determine to which extent the following statements are true:

- Large parts of the restructuring will require new and very forceful policy instruments.
- Policies based on financial incentives and other conventional policy instruments are inadequate

3 SIGNIFICANT REFORM OF ELECTRICITY MARKETS MAY BE REQUIRED

The Nordic electricity market was primary designed to utilize existing resources as efficiently as possible – the ability to replace large parts of the electricity system at lowest possible cost to electricity consumers was never a stated goal of the market design.

This design has worked well for the past 15 years, and the efficiency of the electricity system has in many ways improved. The short-term optimization of the system (dispatch of generation units in merit order) is working well. Cross-border trade has increased over the years, and some excess capacity has been closed down. Customers are beginning to be part of the short-term optimization through spot price-linked contracts, and it has not been possible to show any significant abuse of market power. New market-based policy measures like the EU-ETS have worked as designed: the wholesale price of electricity has increased, as one would expect when the short-run marginal cost is setting the price. However, the ability of the Nordic market design to underpin long-term investment has not yet been fully tested.

Yet, the nature of the European generation mix is undergoing a profound change as a result of European climate change and renewable energy policy, and it is not immediately clear that the Nordic market design is the most suitable for the energy systems of the future, especially if the transformation of the electricity system is to be carried out at minimum cost to electricity consumers.

There are three main aspects to consider when analysing this issue; risk, coordinated investment decisions, and costs to consumers:

- The risks associated with investments in generation capacity and transmission under the current market design are rather high, and the risk will increase as the share of renewables connected to the system increases. In addition to electricity market risk, there is also a price risk stemming from the carbon market.
- The existing Nordic market design does not provide an adequate solution for how to best coordinate transmission and generation investment decisions.
- Market pricing in electricity markets is equivalent to short-run marginal cost pricing. This is an efficient way to price electricity when it comes to short-term utilization, but can at the same time increase costs to consumers compared to other pricing schemes. This would most likely be the case when there are significant needs for new investment.

REFORMATION OF THE EUROPEAN ELECTRICITY MARKETS IS AT A CROSS-ROADS - MORE MARKET OR MORE PLANNING

4

- *If a more market-oriented approach is selected, capacity markets and nodal pricing should be considered.*

The target model for the single European market is being challenged even before it is implemented. Large amounts of electricity generation from renewable energy sources will change the market conditions. The European electricity markets reform is at a crossroads.

The variable and intermittent nature of renewable generation means that it cannot be depended on to meet demand reliably. As a result, large amounts of renewable generation will have to be complemented by large amounts of flexible thermal generation, so the overall installed capacity to meet a certain demand will be higher than in today's electricity markets. The risk of not being dispatched faced by conventional generation with higher marginal costs will increase, and more conventional generation will be idle for longer periods. In addition, for periods when the renewable output is high, the market's clearing price will be lower as large amounts of near zero marginal cost generation will likely depress the wholesale price of electricity. To compensate for fewer running hours and lower prices, conventional generation is likely to resort to offering its generation to the market at costs significantly above short-run marginal costs when the wind is not blowing and demand is high, leading to increased price volatility and occasional extreme prices significantly above the "normal" cost of the price setting unit. This may alienate the public, and may put pressure on politicians to intervene. Revenue uncertainty will increase, investments in electricity generation capacity will become riskier, and the cost of capital will go up, jeopardizing investment.

In four Market Design scenarios we will analyse the appropriate response to these new challenges. Will it be possible to keep the current market design with only "minor" adjustments, like increased demand flexibility, or is there a need for more interventionist approaches aimed at reducing the risk to generators and requiring a more fundamental redesign of the market?

We will analyse four Market Design scenario:

1 **Energy-only** (the Nordic market model for Europe)

2 **Capacity market** (addition of a separate capacity market creating income for capacity even if not used)

3 **Locational Marginal Pricing** (a combination nodal pricing that incorporates the costs for network losses and network congestion into electricity prices and locational capacity markets)

4 **Detailed regulation** (increased central planning and consumer price based on average cost)

Currently it seems like several European countries are opting for redesign and are planning reforms not envisioned by the European target model. For instance, several countries are opting for different types of capacity mechanisms to reduce reliance on price spikes to recoup capital costs. Both the UK and France have decided to introduce sector-wide quantity based mechanisms by 2015. Poland and Italy have similar plans, and Germany is currently discussing the issue. Poland is also planning to introduce Locational Marginal Pricing to facilitate investment decisions through more efficient locational price signals.

In addition to concerns about the financing of generation investments, there are several other issues to be considered. Large variations in generation over both time and space will further strain electricity networks, thus making both efficient expansion and utilization of the grids increasingly important. Demand side engagement should be encouraged and improving locational price signals should be investigated.

5 WE MUST ANALYSE THE POSSIBILITY TO USE EXISTING RESOURCES FOR MORE BALANCING PURPOSES IN PARALLEL WITH THE INVESTMENT ANALYSE FOR NEW RESERVE CAPACITY

As the volume of variable renewable generation such as wind power and solar power continues to increase, more flexibility in the form of modified generating schedules for other units or more demand flexibility will be required in order to continually balance the electricity system to match supply and demand.

Not all reserve capacity resources are equally flexible, i.e. can be activated to provide balancing energy equally fast. It is therefore useful to look closer at what we mean by “need” and “reserve capacity” when analysing the “need for reserve capacity”.

When analysing “reserve capacity”, it is also important to separate between variability and uncertainty:

- Variability - which is obtained from load changes and wind and solar power changes.
- Uncertainty - which is obtained from the difference between forecasts and real outcome for load, wind/solar power, thermal power and interconnections.

Concerning “needs” it is important to consider the distinction between technical and economic needs, and that there is a competition between three technologies/options:

- Production flexibility
- Consumption flexibility
- More and flexible transmission

Our analyses lead to the following results and statements so far:

- More wind and solar power will increase the need for reserves, but not automatically result in a comparable need for investments.
- The big question is what will happen with existing firm capacity in the system. Will it be kept or will it be decommissioned due to few expected operation hours adding to the need of an increased strategic reserve or other market design initiatives.

The effect of cross border trading cannot be ignored when new generation is considered

In the debate surrounding new investment in renewable generation, especially wind power, it is common to hear statements like “X TWh of additional low marginal cost generation capacity in Sweden will depress Swedish electricity prices by Y SEK/MWh”. Often, the effects of cross-border trading are overlooked, but the validity of such statements cannot be properly assessed without considering the impact of cross-border trading.

To verify if such a statement is true or false, the usual procedure is to compare the “original” system with the “new system”, i.e. the original system + X TWh. The “consequence” of additional generating capacity is then given by the difference between the results obtained by running these two different scenarios. When modeling, the following properties of the Swedish electricity system have to be taken into account:

a) Demand, not being very price sensitive, will be about the same in both scenarios.
b) Electricity generation in the other Swedish units, except hydro power scheduling, remains roughly the same. This is because foreign thermal price-setting units have higher marginal costs than Swedish price-setting units, so any additional cheap Swedish generation will primarily displace foreign price-setting units.
c) Hydropower resources will be scheduled differently depending on whether the additional capacity (X TWh) is wind, nuclear or CHP.

In summary, the accuracy of the statement “X TWh of additional generation capacity will depress electricity prices by Y SEK/MWh” will depend on several factors, most notably the steepness of the supply curve of the electricity systems to which Sweden is interconnected. This is valid for all additional generating capacity with low short-run marginal costs and is not limited to wind power.

CONVENTIONAL TECHNOLOGY IS A KEY PLAYER, WHILE TRANSMISSION GRID AND CCS INFRASTRUCTURE ARE CRITICAL

6

The model analyses conducted so far clearly indicate that far-reaching climate-policy targets within the European electricity generation system can be fulfilled with, to a large extent, relatively conventional technology. Even though the share of renewables steadily increases over time in the model runs, a very large contribution may still originate from fossil fuels in the future. The key to this is the assumed availability and commercialisation of CCS technology. In the main scenarios analyzed so far, CCS schemes account for 30-50 percent of total electricity supply in 2050, depending on the region (the sole exception is the Nordic region where renewables are the main providers of electricity and CCS is not profitable). This is, of course, a very important precondition. If, for some reason, CCS will not become commercialized during the coming decades, the development of the European electricity-generation system will be significantly different from what has been shown hitherto, given ambitious climate targets.

However, regardless of whether CCS becomes commercially viable or not, the dramatic change in electricity supply towards low CO_2 emissions will inevitably lead to significant investments in supply-related infrastructures. In the case of CCS, this would include investments in CO_2 transportation and disposal. In the case of renewables such as wind power this may include large reinforcements of electricity transmission and distribution grids. In some scenarios and European regions the future demand for biomass becomes of substantial size. Even though it may be achievable from a supply-side point of view such as development will undoubtedly imply major logistic and infra-structural challenges.

Since the lion share of the technologies identified in the future development of the European electricity-supply system may be characterized as ”conventional”, the key challenges ahead lie less in the technologies per se but rather in the task of putting them altogether into a secure and clean system that provides us with energy at reasonable costs. Even CCS consists of relatively known and proven technology – the challenge is to merge it together into an efficient large-scale electricity-generation system. Such challenges include not only infra structural challenges but also other important factors such as public acceptance. A mixed balance including many technological options and resources is, therefore, desirable not only from a security-of-supply perspective, but also due to the fact that a very large single share of each and one of the key technologies identified here (CCS, biomass, wind power, nuclear power etc) requires enormous investments in infra structure and may be negatively perceived in the eyes of the public opinion.

ELECTRICITY PRICES ARE EXPECTED TO RISE – BUT CARBON PRICES AND CERTIFICATE PRICES RISE EVEN MORE

7

The four NEPP electricity system scenarios show different electricity price development. There is however, one thing in common; increasing prices. When we discuss electricity prices it is in specific situations important to make a distinction between system prices (wholesale prices) and final use prices (retail prices). The difference appears when we apply a support system (e.g. a certificate system) to support renewable electricity generation. In that case the final users, in addition to the system price of electricity, will have to pay for a fraction of the electricity certificate. The electricity price, including possible certificate fees, typically reaches 600 – 800 SEK/MWh by the year 2050 (compared to around 400 – 500 SEK/MWh today). As could be expected the electricity price is typically higher in scenarios with the most ambitious renewable energy and/or climate ambitions. (Prices are discussed in more detail in Chapter 3.)

If we in the scenarios where a certificate system is applied assume that – like today - only a fraction, approximately 50 %, of the electricity users would be included in the electricity certificate system and forced to pay for a fraction of the electricity certificates, the retail price would of course increase even further. Here the long term electricity price reaches 1000 – 1200 SEK/MWh. The other electricity users can in these cases enjoy fairly low electricity prices.

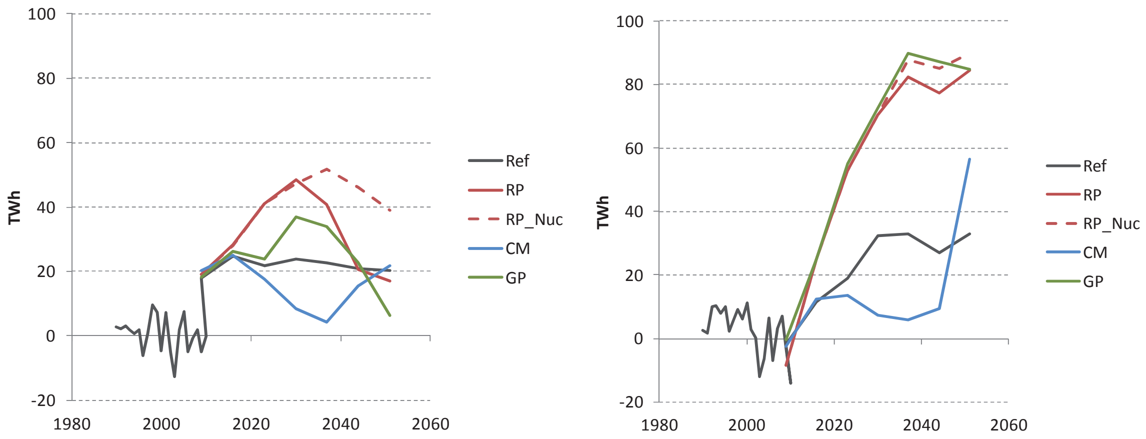
In order to reach a development that is in line with e.g. the 2 degree climate target, very high levels of CO_2 prices will be needed, especially if this is the only policy instruments applied. Our ELIN model runs indicate long term levels of 150-280 €/ton. (This could be compared to the present levels of less than 10 €/ton).

One way of moderating the CO_2-price is to introduce additional policy instruments, e.g. for the promotion of renewable energy. In the NEPP scenarios two of the scenarios include a European electricity certificate system. The high renewables ambitions results in marginal costs for such certificates in the range of at least 300 – 500 SEK/MWh (as described above).

8 SWEDEN WILL BECOME THE LARGEST ELECTRICITY EXPORTER IN NORTHERN EUROPE. WHAT ABOUT THE ROLE OF NUCLEAR POWER?

In the NEPP scenarios the Swedish net electricity export constitutes a dominating part of the common Nordic export up to around 2030.

As seen in the figure the Swedish net export is typically in the range of 20 – 30 TWh/year by 2030, with extremes of 5 – 50 TWh/year. A combination of constant use of nuclear power and strong support for renewable electricity generation facilitates this large export. But the Swedish share of Nordic export decreases significantly in the scenarios, when all Swedish nuclear energy is phased out.



Net electricity export in the four scenarios (Sweden to the left and the Nordic region to the right)

In all scenarios Sweden and the Nordic region act as net exporters of electricity. The Nordic export reaches 80 TWh by 2040, in two of the scenarios (Regional policy and Green policy). At the Nordic level it is interesting to note that the effect of large efforts to expand renewable generation is more important than the effect of continued use of nuclear power. The two NEPP scenarios with nuclear phase-out in Sweden both include strong support systems for renewable electricity generation, and the effect of these policy instruments create more electricity generation than is lost through nuclear phase-out. The scenarios with low or moderate long term support for renewable electricity, results in lower net Nordic electricity export for different reasons, even if nuclear power is kept constant at a high level. The Reference scenario is characterized by low electricity demand and a lack of long term support for renewable electricity. The Climate market scenario combines high domestic Nordic electricity demand and moderate expansion of renewables.

Nordic electricity production: production levels not expected to change dramatically; the challenge lies in ensuring sufficient capacity

The Regional policy and Green policy scenarios are characterized by a decrease in thermal production in favour of variable, and partly intermittent, renewable generation. These generation sources have a certain lack of predictability and reduced capacity value in common. In the Green policy scenario such generation amounts to 55 % of the total Nordic generation in 2050. This forms certain challenges for the electricity system that is discussed in Chapter 3.

This structure of the electricity generation in the Nordic system is problematic from capacity point of view, especially since we foresee a similar development in the rest of Europe. Will market prices on an “energy only market” be sufficient enough to give incentives to build the necessary reserve capacity? This could create a situation with reduced delivery security and/or extreme price volatility. One solution to this is to establish a capacity market. This is discussed further above, and in Chapter 4.

ELECTRIC VEHICLES ARE IMPORTANT FOR A DECARBONIZED TRANSPORT SECTOR – BUT THE EU DOES NOT BELIEVE THAT THE TRANSPORT SECTOR WILL BE LARGELY ELECTRIFIED IN THE NEXT 20 YEARS

9

Electric vehicles, including plug-in hybrids, is an important alternative for the transformation of the transport system. In Sweden we have an ambition to make this change during a short period, in order to make the transport vehicle fleet independent of fossil fuels by 2030. This puts great demand on introduction of electric vehicles and indirectly on the electricity system. In the Swedish Transport Administration´s most ambitious scenario (”Målbild för ett transportsystem som uppfyller klimatmål och vägen dit”, report 2012:105) they assume 1 000 000 electric vehicles by 2030. This puts special focus on the capacity situation and a number of studies are made within the NEPP project to evaluate the impact on the electricity system and on the electricity market.

Simultaneously we can see that our Swedish ambition regarding a rapid transformation of the transport system is not in line with the EU target. The EU Roadmap shows a much more moderate transformation to 2030, and specifies the period 2030 – 2050 as the main transformation period for the EU transport system.

THE CLIMATE TARGETS IN THE NORDIC REGION (AND THE EU) ARE MORE FAR-REACHING THAN THOSE SPECIFIED BY IEA IN ETP 2012

10

NEPP is the Swedish partner in the IEA project to develop a Nordic ETP – a Nordic subproject of the IEA global project called ”Energy Technology Perspectives”. The main scenario in the global ETP is a “two degrees scenario” where by 2050 global emissions are reduced by 50 % compared to 2009 levels.

For the EU, IEA calculations point to carbon emissions that in the year 2050 are 60 % lower than in 2009. However, the main scenario in the Roadmap is about an 85 % reduction in greenhouse gas emissions.

For the Nordic region, IEA foresees in its main scenario that greenhouse gas emissions will be reduced by 60 % between 2009 and 2050. It should be noted that this reduction is much lower than current national targets. For instance Sweden has a climate goal that states that “Sweden should not have any net greenhouse gas emissions by the year 2050”.

According to the IEA, this difference in the target levels is based on a difference in how the global target is allocated among countries and regions. The IEA allocates less of the total target to the EU than the EU itself does.

THE EU MAY FAIL TO REACH ITS 2020 RENEWABLES TARGET

11

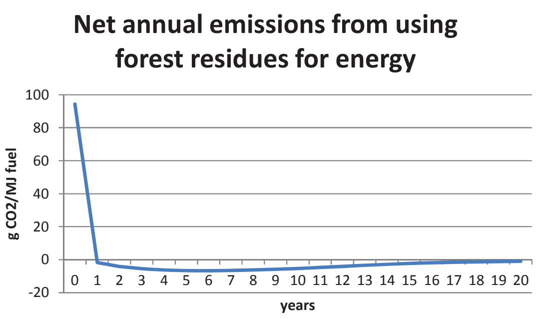
At present, the official line from the EU and Member States is that the EU will reach its targets to reduce greenhouse gas emissions by 20 % and increase its share of renewables to 20 % by the year 2020. The national Progress Reports on the promotion and use of energy from renewable sources and describing the Member States’ progress in increasing their use of renewable energy show that the renewable sub-targets for the year 2010 were reached. Emissions reduction progress reports were also positive. However, analyses performed by NEPP show that the optimism about the renewables target might be misplaced.

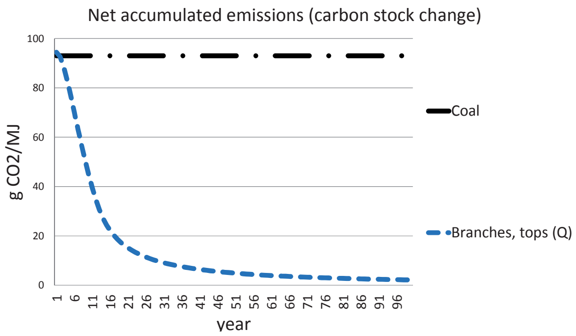
NEPP believes that it is far from certain that the EU will reach its 20 % renewables target by the year 2020. This belief does not stem from scepticism over the renewable energy increase. It is based on the belief that Member States will not be able to reduce growth of overall energy demand sufficiently to reach the goal. The renewables target is a relative target – the amount of renewable energy production divided by the total use of energy (expressed as final energy).

However, given our analysis of the link between total energy demand and fulfilment of the renewables target, we believe that a new Energy Efficiency Directive may contribute to the fulfilment of the renewables target. It may even be necessary to have a more robust Energy Efficiency Directive in place for the EU to reach its renewables target.

12 BIOFUELS ARE NOT CLIMATE NEUTRAL – BUT THEY ARE STILL IMPORTANT IN A LOW-CARBON ENERGY SYSTEM

When biomass is combusted the carbon that once was bound in the growing biomass is released, thus closing the biogenic carbon cycle. For this reason bioenergy is often considered CO_2 neutral. For instance, CO_2 emissions from the combustion of bioenergy are not included in the EU ETS. However, bioenergy production may influence biogenic carbon stocks and atmospheric CO_2 significantly in either a positive or negative way. Using logging residues or stumps for energy instead of leaving them in the forest, will lead to an instant release of carbon to the atmosphere. However, this effect is of transient character. If forest residues or stumps are left in the forest, the major part will decompose over time and release carbon to the atmosphere. The net effect of using forest residues for energy can therefore be described as a pulse emission at t= 0, which is compensated over time due to the avoided emissions from leaving the residues on the ground to decompose, see figure below.





Net annual emissions (left) from using forest residues as fuel and net accumulated emissions (right).

The accumulated climate effect is obtained by integrating the diagram over time. This is done in the figure above (right) and compared to the corresponding graph for using coal. The figure shows that over a 100 year perspective the use of branches and tops are close to being carbon neutral. Over 10 years, however, the net CO_2-emissions are approximately 40 % of those from using coal for energy. The climate impacts of biofuels due to how they influence carbon stocks over time can be implemented in models in different ways:

1. **Either neutral or not.** A biofuel is considered carbon neutral if the time integrated carbon emissions, over a given time perspective (as calculated by principle 2 below) are lower than predefined value.
2. **Time integrated emissions**. Emissions are integrated over a given time perspective, for instance over 20, 50 or 100 years and this value is attributed to the biofuel. For instance for forest residues the integrated emission factors would be approximately 15, 5 and 2 g CO_2/MJ fuel for 20, 50 and 100 year time perspectives respectively.
3. **Time dependent emission factors**. The annual emissions and uptake, as presented in figure 2 are used. In other words, if 1 MJ forest residues are combusted there will be an instant release of 94 g CO_2 at t=0, followed by annual uptake of CO_2 from year 1 and forward.