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NEWSLETTER FROM »PATHWAYS TO SUSTAINABLE EUROPEAN ENERGY SYSTEMS«

#1/2013

Filip's column

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Prof. Filip Johnsson
Project manager of the Pathways project

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

Assessment of the wind power potential within Europe

As a consequence of energy and climate policy, the amount of onshore wind power in Europe must grow substantially towards 2050. Such a development triggers questions related to the potential of exploiting land for wind-power installations in the future. Using a GIS-based reduction method, this work shows that a large part of Europe's land surface area is available for wind power after subtracting areas corresponding to densely populated areas (cities), lakes, rivers, environmentally protected areas (Natura 2000) and roads.

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Solar photovoltaics for your home
- Can DSM help it happen?

The electricity demand for the residential sector has traditionally been met through large-scale centralized generation with the use of transmission and distribution grids to transport the electricity to the end-user. However, transformation of the electricity system increases the possibilities and interest for renewable distributed generation. Emil Nyholm investigates which factors, in a Swedish context, that could affect the incentive for a homeowner to invest in a PV panel. It is found that the use of demand-side management (DSM) could help advance the implementation of distributed PV, especially at higher PV panel price levels.

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Sustainable pathways for the European electricity system

The EU Commission has expressed ambitions to reduce greenhouse-gas emissions by 80-95 % by 2050. Fulfilling such a goal will inevitably lead to significant impact in all parts of the European energy markets. Given the comparatively advantageous options to reduce emissions in the electricity-supply system, emissions in this sector may have to approach zero approach zero. What will such an electricity system look like, how will it work and what are the possibilities and the obstacles in such a development?

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Filip's column

There has been a tremendous development of wind and solar power in Europe over the last years, especially in Germany where favourable feed in tariffs drives the development. Yet, the current installation in Europe as a whole is currently small compared to what is required to meet climate and renewable targets beyond 2020. To continue the strong development will put pressure on land use as well as the transmission and distribution grid, especially in order to secure an efficient deployment of wind and solar power.

In the Pathways project we are investigating the possibilities for efficient utilization of wind and solar power. This newsletter shows some important work related to land use and geographical allocation of wind power. Although our models already have cost supply curves for wind power based on a detailed mapping of the wind conditions from which several wind classes have been defined in each EU member state, we are now assessing other limitations for siting of wind power in order to refine the modelling input data. We are also developing methods to investigate how wind power can be spatially distributed in order to reduce the impact of variations in wind power generation on the electricity generation system. This is an important field of research where we see possibilities for efficient integration of wind power, although this will require coordination between member states and regions in order to take advantage of such possibilities. Demand Side Management (DSM) may facilitate efficient large scale integration of wind power as well as distributed generation such as by means of photovoltaics (PV). This newsletter shows results of initial work on assessing DSM in the context of PV integration. It is shown that DSM can increase the economics of PV panels and thereby help advance the implementation of distributed PV. Based on a previous work carried out in the US, we have started to do performance-cost modelling of distributed solar combined heat and power systems. In all, I am very much looking forward to identifying efficient ways to integrate these technologies in the energy system.

This newsletter summarizes some of the results from the Pathways project which have also been discussed and communicated within the North European Power Perspectives (NEPP) project. The NEPP project gives us a good platform for communicating the results to relevant stakeholders, especially in a Swedish context.

Finally, I conclude that although the current economic recession in Europe has to some extent slowed down the transformation of the energy system, the analysis of our work points in the direction that there are significant opportunities for Europe to take advantage of coordinated strategies when it comes to large scale integration of renewable electricity generation. The challenge is for EU to find policies which can take advantage of these opportunities. At least, we hope our project can help EU policy makers to see new opportunities.

Prof. Filip Johnsson
Project manager of the Pathway project

New Doctoral thesis:

Options for the oil refinery industry to meet CO_2 targets

To reach the objective endorsed by the EU Council for reducing EU greenhouse gas (GHG) emissions by 80-90% compared to 1990 levels by 2050, extensive cuts are necessary in all sectors. The oil refining sector is a major energy user and thus a major GHG emitter. For oil refineries to reset to a more profitable and environmentally sustainable activity, new technologies are required. The choice of technology is, however, not simple.

The overall aim of Daniella Johanssons research work is to analyze the potential for reductions in GHG emissions in the oil refining industry. The focus is on the implementation of three development routes at case refineries: three development routes at case refineries: Large-scale biomass gasification to hydrogen; Large-scale biomass gasification to Fischer-Tropsch fuel; and Post-combustion CO_2 capture and storage (CCS). The analysis has been conducted both at an aggregated level; investigating the potential for on-site CO_2 mitigation for the EU refining sector, and at the case study level; focusing on the three development routes and including global reduction in GHG emission as well as economic performance.

In a comparison between Fischer-Tropsch and post-combustion CO_2 capture, the most profitable option depends on the assumptions on the future energy market. All three development routes lead to reductions in GHG emissions. However, as biomass should be considered a limited resource it is reasonable to assume that the biomass will be used in applications with highest efficiency. In this thesis it is shown that, in most cases, large-scale biomass gasification at a refinery results in lower potential for GHG emission reduction compared to using biomass in coal condensing power plants.

Daniella Johansson defended her Doctoral thesis *"System studies of different CO_2 mitigation options in the oil refining industry: Post-combustion CO_2 capture and biomass gasification"* at Chalmers University of Technology in February 2013.

For further information:
DANIELLA JOHANSSON, Chalmers University of Technology

Assessment of the wind power potential within Europe

As a consequence of energy and climate policy, the amount of onshore wind power in Europe must grow substantially substantially towards 2050. Such a development triggers questions related to the potential of exploiting land for wind-power installations in the future. Using a GIS-based reduction method, this work shows that a large part of Europe's land surface area is available for wind power after subtracting areas corresponding to densely populated areas (cities), lakes, rivers, environmentally protected areas (Natura 2000) and roads.

A first approach to assess the potential for wind power in the EU27, Norway and Switzerland has been performed on a grid cell level with a resolution of 200-670 square kilometers. The assessment was performed by calculating the geographic area, for each cell, that remains after lakes, rivers, cities, Natura 2000 and major roads (i.e. the so-called "reduction" areas) have been withdrawn from the original geographical area represented by the countries studied. All calculations have been performed using the GIS (global information system) program ArcInfo. Thus, the remaining area within each grid cell is considered as potentially available for wind power installations.

The first model results show that approximately 80 % of the original geographical area (EU-27, Switzerland and Norway) remains as potentially available after the surface reductions mentioned above, see Figure 1. Currently in the work, buffer zones are included, i.e. areas surrounding the reduction areas, in order to reflect safety and publicly accepted distances to wind power installations. For instance, wind power installations need a certain safety distance to roads. The inclusion of buffer zones will further reduce potentially available areas.

Even after the reduction of buffer zones the potential is only to be considered as a theoretically possible wind power potential, which according to our definition is an available area for wind power investment. The available area will in fact be further reduced after taking into account other factors that affect the ability and willingness to invest in establishing wind power, for example the proximity to the electricity grid, the need of good transport routes for establishment of wind power, military areas, heritage sites etcetera.

Since it is an extensive and time consuming task to include all factors that affect the willingness to invest in wind power for a geographical area comprising EU27, Norway and Switzerland, the forthcoming work will focus more in detail on a selection of (smaller) European regions. The results from the detailed regional study will be compared to the more overall and simplified estimate on the potentially available area for wind power installations.

For further information:
KAROLINA NILSSON, Profu AB

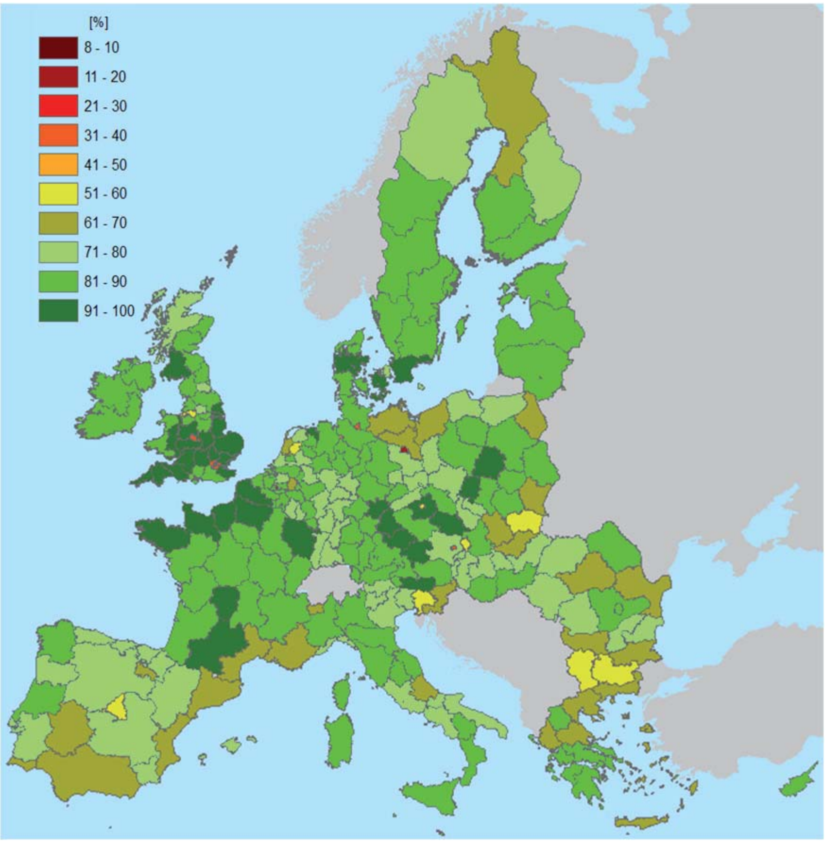

Figure 1. *Percent of original geographical area that remains after subtracting the so-called "reduction areas"*

Variation management through spatial distribution of wind power capacity

The possibility to spatially distribute wind power capacity to reduce the impact of variations in wind power generation on the electricity generation system is regarded by research within the Pathways project. Lisa Göransson and Thomas Unger have developed a method that can measure the benefits of doing so. Three different distribution strategies have been studied: the first aims to minimize the total variance in aggregated wind power output; the second to minimize the total hourly variations; and the third to minimize investments in wind power capacity. Total running costs are reduced in the first two strategies, but these cost reductions cannot compensate for the cost of additional capacity that will be required compared to the capacity minimizing case.

Variations in wind power (WP) generation decreases as the area over which wind power is distributed increases. In theory it is thus possible to reduce hourly variations in wind power generation by distributing the wind power capacity geographically. To what extent can geographical allocation of wind power be beneficial to the electricity generation system? To answer this question, the response of the electricity generation system of northern Europe (Denmark, Finland, Germany, Netherlands, Norway, Poland and Sweden) to the three following WP distribution criteria has been investigated;

1) to minimize the total variance in wind power generation,
2) to minimize the total hourly variations in wind power generation and
3) to minimize investments in wind power capacity.

Wind power generation corresponds to 30% of the total electricity demand in all three cases. In this first evaluation, internal bottlenecks, as well as the possibility to meet variations with flexible hydro power generation, are omitted.

Figure 1 illustrates the resulting wind power distributions as wind power investments are optimized according to the three different criteria. A distribution minimizing variance (distribution 1) or hourly variations (distribution 2) result in substantial amounts of wind power capacity located in Finland (around 20 GW out of 170 GW) and Poland (around 30 GW out of 170 GW). Minimizing wind power capacity (distribution 3) results in investments along the Atlantic coast and with relatively more capacity located in Denmark and northern Germany compared to the other investigated distribution cases. In this case it is sufficient with 140 GW to meet 30 % of the load in northern Europe. Wind power capacity is fairly well distributed geographically also with the minimum capacity distribution in order to make use of the best sites in e.g. northern Norway and northern Germany.

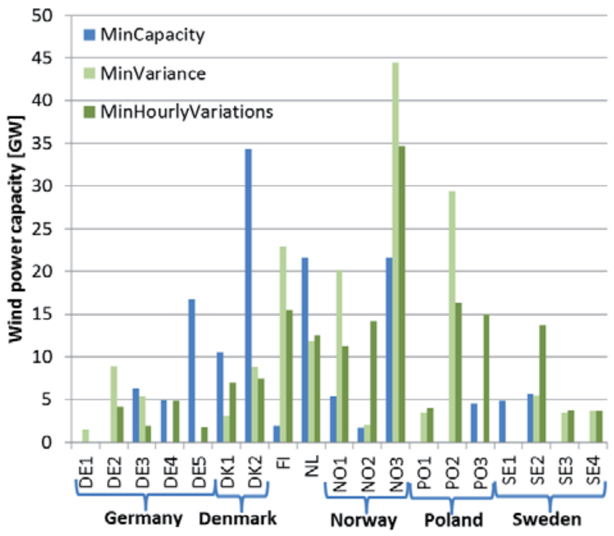

Figure 1. Location of WP capacity in the three different wind power distribution cases investigated.

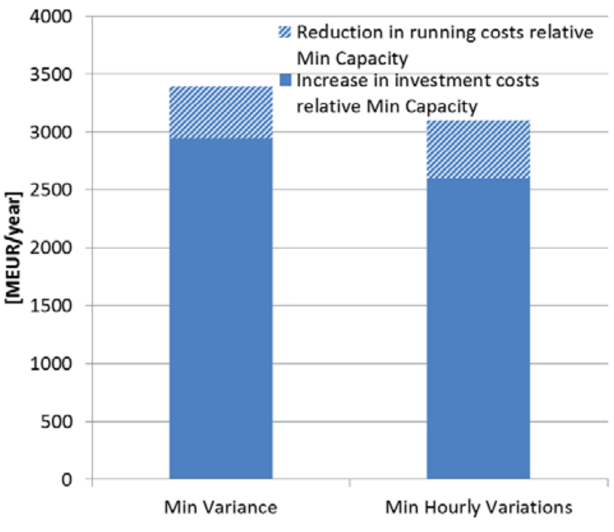

***Figure 2.** Impact on total system costs for the minimized variance strategy and the minimized hourly variance strategies (distribution 1 and 2) given relative costs for the minimized capacity strategy (distribution 3)*

The modeling shows that both allocation with reduced hourly variations) and with reduced variance result in lower system running costs compared to a distribution which minimizes the wind power capacity. To reduce wind power curtailment a distribution which minimizes the hourly variations is particularly efficient while an allocation that minimizes the variance facilitates base load operation.

Figure 2 illustrates the impact on total system costs. For the hypothetical case investigated (northern Europe without transmission limitations and hydro power) total system running costs is reduced with 500 MEUR/year (fuel costs and cost of cycling thermal units) for the first two minimization criteria compared to the capacity minimization distribution. However, to achieve these two cases of wind power distributions (1 and 2) some additional investments in 30 GW wind power capacity is required. With an annuity factor of 0.08 this capacity corresponds to a cost of 3000 MEUR/year. This implies that for northern Europe, the benefits from a low variance or low hourly variations cannot compensate for the cost of additional capacity needed to achieve this. A cost minimal distribution of wind power capacity in northern Europe is likely to balance variation reduction with capacity minimization.

For further information: LISA GÖRANSSON, Chalmers University of Technology

New Doctoral thesis:

Municipal energy companies assist in the energy system transition

Acknowledging the severe impact of energy generation on the global climate, the transformation of today's carbon-based energy systems is a key challenge. Sweden is recognized as a forerunner in climate change mitigation, particularly with regard to the transition to a more sustainable energy system.

Gabriela Schaad's PhD thesis provides insights into how companies at the forefront of decarbonizing the energy system manage the transition towards environmentally more sustainable business. Three case studies of Swedish municipal energy companies with a high environmental commitment illustrate what the strategies at the core of such a transition entail.

The dynamic ways in which highly committed municipal energy companies work with sustainability issues is captured in the concept of greening mechanisms. These mechanisms facilitate the embedding of a strategy for environmental sustainability in the firm and its surrounding field.

To investigate how such strategies can contribute to the sustainable development of municipal energy companies and society, a broad view of value creation is applied. Capabilities and resources associated with strategies for environmental sustainability provide the basis for assessing value created for the firm and shared value between the firm and society.

Bridging firm strategy and sustainable development requires that a broad set of challenges is addressed by the firms. Energy companies must be able to handle social complexity beyond the firm to successfully manage the transition towards a sustainable energy system. It is positive news that municipal energy companies irrespective of size have good abilities to improve energy system sustainability. The thesis concludes that thanks to their local embeddedness and an ambition to contribute to public welfare, these companies are well-positioned to assist in the transition towards a sustainable society in energy issues.

Gabriela Schaad defending her Doctoral thesis.

Gabriela Schaad defended her Doctoral thesis *"Strategies for Environmental Sustainability of Municipal Energy Companies. Pathways of Sustainable Development between Business and Society"* in December 2012 at the School of Business, Economics and Law at the University of Gothenburg.

For further information:
GABRIELA SCHAAD, School of Business, Economics and Law, University of Gothenburg

Solar photovoltaics for your home

– Can DSM help it happen?

The electricity demand for the residential sector has traditionally been met through large-scale centralized generation with the use of transmission and distribution grids to transport the electricity to the end-user. However, transformation of the electricity system increases the possibilities and interest for renewable distributed generation. Emil Nyholm investigates which factors, in a Swedish context, that could affect the incentive for a homeowner to invest in a PV panel. It is found that the use of demand-side management (DSM) could help advance the implementation of distributed PV, especially at higher PV panel price levels. However, if panel prices drop, the impact from DSM is expected to decrease as selling electricity, instead of consuming it in-house, becomes more profitable.

Several different factors affect the cost, and thereby the incentive for an individual household to invest in PV technology. Levels of subsidy such as investment support and renewable certificates are obvious factors. Another factor is the amount of produced PV electricity that is consumed within the household. Therefore, the effect of DSM is investigated, here in the form of load shifting. The amount consumed in the household can be increased by shifting loads and fitting these with the production curve of the PV panel. Loads considered for DSM are initially dishwashers, washing machines, driers and refrigerators/ freezers. However, it might not be possible to consume all produced electricity within the household. Thus, the possibility to sell overproduced electricity becomes important.

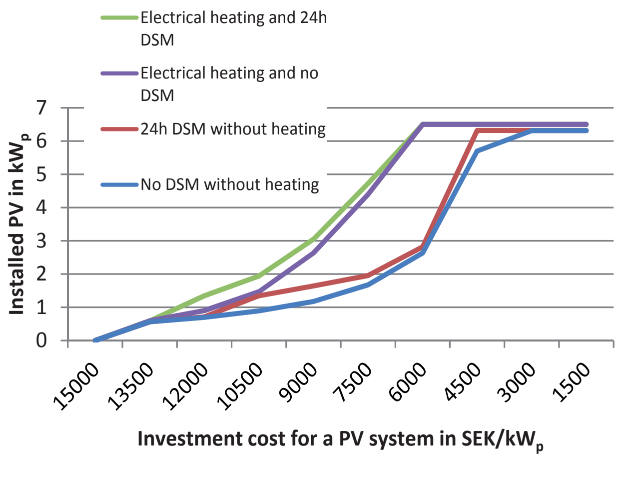

Figure 1. *Optimal installed PV size, based on economic criteria, for different PV system investment costs for a house with and without electricity heating. Maximum installable capacity is 6.5kW.*

Initial results – The impact of DSM

Initial findings show that at current prices PV panels cannot compete at today's investment cost without subsidies. Figure 1 illustrates that investment does not occur for investment cost above 13500SEK/kW$_p$ (for a household without electric heating). Current investment cost is assumed to be 30000SEK/kW$_p$, which should be seen as a conservative value, this would at current subsidy levels correspond to a PV investment cost of 16500SEK/kW$_p$. Moreover, implementation of DSM measures, free dispatch during a 24 hour period of DSM loads, will neither affect at which investment cost an investment occurs nor the size of PV panel for an investment costs up to 12000SEK/kW$_p$. This, since it is more cost effective to move DSM loads to hours with low electricity prices instead of investing in additional PV capacity. At an investment cost of 11000SEK/kW$_p$ a larger PV panel can be installed if DSM is applied as more own- produced electricity is used within the household. Household PV systems are typically sold in fixed-size packages and for a package size of 1.5 kWp one can see that DSM could lower the investment cost of about 1500SEK/kW$_p$, since an investment of 1.5 kW$_p$ is economical at an investment cost of 9000SEK/kW$_p$ instead of 7000SEK/kW$_p$. At lower investment cost, around 6000SEK/kW$_p$, the difference disappears while the difference in amount of produced electricity used within the household continues to increase. Thus at low investment costs the positive effects of DSM diminishes as selling the electricity becomes an increasingly profitable option.

For a household with electric heating investment occurs at the same cost level as for a house without electric heating, see Figure 1. This, since the same expensive load hours are covered by PV production in both cases. As investment cost decreases, the amount of PV installed for a house with electric heating becomes larger compared to a house without electric heating due to the higher load. The effects of DSM are still present, although not as substantial. This since the amount of produced electricity used within the household is higher and, thus, reducing the number of hours of produced electricity available for DSM.

DSM will therefore have an impact on the amount of PV, installed for households, based on economic criteria. At higher panel costs, DSM could increase the economic viability considerably and could thereby help advance the implementation of distributed PV. When panel prices drop, the impact from DSM is expected to decrease as selling electricity becomes more profitable. It is also evident that houses with electric heating can support a larger PV panel since more electricity can be consumed within the household.

For further information: EMIL NYHOLM, Chalmers University of Technology

Performance-cost modeling of distributed solar CHP systems in Europe

The solar conversion process has historically been too expensive to compete effectively against conventional power generation technologies when the economic system appropriately values neither environmental health nor social welfare.

There are currently two primary technologies for solarelectric energy conversion: photovoltaics (PV) which utilize the photo-electric effect for direct conversion of light to electricity, and solar thermal technologies that collect light as heat, typically driving mechanical-electrical generators. The Combined Heat and Power (CHP) systems convert sunlight to both heat and electricity. The commercial efficiencies of PV technologies today are 10 - 20%, while commercial solar thermal systems reach 20 - 35% solar-electric efficiency. The research by Zack Norwood focuses on concentrating solar CHP for the following reasons: (a) concentrating solar CHP has the potential for 60 - 80% solar-thermal conversion efficiency. (b) Electricity is currently very difficult to store economically; while energy in the form of heat can be cost effectively stored with available technologies. (c) Solar-thermal technology can be manufactured using abundant and easily processed engineering materials such as steel, glass, and rubber. (d) Thermal demands worldwide (including space heating and cooling) are a large fraction of total energy demands for small (less than 10kW peak) customers.

In practice, the Rankine cycle is a robust option for development of a solar-thermal combined heat and power system. Although many processes are interesting for thermal-electric conversion, the Rankine cycle is the most common worldwide, where an estimated 80% of all electric power is generated using a Rankine heat engine. Note that greater than 50% of Carnot efficiency is reasonably achievable with moderate temperatures (less than 250ºC), pressures (less than 11bar), and with a ubiquitous harmless fluid (water). Not any other thermodynamic cycle for solar power generation exhibits such promising results with attainable technology that is also appropriate for household or unsupervised operation. Toxic or exotic working fluids are also eliminated in steam Rankine systems, making them a benign choice, and a low-cost choice for heat and electricity. Previous work at the University of California, Berkeley, to characterize the performance and cost of solar CHP systems in the United States has been expanded to Europe, and new solar technologies and modeling methodologies have been added to the distributed concentrating solar combined heat and power (DCS-CHP) software.

Four representative system types will be modeled to predict distributed solar production potential in Europe: (1) a concentrating solar CHP system; (2) a concentrating PV system; (3) a concentrating thermal system without electricity generation; (4) a hybrid PV-thermal system. The model predicts hourly output of such a system for a typical meteorological year across an approximately ten thousand point grid in Europe. Model output for electricity generation from a concentrating solar CHP system are shown in Figure 1. Note that for each location in Europe the amount of usable heat captured from the cycle will be 4 to 5 times the electrical output. Southern latitudes show a three to five time increase in electricity generation for the same area of collector aperture making them proportionally less expensive in those locations. Once technology learning curves based on European costs and life-cycle analysis are added to this model, these results will be integrated into the EPOD model. Ultimately, this will allow us to analyze economically and/or environmentally optimal investment and deployment of distributed solar technologies in future electricity dispatch scenarios.

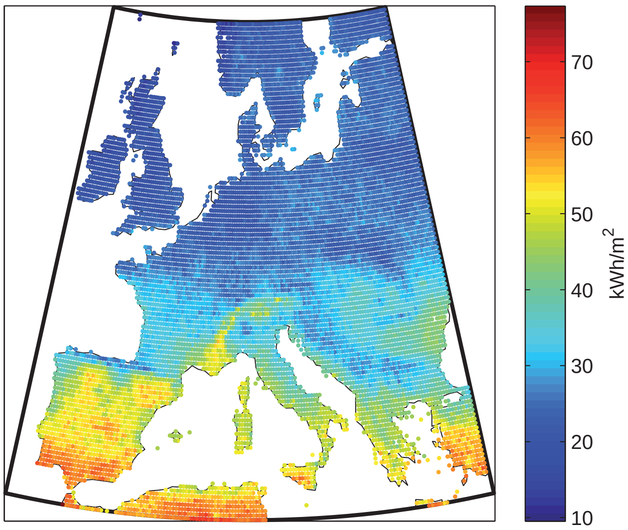

Figure 1. *Predicted yearly output of a concentrating solar CHP system (kWh electricity generated per square meter of collector aperture)*

For further information:
ZACK NORWOOD, Chalmers University of Technology

Sustainable pathways for the European electricity system

The EU Commission has expressed ambitions to reduce greenhouse-gas emissions by 80-95 % by 2050. Fulfilling such a goal will inevitably lead to significant impact in all parts of the European energy markets. Given the comparatively advantageous options to reduce emissions in the electricity-supply system, emissions in this sector may have to approach zero. What will such an electricity system look like, how will it work and what are the possibilities and the obstacles in such a development? These are fundamental questions addressed by the current energy systems research carried out in the Pathways project.

The work performed out so far has focused on developing modelling tools for analyzing the research questions addressed in the project as well as formulating important intermediate, and still somewhat preliminary, research results and findings.

Intermediate results of the analysis

Based on the current research some of the more important findings may be summarized into:

- Existing technology and fossil fuels will continue to play a decisive role for at least 20-30 years
- The share of renewables in electricity generation is constantly increased and may reach 50 percent in the EU by 2050
- Due to ambitious climate-policy targets, the carbon price is likely to become high while the system price of electricity is less affected
- Accelerating efforts to develop low-carbon technologies are needed in the industry sector, and CCS seems to be a key technology
- The European building stock can be assessed by archetype buildings, country for country
- Realizing large scale implementation of CCS is challenging, especially if only off-shore storage is allowed
- Abundance of natural gas may significantly change the scene for future European electricity generation
- Security of supply can go hand in hand with climate change mitigation
- Improved strategies for geographical allocation of wind power is crucial for efficient large scale implementation of wind power
- The demand-side perspective is important when considering distribution and decentralized production.

Model and methodological development

The model development has now generated an extensive model package which covers and can analyze the most important aspects of the electricity system. This includes:

- Detailed and updated database on all existing power plants in the EU, Norway and Switzerland
- Extensive model package for analysis of future routes for the European electricity-generation system
- Regionalization of EU Member States into 53 regions defined by major bottlenecks in electricity transmission
- Extended model description to include also transmission-grid and load flow characteristics
- Highly detailed description of wind and solar resources across the EU
- Further refinement on mapping of fuel resources and CO_2 storage sites
- Methods and models to assess the energy use, specifically electricity, in the industry and building sector
- The definition of four main scenarios to set the prerequisites for the pathways to the year 2050.

Furthermore, a set of approaches to also handle load management, storage, and medium-voltage distribution is under development.

The research team

The research team consists of researchers from three divisions at Chalmers: Energy Technology; Physical Resource Theory; and Electric Power Engineering and from the research and consultant company Profu AB. Both senior researchers and PhD students are involved in the team. Furthermore, the research team continuously cooperates with other research teams in similar research projects such as the recently finalized IEA Nordic Energy Technologies Perspectives (NETP) project, the ongoing and closely related North European Power Perspectives (NEPP) project, and with interrelated projects conducted at EU-JRC in Petten.

The method

The research includes a setup with different model approaches and detailed data on the existing energy infrastructure across the EU. In the analyses, the entire electricity system, i.e. supply, transmission, distribution, storage and use, is considered. Furthermore, detailed mapping of existing infrastructure, e.g. electricity-generation capacity, and fuel resources is frequently being updated and refined.

The projects

The research presented here is the collective effort of ongoing subprojects jointly conducted, such as the Pathways project financed by Vattenfall and the Swedish Energy Agency, the ”Electricity networks for tomorrow” project financed by E.ON and the NEPP project.

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More information about the Pathways project:
www.energy-pathways.org