EUROPEAN
pathways

NEWSLETTER FROM »PATHWAYS TO SUSTAINABLE EUROPEAN ENERGY SYSTEMS«

#3/2011

Filip's column

"As can be seen from this newsletter we have participated in several international meetings and conferences. This has been stimulating for all of us and has made it possible to communicate and further stress some of the important results from the Pathways project as well as getting inputs to the on-going and continued work.

cont'd on page 2

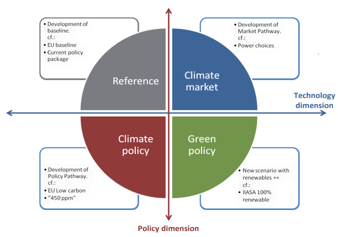
Prof. Filip Johnsson
Project manager of
the Pathway project

Impact of the German nuclear phase-out

The recent German governmental decision on the future of nuclear power in Germany, implies phase-out all 17 reactors by 2023 and the immediate shutting down of 8 of the 17 today operational nuclear reactors. The consequenses of this nuclear phase-out has been analysed by applying techno-economic energy systems modeling. The analysis considers both short-term and the long-term perspectives.

The analysis indicate that as a consequence of taking eight reactors out of operation (corresponding to 60 TWh reduction in supply), the increase in short-run marginal electricity cost generally remains below 4 €/MWh in the German electricity market during a calendar year.

read more on page 4



Workshop for the Pathways energy system modeling group

page 3

The linkage between bioenergy and water

Bioenergy and water are inextricably linked. The availability and quality of water will be an important factor determining to what extent bioenergy can contribute to the overall energy mix. Increased production and use of bioenergy products are likely to lead to increased pressure on water resources unless well managed. However, proper integration of bioenergy systems into forestry and agriculture can reduce some of the impacts of present land use, such as eutrophication and soil erosion. These issues are of emerging concern in bioenergy research.

read more on page 6

The Pathways research network is expanding

page 8

Geographical allocation of wind power

The choice of wind power allocation is influenced by factors such as wind conditions, distance to load and the power system in place (generation and transmission capacities). In order to maximize utilization, wind investments obviously have to be at sites with favorable wind conditions. On the other hand, the prospects of minimizing transmission investments can motivate wind investments close to load centers in spite of less favorable wind conditions.

read more on page 7

Licentiate seminar:

Realise the Potential!
- Cost Effective and Energy Efficient District Heating in European Urban Areas

page 8

Pathways to Sustainable European Energy Systems is a project within THE AGS The Alliance for Global Sustainability

Filip's column

As can be seen from this newsletter we have participated in several international meetings and conferences. This has been stimulating for all of us and has made it possible to communicate and further stress some of the important results from the Pathways project as well as getting inputs to the on-going and continued work.

An interesting experience for me personally, was the possibility to take part in the meeting "Global Challenges in Asia: New Development Model and Regional Community Building" arranged by the Seoul National University Asia Center (SNUAC). It was clear from the meeting that although there are significant challenges in Asia, there is also a tremendous momentum and optimism in the development which, perhaps, may be compared to the prospects in the 60s and 70s in Europe. Yet, it is also clear that a difference from the previous European expansion is that the development is now associated with significant and well known environmental challenges, most notable the climate change and related effects. In addition, the European view, which I think is widespread among decision makers and politicians on wanting to take the lead in the global climate change mitigation work is a challenging standpoint, considering the tremendous momentum in the Asian economy. Thus, it is likely that international co-operation and understanding will be increasingly important in order to find common solutions to the global challenges which, after all, are shared between Europe and Asia as well as the rest of the world. Some of the general conclusions from the Pathways project – such as the challenge imposed from the abundance of fossil fuels and need for CCS and that all technologies and measures are required to meet the climate challenge – are valid also in Asia. I communicated and discussed some of these Pathway results in my talk "Global and Regional Energy Challenges to 2050 and Beyond - Experiences from assessing energy pathways for Europe". From the discussion in the Asian forum I can conclude that there is not only Global Challenges in Asia but also in Europe!

In this newsletter we also report from a recent work on the effects of the phase out of nuclear power in Europe, a workshop which discussed Pathway scenarios, the linkage between bioenergy and water and some key issues related to geographical allocation of wind power.

I hope you enjoy reading!

Prof. Filip Johnsson
Project manager of the Pathway project

Pathways at international conferences summer/autumn 2011

During the summer and beginning of the autumn, several of the Pathways researchers have presented their results and research at different conferences, seminars and workshops. A selection of these activities follows below.

Filip Johnsson and **Göran Berndes** were invited to participate in the International Workshop on "Modeling and Policy of CO_2 Removal from the Atmosphere" in Venice, Italy, organized by FEEM in collaboration with Princeton University. The paper *Bioenergy availability and impacts* was also presented.

In June, **Eoin O'Broin** contributed with a poster and associative paper entitled *Quantifying the Energy Efficiency Gap for Space and Water heating in the Residential Sector in Sweden* at the ECEEE Summer Study "Energy efficiency first: the foundation of a low-carbon society" in Belambra Presqu'île de Giens, France.

Erik Pihl attended the International SolarPACES Conference in Granada, Spain, where he also presented his paper *Thermoeconomic Optimisation of Solar Hybridisation Options for Existing Combined-Cycle Power Plants*.

The 6th Dubrovnik Conference on Sustainable Development of Energy, Water and Environmental Systems was held in the end of September. A special session was dedicated to the subject of Geopolitics of Climate Change where **Jan Kjärstad** and **Filip Johnsson** presented two papers: *The importance of CO_2 capture and storage – a geopolitical discussion* and *Fossil fuels: climate change and security of supply*.

Göran Berndes co-organized, in the middle of September, the IEA Bioenergy workshop "Quantifying and managing land use effects of bioenergy" in Campinas, Brazil. This workshop aimed to bring together current state-of-the-art research concerned with assessing land use effects of bioenergy, mitigating negative impacts, and promoting beneficial outcomes.

Filip Johnsson attended in October the Seoul National University Asia Center (SNUAC) Second International Conference with theme "Global Challenge in Asia: From Conflict to Collaboration" where he presented his paper *Global and Regional Energy Challenges to 2050 and Beyond – Experiences from assessing energy pathways for Europe*.

The 10th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants was held in Aarhus in the end of October. At this workshop, **Lina Reichenberg** presented a poster entitled *Dampening Variation in the Northern European Wind Energy Output – Influence of Geographical Location*.

Workshop for the Pathways energy system modeling group

In the middle of September, the researchers working with questions related to modeling the European power generating system within the Pathways framework met up for a two day workshop.

Within the Pathways framework a modeling package has been developed containing different energy system models which are more or less linked to each other. These models are continuously being developed, updated and modified depending on research questions in focus, changes in boundary conditions and to refine the description of the present system as well as potential technology options.

The purpose of this workshop was to elucidate our common as well as individual objectives, needs and demands regarding the models that are developed within the Pathways framework. It was concluded that several of our current research questions relate to the large-scale integration of intermittent power integration and issues associated to the transmission system. For these reasons the following near-term priority areas for model development were identified.

- Elaborate the description of hydro power regarding factors such as reservoir capacity, water inflow profiles, storage equations, and generating technology methods.
- Refine the description of wind power based on more detailed wind data (e.g. spatial resolution, cost classes for wind power)
- Develop model that considers overhead bottle-necks in the electricity transmission network
- Improve the representation of other intermittent power generation (other than wind power) with special focus, initially, on solar power.

Main scenarios

In the first phase of the Pathways project, analysis was focused around two main scenarios, i.e. the Policy Pathway and the Market Pathway in addition to a Baseline scenario. In the second phase, the scenario analysis process is extended to include four different scenarios or pathways: a reference, a climate market, a climate policy and a green policy scenario. These four scenarios will also be applied in adjacent projects, e.g. in NEPP, which will provide an opportunity to put our results into a larger context and exchange data and results.

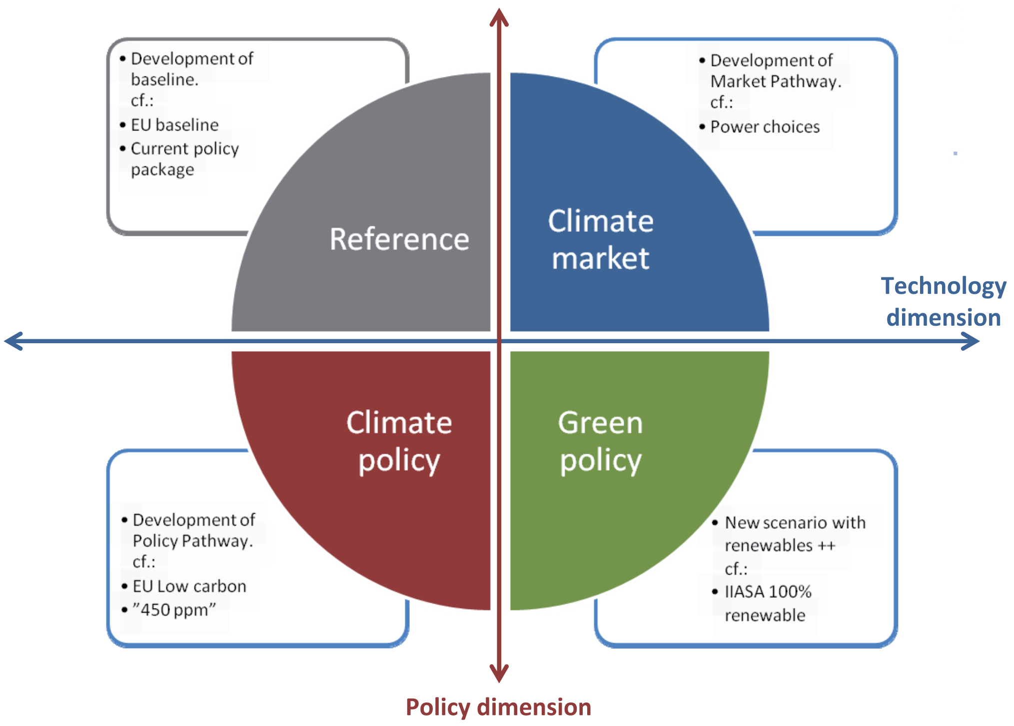


Figure: The four suggested scenarios for Pathways 2

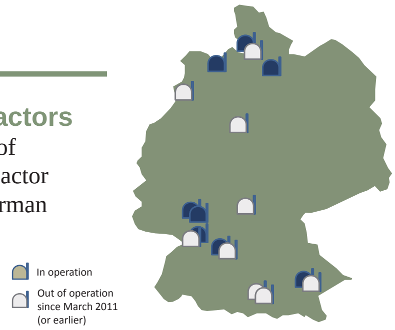
Impact of the German nuclear phase-out - model results

This study applies techno-economic energy systems modeling to analyze consequences of the recent German governmental decision on the future of nuclear power in Germany, i.e. to phase out all 17 reactors by 2023 and the immediate shutting down of 8 of the 17 today operational nuclear reactors. The analysis considers both short-term and the long-term perspectives.

Our analysis indicate that as a consequence of taking eight reactors out of operation (corresponding to 60 TWh reduction in supply), the increase in short-run marginal electricity cost generally remains below 4 €/MWh in the German electricity market during a calendar year. At certain points in time, e.g. during certain peak-load situations, the marginal electricity cost increase may, however, become significantly larger. Unbundled and interconnected electricity markets across Europe lead to cost increases also in Germany's neighboring countries. On the other hand, such cost increases become less significant outside Germany. In the Nordic market, the corresponding price increase rarely exceeds 3 €/MWh during a year compared to a case where all 17 reactors are in operation. The electricity production in the eight reactors is mainly replaced by gas and coal fired power as well as by an annual increase in German net electricity import of approximately 20 TWh.

Compared to a reference case where all 17 reactors remain in operation beyond 2030 (through lifetime extensions), the phasing out by 2023 implies that Germany moves from a significant net exporter of electricity in the long run to instead become a net importer of considerable size. This assumes, however, that no sudden and/or significant capacity deficits occur in Germany's neighboring countries.

German nuclear reactors



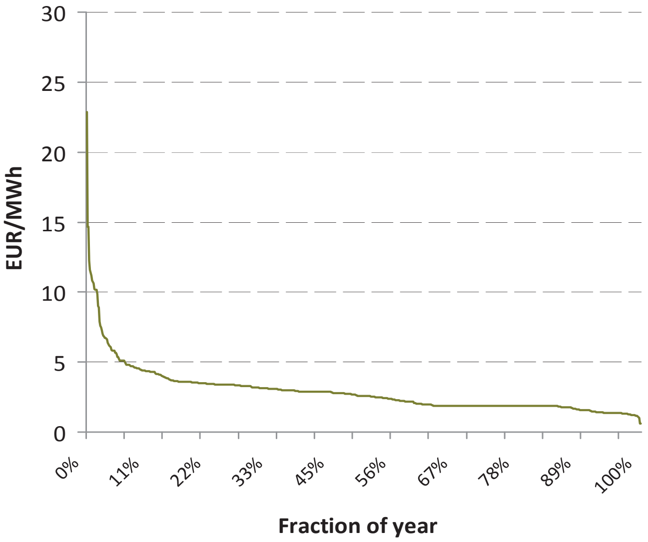
As a direct consequence of the Fukushima nuclear reactor accident in Japan, the German government agreed in June 2011 on a decision to finalize a complete nuclear phase out by the end of 2022. Furthermore, the eight of the today 17 operational nuclear reactors that were closed down as an immediate response to the Fukushima accident in March are not to be brought back on line again. These eight reactors include the seven oldest facilities (commissioned prior to 1981) and one additional unit that has been out of operation since 2009 (the Krümmel plant commissioned in 1983), together corresponding to about 8.5 GW. The aggregated capacity of the remaining 9 reactors is about 12 GW. The figure shows the location of the German nuclear reactors.

Impact on short-run marginal electricity generation costs

Figure 1 (left panel) presents the increase in short-run marginal electricity generation cost in Germany, i.e. the difference from comparing the reference case including all 17 German nuclear reactors to the case where the eight reactors are excluded. In the figure, the increase in marginal cost during 730 days and nights, i.e. a whole year (model year 2010), is depicted according to decreasing order. It can be seen that the increase in marginal cost typically stays below 5 €/MWh. More specifically, more than 80 percent of the model year the increase in marginal electricity generation cost remains below 4 €/MWh. However, at certain points in time it may reach 10 €/MWh (and, occasionally, higher than that). This increase in generation cost becomes less significant in the neighboring countries due to interconnector bottlenecks. In the Nordic market, represented here by Denmark, the increase in generation cost is below 3 €/MWh during 90 percent of the modeled year (see Figure 1 to the right). When looking at Sweden, model results indicate that this cost increase is somewhat lower.

Limited impact on long-run marginal costs

Even though all nuclear reactors in Germany are taken out of operation by 2023, the model-estimated increase in long-run marginal costs of electricity is relatively small, 2-3 €/MWh in Germany after 2020. One of the explanations is that CCS sets the long-term marginal cost for new power post 2020. A withdrawal of other capacity, in this case nuclear, is, thus, replaced by additional CCS implying a limited impact on the long-run marginal costs of electricity. Prior to 2020, the nuclear phase-out is, as indicated above, mainly covered by an increase in gas power (and a reduction in coal power in order to meet the given CO_2-emission reduction target). In a short-to-mid term perspective there is considerate "idle" capacity of gas power in the EU-27 that may supply a large part of the gradually phased-out nuclear capacity in Germany. Furthermore, new interconnectors may be built endogenously in the model as a response to the German nuclear phase-out, which further integrates the European electricity markets. Thereby, the increase in German long-run marginal cost of electricity is spread across Europe and becomes "diluted". In the context of an integrated European electricity market, the total German operational nuclear generation capacity is relatively small, roughly five percent of the total European electricity generation.



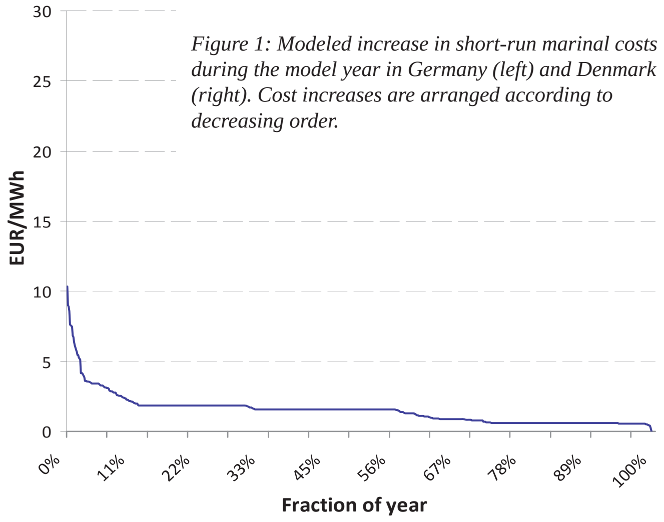


Figure 1: Modeled increase in short-run marinal costs during the model year in Germany (left) and Denmark (right). Cost increases are arranged according to decreasing order.

The corresponding increase in marginal CO_2-reduction cost, a proxy for the price of European tradable emission rights, obtained in the model runs is approximately 1-3 €/t CO_2.

Estimates on wholesale-electricity price increases due to a complete nuclear phase-out differ significantly between different studies. For instance, the Umweltbundesamt (2011) estimates the price increase to around 6-8 €/MWh for electricity and 2-4 €/t for the EU ETS while R2B Energy consulting GmbH (2011) makes corresponding estimates at around 11-16 €/MWh electricity and 5-10 €/t CO_2. Both these studies assume a completed nuclear phase out in 2017 which is a tougher goal than 2023 as assumed here. Thus, if the same phase out year would have been applied in the present analysis, this should generate somewhat higher price increases, all else being identical.

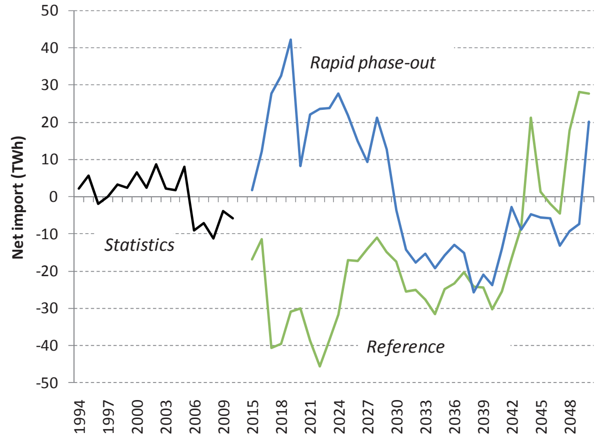


Figure 2: Long-run impact on German net electricity import (trade with Switzerland excluded) as obtained from the modeling in this work.

Future impact on the German electricity-trade balance

The nuclear phase out results in a significant change in the German electricity-trade balance with its neighbors. In Figure 2, net electricity import to Germany is shown for both cases investigated, the reference case and the “Rapid phase-out” case. In the reference case, Germany becomes a significant net exporter, typically 25 TWh around 2020-2025. This is due to a continued expansion in the field of renewables, investments (and comparative advantages) in CCS schemes and, not the least, the full utilization of the 17 nuclear reactors. At the same time, domestic demand is stagnating. In the “Rapid phase-out” case, on the other hand, Germany instead becomes a significant net importer of electricity, typically 20 TWh around 2020-2025. Thus, the short-fall of around 150 TWh of domestic production is met by an almost 50 TWh increase in German net import. The rest is supplied domestically.

For further information:
MIKAEL ODENBERGER, Chalmers University of Technology
and THOMAS UNGER, Profu

Final remarks

The analysis presented here makes a number of important assumptions which may underestimate the impact of the German nuclear phase out. One of these important considerations is that CCS becomes commercially available from 2020 and onwards. Thereby, nuclear baseload power may be replaced by another means of generating low-emitting baseload power. If CCS fails in becoming commercially available, or is substantially delayed, other types of baseload power must be used, e.g. conventional fossil power which most probably would lead to a more significant impact on EU ETS prices than estimated here. Furthermore, the model approach used here permits unlimited interconnector investments. Thus, the impact on the German electricity market becomes geographically spread and diluted. Limiting the analysis to existing interconnectors is likely to increase the impact in the German electricity market (and probably reduce impact on neighboring markets) compared to what has been reported here. A supplementary model run indicates that such limitations (new interconnectors and a later commercialization of CCS) have an impact especially on the marginal CO_2-reduction cost. In such a case, a cost increase of around 7 €/t was obtained as compared to the 1-3 €/t in the reference case. Accordingly, the marginal electricity cost increase was roughly one €/MWh above the outcome in the reference case.

The linkage between bioenergy and water

Bioenergy and water are inextricably linked. The availability and quality of water will be an important factor determining to what extent bioenergy can contribute to the overall energy mix. Increased production and use of bioenergy products are likely to lead to increased pressure on water resources unless well managed. However, proper integration of bioenergy systems into forestry and agriculture can reduce some of the impacts of present land use, such as eutrophication and soil erosion. These issues are of emerging concern in bioenergy research.

Pathways researcher Göran Berndes – together with colleagues at The United Nations Environment Programme (UNEP) and Oeko-Institute – organized an international workshop on the topic bioenergy and water in Paris in 2010. In a recently published follow-up report – The bioenergy and water nexus – about 30 of the workshop participants provide an overview of this multifaceted issue, addressing two general questions:

- In what ways can the production and use of bioenergy products influence the future state of water resources?
- How can society address negative impacts and promote bioenergy expansion that contributes to a more sustainable use of land and water?

The report examines in depth the bioenergy-water interlinkages, highlights the risks and opportunities, and offers an outlook on ways to address them, ranging from technical tools to processes, and from policy to project-level measures, such as certification. The report also points to the need for further research, filling data gaps, and the development of regionalized tools. Among the key messages and recommendations provided are:

Water use for bioenergy needs to be evaluated at different scales

Inventories of water requirements can serve as basis for management and planning where also different indicators on water use can be applied. However, local and regional conditions determine the relevance of each indicator, and historic and alternative future land use should be considered.

Take a holistic perspective and base decisions on impact assessment

For sustainable land and water use it is essential to understand the consequences of different land and water management systems. In order for operators and policy makers to evaluate both positive and negative effects an assessment framework is critical. This framework should consider the activities' water intensity, the state of water resources, and assess local effects considering the specific environmental and socioeconomic situation.

Address point source and cumulative effects

Bioenergy systems can influence the quality of water locally but also larger geographic scales. Evaluation of water impacts and associated consequences for, e.g., biodiversity and human health must therefore consider impact on water quality at the project level (point source) and watershed level (cumulative effects). There are options to avoid or mitigate negative effects, and both on-site and off-site benefits may be achieved (e.g., water erosion reduction and flood prevention).

Policy instruments are needed to address the water implications
Policy instruments can directly or indirectly influence how bioenergy production affects water availability and quality. These instruments should be designed to help avoid long-term negative outcomes while maximizing potential benefits (such as new rural jobs and new options for sustainable land and water use). It is also important that they are coherent with regard to instruments in related policy sectors and existing water policy instruments.

Voluntary certification schemes
Certification is a way for decision makers at a project level to respond to concerns over socioeconomic and environmental impacts, including those associated with water related effects. At present numerous biomass and biofuel sustainability certification systems are being developed or implemented by a variety of private and public organizations.The practically of certification schemes and also the effectiveness in preventing harmful impact need to be monitored and evaluated in the coming years.

The report and also a summary report can be downloaded at: http://www.unep.fr/energy/bioenergy/.

An associated Special Issue of Biofuels, Bioproducts and Biorefining features a set of peer-reviewed papers mainly written by the authors of the report. The Special Issue can be found at: http://onlinelibrary.wiley.com/doi/10.1002/bbb.v5.4/issuetoc

For further information:
GÖRAN BERNDES, Chalmers University of Technology

Geographic allocation of wind power

– the importance of wind speed, transmission lines and load centers

The choice of wind power allocation is influenced by factors such as wind conditions, distance to load and the power system in place (generation and transmission capacities). In order to maximize utilization, wind investments obviously have to be at sites with favorable wind conditions. On the other hand, the prospects of minimizing transmission investments can motivate wind investments close to load centers in spite of less favorable wind conditions.

To study these issues more in detail, Lisa Göransson has analyzed scenarios where 20% wind power (share of total electricity demand) are enforced on the present Nordic-German power system under the simplification that wind power replaces conventional generation (total load remains constant). This has been done by integrating a detailed description of the wind power resource in a linear cost minimization model of the heat and power sector with a 1-hour time resolution.

Wind power generation costs range between 45-75 EUR/MWh

It is found that wind power generation costs (including annualized investment costs) can differ from 45 EUR/MWh to 75 EUR/MWh between regions with good and poor wind conditions in the Nordic-German system (based on wind speed data from SMHI some regions are limited to sites with wind farm capacity factors of 20-25% whereas other regions can offer sites with wind farm capacity factors above 35%). With a target on wind power, this cost difference can motivate investments in transmission capacity. Thus, a cost minimizing allocation of wind power capacity would imply a concentration of new wind farms to windy regions. However, the difference in wind power generation costs between different regions with good wind conditions is in the same range as the difference in transmission costs between these regions.

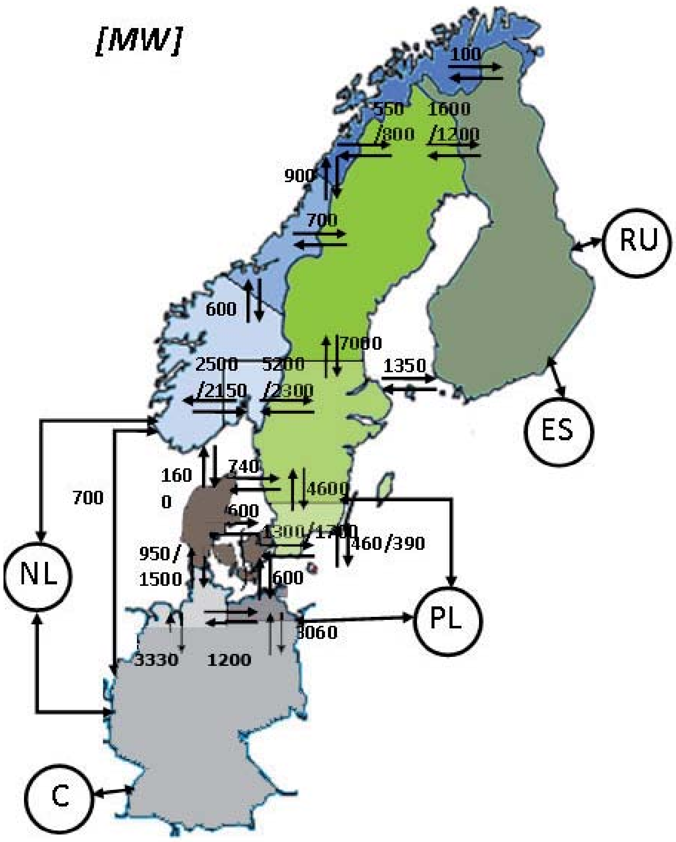
Two factors influence wind power allocation

The model results show that the distribution of wind farms between windy regions depends on two factors:

- To what extent existing lines can be used to transmit new wind power
- The correlation in wind power generation between the exporting and the importing region in case there is already a substantial amount of wind power in the importing region.

The results indicate that opportunities for additional wind power investments in Denmark are limited, and to some extent also north-western Germany, despite good wind conditions and closeness to fossil fuel supplied demand (e.g., in south-central Germany). This since new wind power generation in Denmark and north-western Germany obviously will be well correlated to already existing wind power in these regions (also including south-central Germany).

Winds in Norway and Sweden, on the other hand, have lower correlation with winds in south-central Germany. In addition, Norway and Sweden have existing cross-border interconnectors to continental Europe. These interconnectors can be used for the purpose of transmitting Nordic surplus power attributed to a large expansion of wind power installment to the German system (by using existing transmission capacity mono-directionally rather than bi-directionally as is the case today) and there through replace fossil fueled based power generation.



For further information:
LISA GÖRANSSON, Chalmers University of Technology

The Pathways research network is expanding

During the first phase of the Pathways project we established an extensive network, both national and international, around the project, its research focus and its activities. This has provided us an excellent opportunity to increase the leverage of the project results and ensuring a more extensive platform for discussing the results within EU and in other international fora.

As Chalmers is a partner of AGS we could benefit from existing cooperation with the other partner institutes and associated members of AGS, as well as from the Pathways framework especially with ETH in Zurich and with the research and strategic divisions of Vattenfall AB. In addition, we have cooperated with the EU commission through projects such as ELOBIO, REFUEL, PLANETS and PATH-TO-RES. During the first phase of the Pathways project the Pathways industrial network were extended to include E.ON Sverige AB (through the Chalmers-E.ON initiative), Preem AB and Södra's Foundation for Research, Development and Education. There were also a close dialogue with several Nordic-related research programs such as the Skagerakk/Kattegat Interreg program on CCS and the project Nordic Energy Perspectives.

As we have set off the second phase of the Pathways project it is apparent that the project and its research activities are attracting the interest of new partners for additional cooperation. We have therefore been able to expand and reinforce our research network further. An interesting collaboration regarding the development of the energy infrastructure in EU has been initiated together with the Joint Research Center of the European Commission (EU-JRC). We will also interact with IEA and the Nordic Council of Ministers in the work to develop a Nordic ETP and participate in North European Power Perspective, a north-European research cluster. In addition, we have recently become partners of NORDICCS a so called Top-level Research Initiative on Carbon Capture and Storage.

Licentiate seminar:

Realise the Potential!

- Cost Effective and Energy Efficient District Heating in European Urban Areas

Urban Persson will present his licentiate thesis, *Realise the Potential! Cost Effective and Energy Efficient District Heating in European Urban Areas*, on 21 December 2011 at 10:00. The seminar will held in Room EA, Hörsalsvägen 11, Chalmers University of Technology.

In this thesis, enhanced excess heat recovery in expanded European district heating systems is conceived as a structural energy efficiency measure that can contribute substantially in reaching the 20% energy saving target by 2020. The thesis introduces methodologies and concepts by which assessments of feasibility thresholds for cost effective heat distribution in district heating systems are made possible, as well as estimations of plausible future excess heat recovery potentials from thermal power generation and industrial activities".

For further information:

URBAN PERSSON, School of Business and Engineering, Högskolan i Halmstad

Upcoming event

Conference

A conference marking the end of the Interreg/Gassnova project Handling CO_2 in the Skagerak/Kattegat region will take place on 7 December in Oslo. The conference will summarise and discuss the results of the project as well as the way forward for CCS in the region. For more information please contact Jan Kjärstad, Chalmers University of Technology (kjan(at)chalmers.se).