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Perspectives on hydropower's role to balance non-regulated renewable power production in Northern Europe

Report on the CEDREN workshop,
Düsseldorf, 15-16 December 2010

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Report

Perspectives on hydropower's role to balance non-regulated renewable power production in Northern Europe

Report on the CEDREN workshop, Düsseldorf, 15-16 December 2010

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ABSTRACT
This report summarizes the discussions during the CEDREN workshop 'Perspectives on hydropower's role to balance non-regulated renewable power production in Northern Europe'. The workshop was hosted by Statkraft Markets GmbH in Düsseldorf, Germany, 15-16 December 2010.

The purpose of the workshop was to discuss opportunities and challenges in the development of new hydropower capacities in Norway, for balancing non-regulated renewable power production in Northern Europe. The workshop provided a meeting and discussion arena for important actors that are and will be involved in the future decision making process in Norway and Germany: power generation and grid companies, authorities and research communities.

The discussions and reference studies presented during the workshop will be used as basis for future scenario work in CEDREN.

Workshop participants:
Statkraft Markets GmbH , EnBW AG, 50Hertz Transmission , Statnett SF, THEMA Consulting Group , Fraunhofer IWES , University of Flensburg , Energy Norway, NTNU, SINTEF Energy Research

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1 Introduction

This report summarizes the discussions during the CEDREN workshop '*Perspectives on hydropower's role to balance non-regulated renewable power production in Northern Europe*', which was hosted by Statkraft Markets GmbH in Düsseldorf, Germany, 15-16 December 2010.

The purpose of the workshop was to gather important actors that are and will be involved in the future decision making process in Norway and Germany and to discuss opportunities and challenges in the development of new hydropower capacities in Norway to cover the need for balancing non-regulated renewable power production in Northern Europe.

The discussions during the workshop confirmed that Norwegian hydropower can play an important role towards achieving a European and German renewable electricity future.

However, the debate showed that the German and Norwegian central actors have still to discuss ***how large*** the need for balancing power is, ***when*** the development should take place and ***how*** the benefits of a *future based on RES (Renewable Energy Sources)* should be shared between countries and across the value chain (generation-transmission-end users).

The report is organized as in the following. The next chapters present the main issues discussed during the workshop:

- The German electricity market: facts, figures and challenges.
- Estimating the future need, in Europe, for *Norwegian balancing power*.
- Conditions for large scale development of Norwegian *balancing* hydropower.

The last chapter gives a short summary of discussions. All workshop presentations are included as Appendices.

2 Facts, figures, challenges

2.1 Trends for the electricity generation mix in Germany

In 2009 the RES in Germany accounted for 93,5 TWh, which corresponds to 16 % total German electricity consumption.

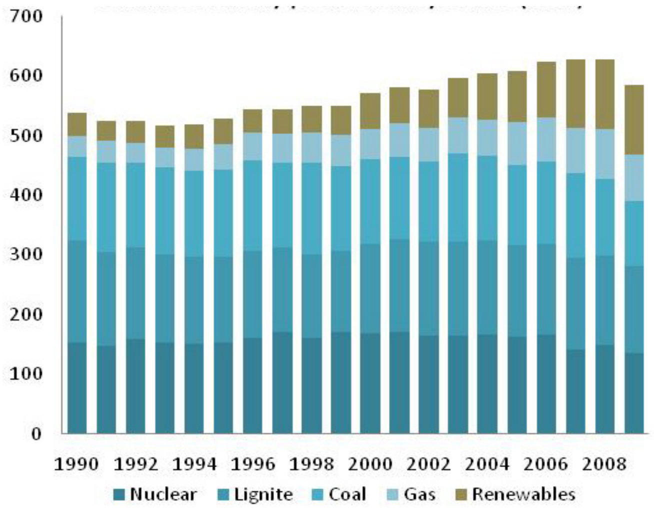


Figure 1 German electricity production by source (TWh) (see Appendix 2)

Wind and solar are among the fastest developing renewable energy sources. Partial figures presented at the workshop indicate that 16 GW of Photovoltaic generation units have been installed in Germany before October 2010 (while the total increase is expected to be 17-20 GW at the end of 2010).

There are also many plans for building offshore wind farms in Germany – however the future amount is highly uncertain as shown in Figure 2. Wind power capacities are concentrated in North and East Germany, far from the main load centers in the South.

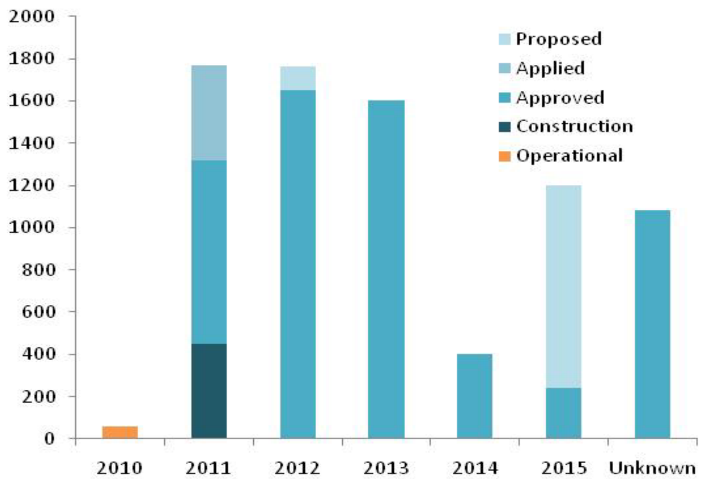


Figure 2 German offshore wind farm development (MW) (see Appendix 2)

In addition, 1300 MW new gas fired units were built in 2010 and over 5000 MW new coal fired units (lignite and coal) are expected to be installed in 2011, as shown in Appendix 2.

When talking about the future generation mix, the utilities present at the workshop referred to the DENA I and II studies, written by a consortium of authors involving German utilities and research institutes under the coordination of the Deutsche Energie - Agentur GmbH (DENA) - the German Energy Agency. The second study, DENA Grid Study II, assumes up to 39% renewable share in 2020.

Several other scenarios proposed by German research institutes have been discussed during the workshop and are presented in Section 3.1.

2.2 Transmission and distribution grids in Germany

Two German utilities owning TSOs were presented in the workshop: EnBW AG and 50Hertz Transmission (see their presentations in Appendices 4 and 11). They gave a good overview of the challenges German TSO's face in the (near) future with respect to integrating large shares of RES into the existing network.

The first clear message they brought forward is that the German transmission and distribution grids are already under 'pressure'. A major challenge for the (entire) German system is the lack of transmission capacity to transport the wind power (rapidly increasing) in the North and East to the main load centers in the South. This situation has been difficult for the market in certain periods (negative prices – see presentation, in Appendix 11).

Another challenge (this time also for the distribution systems) is the rapid increase in the number/capacity of new Photovoltaic (PV) units, mostly in the South of Germany – the PV capacity is expected to reach 50-70 GW by 2020.

In the Grid Study II, the Deutsche Energie-Agentur GmbH (DENA) - the German Energy Agency - has investigated how Germany's power system must be expanded and optimized over the period to 2020/25 in order to integrate up to 39% renewable share. The study indicates that for the basic scenario, the need for construction of additional transmission grid is of 3400-3600 (even up to 4000) km of new lines.

However, all utility representatives present in the workshop indicated that new transmission (and distribution) lines are difficult to build due to low social and political acceptability. For example, 50Hertz Transmission (having its main activity in East Germany) will need to invest in approx. 1500 km of new lines (of which only 90 km are built!) in order to integrate new wind power plants, onshore and offshore. This will be needed for a full integration of renewable energy sources in the future (see Appendix 11).

There is no doubt that a large increase in renewable power supply (in Germany) requires major investments in the transmission system inside Germany and a considerable increase of interconnection capacity with the neighboring countries. The question is whether the German society is willing to accept and pay for infrastructure development in order to enjoy such a large share of renewable generation.

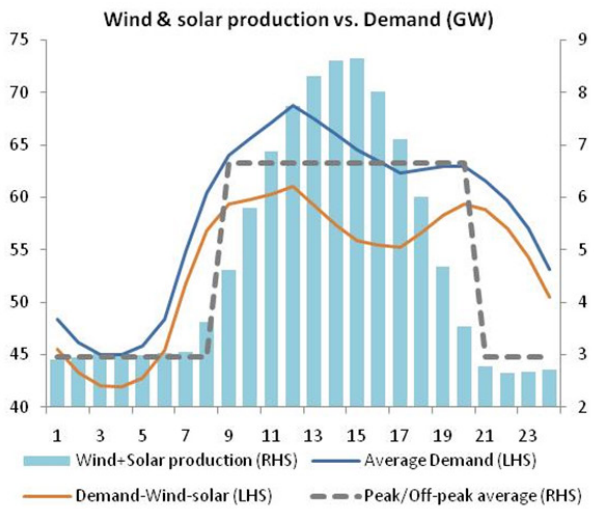
2.3 The electricity market

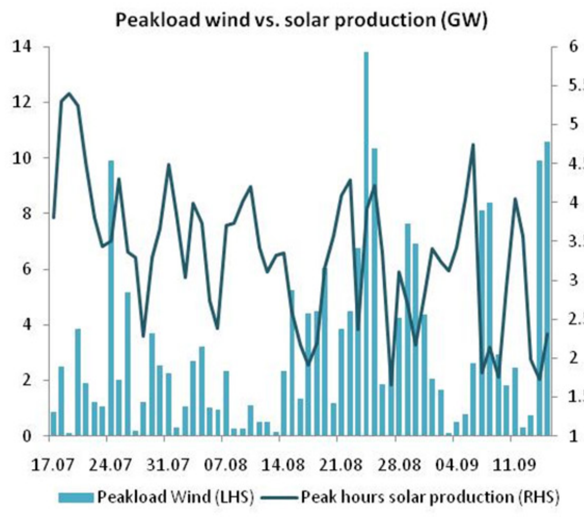
A clear signal during the workshop was that the electricity market (structure and rules) must change in order to allow for a large scale renewable generation trading. For example, A.S. Estermann from 50Hertz Transmission signalizes that there is a need for a special tendering scheme for marketing RES – outside of the 'classical' market structure.

Market transparency is a key issue and in this respect the greatest challenge is to make German market participants to understand the impact of RES on the markets and new flexibility demands.

The utilities present in the workshop have commented both the negative and positive influence RES generation already has on the market price.

A positive aspect is that a large share of PV generation mitigated the volatile behaviour of wind production thus decreasing the peak-load prices and reducing the frequency of 'negative prices', on periods. The example presented by Stefan Jörg Göbel from Statkraft Markets GmbH (see figure 3 and Appendix 2) shows that solar and wind production averaged 6,7 GW during peak hours during two summer months, in Germany.





Solar + wind production averaged 6.7GW during peak hours in the past 2 months.

	Wind	Solar	Wind+Solar
"Volatility"	1.39	0.29	0.47

Solar production mitigated volatile behavior of wind production.

Statkraft *Source: EEX, Statkraft.*

Figure 3 Impact of solar (PV) and wind generation on German spot price

Another aspect is that the increase RES share in Germany's electricity generation influences the trading possibilities of conventional fuel (gas) plants (see Appendix 2). Significant RES generation may require specific conventional generation units to shut down – so the existing gas fleet is expected to be less utilized (in terms of hours/day of production). Conventional generation units have relative long start-up times and high start up costs which make their operation more difficult to plan and utilization suboptimal (and more costly) when there is a need for back up RES variations on short term.

3 Estimating the need for Norwegian balancing power, in Europe

3.1 Contribution to Germany's 100% renewable electricity future

Electricity generation is a key area of Germany's energy and climate policies and the German government is currently in the process of developing an energy concept that will form the basis for its future energy policies. The main issues discussed in the workshop were how large the share of RES (wind and PV) in the German electricity supply will be in the future and how this can be achieved. A large scale RES generation requires solutions for back-up power and energy storage to compensate for the variability in wind and PV. In this respect several storage technologies have been discussed: pumped hydro storage systems, compressed air energy storage (in salt caverns), hydrogen storage, batteries.

Several state and research institutions in Germany are working with the development of scenarios that will give the background for future energy strategies. During the workshop, several scenario studies have been discussed. The remaining of this chapter will present the main findings of these studies, with focus on the estimated need for balancing power from Norway.

First, the ***DENA Grid studies I and II*** where often used as references in the presentations of the German utilities representatives (Statkraft Markets GmbH , EnBW AG and 50Hertz Transmission). These studies were developed by a consortium of authors involving German utilities and research institutes under the coordination of the Deutsche Energie - Agentur GmbH (DENA) - the German Energy Agency.

Both studies investigate the extension needed in the German electricity transmission grids in order to be able to integrate renewable sources. The results consist in specifications of power line-specific grid enhancement measures and extension requirements. The two studies are built on different assumptions regarding the share of RES and the time horizon for the analysis. The *DENA Grid study II* builds upon the assumptions made in the first study. The results advise that in order to fully integrate a **39%** share of RES (mainly wind and PV) into the German power grid by **2020 (2025)** there is a need for **3400-3600 km** new transmission lines (assuming also, different storage and demand side options). These studies take into consideration a limited transmission capacity with other countries and some possibilities to use pumped hydropower in South Germany, Austria and Switzerland (in which case they will need over 4200 km of new transmission lines). *These studies include no reference to power balancing possibilities with Norway*. Future DENA studies will look at possibilities for a 50% share of RES by 2030 and they will include an evaluation of storage capacities in the Alps and Scandinavian counties.

During the workshop two research groups in Germany presented the results of several scenario studies they have been involved in. All these studies look at the possibilities to achieve 100% renewable electricity supply in Europe and Germany, within different time frames.

Amany von Oehsen from Fraunhofer IWES presented the result of two studies (Appendix 7).
The first study, coordinated by SIEMENS, looks at scenarios for large scale integration of wind and solar PV Energy in Europe (Requirements for transmission and storage). The results show that in order to achieve 100% renewable energy supply in Europe (by 2050) there is a need for:

- very large transport capacities between countries
- very large storage capacity, 190 GW
- deployment of different RES must be coordinated in Europe to reduce fluctuations, power losses and storage capacity.

The second study, coordinated by the German Federal Ministry of Environment, looks at possibilities for Germany to have 100% renewable electricity supply by 2050. This share will be fulfilled by approximately 62% wind, 18,6% PV, 14,4 % other RES and 5% import (see Appendix 7). The study concludes that 100% renewable electricity in Germany is technically possible provided that:

- the electricity demand in Germany will decrease considerable, from 800 TWh down to 105 TWh/year (see Appendix 7)
- a large amount of balancing power and large storage capacity is available (and, in principle, this can be achieved only through underground storage of hydrogen or methane, in Germany).

The presentation did not include any reference to balancing needs/possibilities from Norway.

The last study was presented by Prof. Olav Hohmeyer from University of Flensburg (Appendix 9 and [1]). The study details *scenarios for a climate friendly, reliable, affordable 100% renewable electricity supply in Germany by 2050*, and is developed by the SRU – The German Advisory Council on the Environment.

Some of the findings of this study are:

- 100% renewable electricity supply in Germany and Europe is possible and the cheapest way to get this is through inter-regional cooperation: Germany-Denmark-Norway or Europe- North Africa
- The scenarios oriented towards using the potential for pumped storage in Norway (and Scandinavia) assume a 15% exchange of the total German energy output (of ca.509 - 700 TWh/yr) with Scandinavia and predict a need for balancing power of about 50 GW and an extension of the transmission capacity between Germany and Norway by 2050 to around **42 GW - 69** GW (depending on the evolution of the German electricity demand).
- The scenarios focused on the larger Europe-North African region, predict an increase in transmission capacity between Norway and Denmark of about 115,7 GW and a total of approx. **200 GW** transmission capacity out of Norway, as illustrated in Figure 4 .

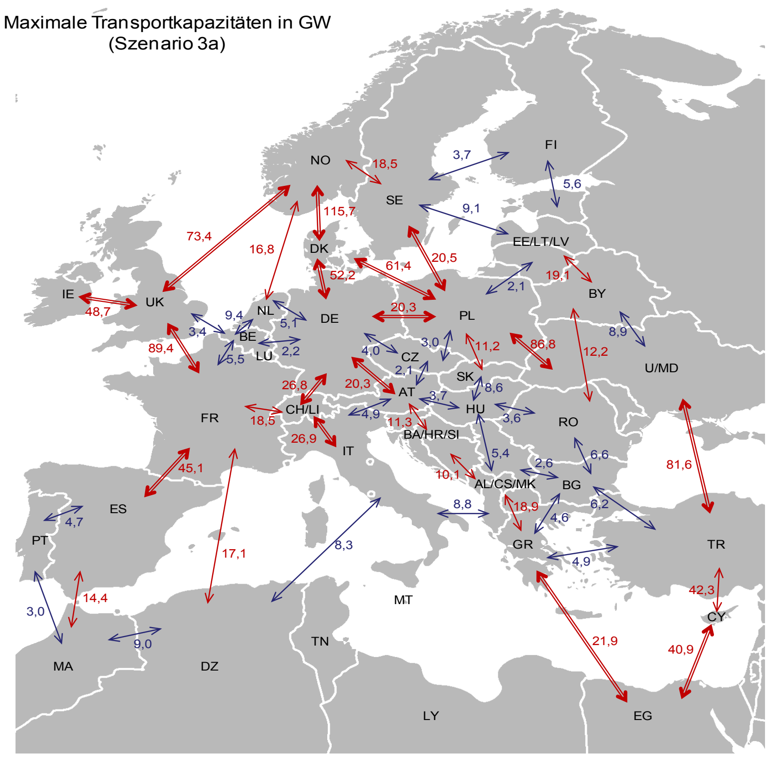


Figure 4 The necessary (max) grid capacities in 2050 (Appendix 9 and [1]).

3.2 Other countries interested in exploiting the hydropower potential in Norway

Germany is not the only country interested in collaborating and using the Norwegian hydropower potential – see Appendix 13 for an overview of the pan-European initiatives concerning this matter.

A report from 2010 made by two consultant companies (Sinclair Knight Merz-SKM, and Deloitte) [2] for the UK Department for Energy and Climate Change, investigates opportunities for developing joint projects with neighboring countries which will allow Great Britain to meet its renewable and carbon targets. The results of a simple CBA (cost-benefit) analysis indicate that interconnection with Norway (onshore to onshore direct connection) offers the highest economic benefit and the lowest cost from an investor perspective (in the UK interconnection construction is undertaken by private companies whose investment decisions is based upon an assessment of the costs and revenues from the project).

4 Conditions for the development of large scale balancing hydropower capacities in Norway

Theoretically, Norway has a very large hydro energy storage capacity – half of the total European storage capacity – according to some sources [4]. The question is how much of this potential can be developed and what would be the conditions that will allow such development.

4.1 The 'balancing' potential of Norway

Most of Norway's approximately 370 storage hydroelectric power stations comprise multi-reservoir systems whose various lakes are often interconnected by underground tunnels and pressure shafts. Such systems can theoretically be converted to pumped storage systems at relatively low cost. However to obtain 50 GW or more of balancing power, the turbine capacity in Norwegian power plants (currently 29,6 GW) will have to be expanded, in addition to stepping up the pumping capacity. This implies the construction of additional inflow tunnels, pressure shafts, pumps and turbines whose realization would require rather long term planning. In this respect, Bjarne Børresen (see Appendix 12) from Energy Norway gave a brief presentation of a joint (industry and research) project for the realization of a pump storage demonstration and pilot plant.

A study of the balancing potential in the Southern part of Norway was presented by Jon Ulrik Haaheim from Statkraft Energy (see Appendix 10). The study concludes that there are significant possibilities for capacity increase and pumped storage plants. For example, at specific reservoirs in South of Norway, the short term potential for 1 day pumping may reach 85 GW (assuming a 0,5 m/hour reduction in reservoir level), 30 GW for 5 days pumping and 2,6 GW for 60 days pumping – see Table 1.

Table 1 Technical potential for pumping in Southern Norway (Appendix 10)

Øvre begrensning i vannstandsendring	Pumpekraftverk (MW) med svingperiode (hver fase)			Effektverk (MW)
	1 døgn 24 t	5 døgn 5x24 t = 120 t	60 døgn 60x24 t = 1440 t	65 - 120 døgn 7x24x9 t= 1500 t
				7 500
0,50 m/time	85 000	30 000	2 600	
0,10 m/time	30 000	16 000	2 600	
0,01 m/time	3 200	3 200	1 500	

Statkraft will continue to analyze the possibilities for capacity increase in pumping and storage all over Norway considering: the theoretical technical potential, market aspects, legal issues, environmental consequences, business models that will allow the exchange of balancing power.

4.2 Necessary transmission capacity

Large scale use of balancing power from Norway will require a significant increase of the transmission capacity out of Norway.

While the German scenarios predict a need for transmission capacity out of Norway between 42 GW and 200 GW, other studies focused on the short and medium term benefit of new interconnectors which would ensure the transition to large scale transmission investments.

The study made by Thema Consulting and Pöyry and presented by Arndt von Schemde (see Appendix 5) is based on the expectation that there will be a substantial power surplus in the Nordic countries (towards 2020).

With the expected power surplus, Nordic electricity prices will be lower than electricity prices on the Continent, even if the interconnector capacity will increase substantially between the Nordic countries and the rest of Europe. The study presents estimates of the economics of interconnectors which indicate that the projects generate a positive social surplus.

In all scenarios the interconnectors generate revenues above the capital and operational costs of the interconnectors as long as there will be a price difference between the markets. Regarding the investment costs in the internal grid, the profits are estimated to be higher than the associated investment costs.

The transmission capacities considered in different scenarios vary from 7,7 GW (scenario assuming stagnation in both generation investments and demand) to 12,4 GW (in the scenario assuming 'green growth'- economic development and large increase in RES in the Nordic region) [3]. The overall profitability of these interconnectors will decrease as their number will increase.

4.3 Market design and regulatory challenges

During the workshop, the participants agreed that there is a regulatory and market challenge to optimise flexibility mix.

Further market development is decisive if optimization of hydropower in Northern Europe is to take place. A stepwise development of market design is preferable, while still preserving elements of existing market structures; communicating a 'double/complex agenda' - see (Appendix 6). There will also be a need for market coupling within the EU area through German TSO cooperation (vs. Nordic countries) and to impose a uniform market design (currently, there are different market designs, nationally).

Regarding the trading of 'balancing' and flexibility, it is expected that the spot market continues to be dominant and the intraday market will develop further. The ancillary services market will have to be developed and harmonized across countries. The present ERGEG guidelines allow allocation of ancillary services at different time frames. The Danish energy authorities allow exchange of ancillary services, but a re-evaluation of this arrangement will be made (Appendix 6).

4.4 Political and social commitment

It was clear for all participants in the workshop that a future electricity supply based on renewable energy sources cannot be realized without political and social support, nationally and internationally.

The main long-term driver behind the development of the power system will always be to maximize the value of electricity consumption to society. Society involvement will be a crucial parameter in any political decision (on short and long-term) that will enable full scale use of renewable energy resources. The speakers gave examples how low social acceptance pose difficulties for building new hydro power plants and transmission grids in Norway and transmission infrastructure in Germany.

The current EU decision-making structure was discussed by Audun Ruud from SINTEF Energy Research (see Appendix 3). The EU energy policy decisions are fully dependent on national implementation. On the other hand, the EU has no authority vis-à-vis deciding the composition of the energy mix nationally, but has some influence, indirectly, by setting for instance targets for renewable energy.
Inter-governmental agreements and an even benefit sharing among countries and across the 'value chain': generation, transmission and end-users, are essential.

5 Discussion

The workshop concluded that Norwegian hydropower may play a very important role in the future European energy supply. Large capacities for balancing power are desired by German scenario makers and possible to achieve according to the largest power producer in Norway (Statkraft).

However, this can only be possible if the right political decisions are made and accepted by the energy industry partners and citizens in both countries. When addressing the issue at a high political level, it should be presented as a '(renewable) package' with a coherent business case explaining the sharing of profits/benefits nationally, and across the value chain. 100 % renewable electricity supply in Germany is possible by 2050, and Norwegian supply of balancing services is the cheapest and most secure solution.

A question raised is what would be the way to move forward on short term, i.e. either to move forward bilaterally (Germany and Norway/Scandinavia) or wait for EU to create the conditions (political, legal, etc.) for such collaboration.

However, technically, in order to achieve a very lager share of RES in Germany there is a need for rapid and substantial investments in the transmission infrastructure both inland and with the neighboring countries.

Most German industry representatives expressed their doubts regarding the achievement of 100% RES in Germany, however they agree that the country is moving in this direction, but that RES development will be enabled mostly by available storage possibilities in Germany. In fact there is more flexibility in the German system than previously expected (see all estimation for different energy storage technologies, as alternatives to Norwegian balancing power). They added that major changes in the German (North sea) price formation will have an important impact on Germany's economy and on other countries (although not part of the bilateral discussions).

From Norway's perspective, simply put, balancing capacity can be developed only if there is a German/European 'customer' to 'buy it'. However, even if there will be a 'buyer', the next barrier to new infrastructure projects will be the difficulty to attain public acceptance/social consensus (see Sima - Samnanger case). To overcome this, the society must 'feel' that it is contributing to something important and that it is getting something back (for example, the costs for the Norwegian society can be given back though reduced taxes). Moreover, all environmental impacts have to be accounted for locally, as well as in a European perspective.

For investors in Norwegian balancing power it is important that long-term political and economic agreements (through TSO's) are made and that markets will be re-constructed in order to allow for large scale trading of RES. This is in addition to complying with the environmental and social requirements.

For investors in transmission capacity the most important is the timing when the cables will be built: new North Sea transmission sea cables are only 'marginally' profitable. On short term, a 'good' payback is expected in cable investments, due to price differences between Norway and the EU. However, at the beginning, up tot a certain capacity, cables investments may be higher than investments in new pumped storage capacities.

Interconnectors have thus to be planned in a more coordinated manner (financing, prices, time scale): for example in order to be able to use 20 GW of balancing capacity there will be a need of approximately 28 cables (see also Appendix 14). It is likely that bilateral cooperation (following the experience with the existing interconnectors) will work better than multi-national initiatives. A suggestion was also to look at the parallel gas sector and experiences with (multi-national) infrastructure investments (Ruhrgas).

6 References

[1] "Climate-friendly, reliable, affordable: 100% renewable electricity supply by 2050," The german Advisory Council on the Environment May 2010.

[2] "Offshore Grid Development for a Secure Renewable Future – a UK Perspective," Sinclair Knight Merz June 2010.

[3] "Chellenges for Nordic Power. How to handle the renewable electricity surplus," Econ Pöyry and Thema Consulting Group 2010.

[4] K. E. Stensby, "Potential for large scale exchange " presented at the International workshop 'Exchange of balancing services between the Nordic and the Central European synchronous systems', Oslo, 26-27 January 2011.

Appendix 1

The centre for environmental design of renewable energy, CEDREN

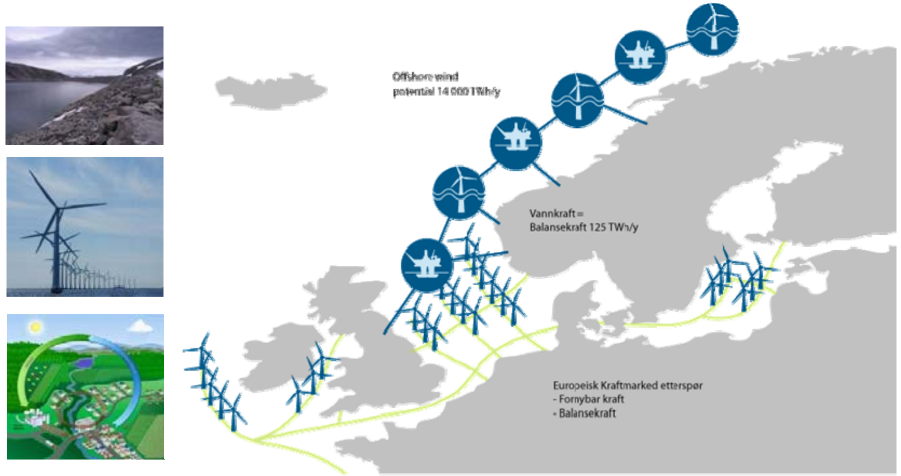
Atle Harby, SINTEF Energy Research

Centre for environmental design of renewable energy – CEDREN

SINTEF
NTNU 100 skapende år
NINA Norsk institutt for naturforskning
NATURHISTORISK MUSEUM UNIVERSITETET I OSLO
NIVA
uni Research

Forskningsrådet

Energi21 and The Parliament
→ 8 new research centres on environmental-friendly energy



CEDREN Centre for Environmental Design of Renewable Energy

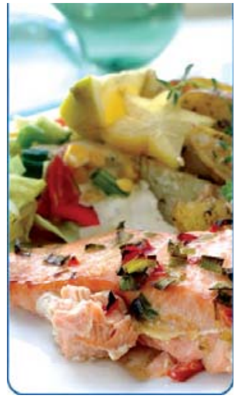
Renewable energy respecting nature

- 6 large research projects
- 7 Norwegian research partners
- 10 Industry partners and 2 management partners
- Budget: 263 MNOK (67 MNOK in 2010)
- 15 PhD and 4 Post-doc positions

Industrial partners

agder energi
BKK
ECO
Eidsiva
EnergiNorge
HYDRO
ICH
Sira-Kvina kraftselskap
Statkraft
Statnett
TrønderEnergi
NVE


Technology development for the future hydro system



Increased power *and* salmon production

Hydropower development

Environmental impacts of flow fluctuations – methods and tools

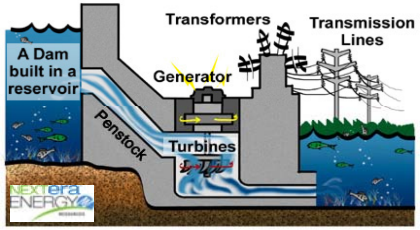

Power transmission: Impacts on wildlife

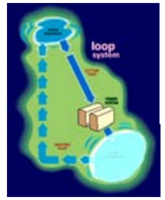
Environmental design


Birds and wind turbines

Policy and society: How to reconcile energy and the environment?

HydroPEAK









BirdWind




OPTIPOL – Power lines and wildlife


- Improved planning tools
- Reduce conflicts

GOVREP

GOVernance for **R**enewable **E**lectricity **P**roduction



How to reconcile environmental- and energy policy concerns?

Enabling a more effective realization of both energy- and environmental objectives as agreed upon by the Parliament

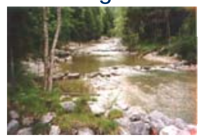
Environmental impacts of rapid and frequent flow changes

Knowledge about how, when and where rapid variations in power production may be done with acceptable impacts on the ecosystem.

Physical processes

Biological processes

Mitigation



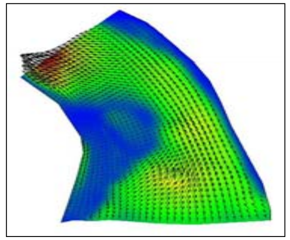
EnviDORR

Increased power and salmon production with Environmentally Designed Operation of Regulated Rivers

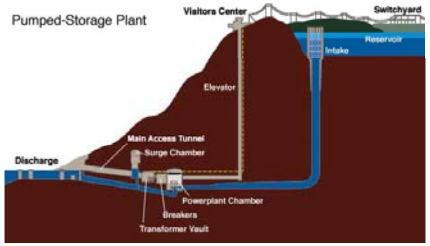
In *situ* study

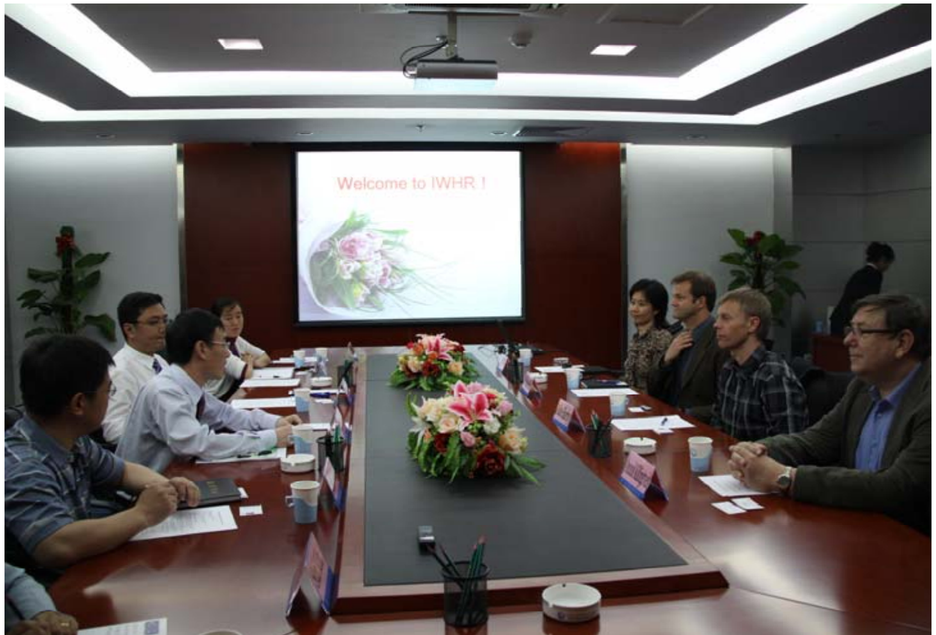
Laboratory

Model simulation

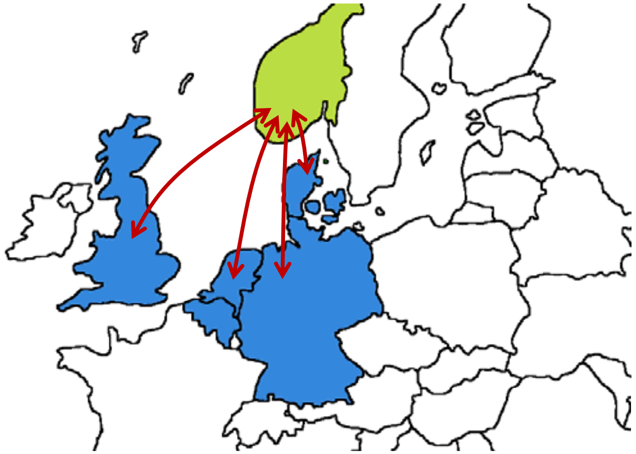


Demonstration



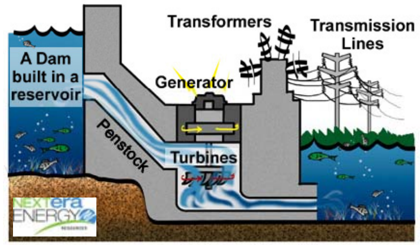


Norway's role in Europe?



HydroPEAK scenario study

- Hydropower development in Norway to cover peaking and load balancing needs in a European system with increasing use of non-regulated renewables
- Scenario framework for further studies in CEDREN/HydroPeak
  - Policy
  - Marked
  - Transmission
  - Generation
  - Environment



Scenarios

- Small scale export/import
  - Workers' union and industry argument
  - Prices for end users?
- Large scale balancing
  - Climate change and need for renewable energy
  - Demand from EU policy?
- Most probable – in between?
  - 20 GW capacity by 2030 ?
  - Large installations parallell to existing
    - No new reservoirs or dams
    - Reinforcements of the grid

Scenario 20 GW in 2030

- 10 GW of balance capacity for export in 2020 and 20 GW in 2030
- Challenges and feasible measures/ solutions regarding
  - political and public support
  - long term agreements and collaboration (EU, TSOs, etc.)
  - funding
  - balancing benefits/disadvantages between domestic 'stakeholders'
  - planning and construction capacity
  - environmental design
  - marked design
  - concession processes

Scenario
20 GW in 2030

	2010		2020		2030
Policy	Policy headlines	→	Relevant changes/policy implementation 2020	→	Relevant changes/policy implementation 2030
Market	Present market situation	→	Relevant market developments	→	Relevant market developments
Transmission	Existing transmission capacity	→	New transmission lines 2020	→	New transmission lines 2030
Generation	Total capacity Balancing services	→	Total capacity Balancing services	→	Total capacity Balancing services

SUSTAINABLE ELECTRICITY GRIDS (SUSGRID)
A need for new multi-level regulation designs

The SUSGRID project will focus on current grid development and how economic, social and environmental concerns can be better integrated

Empirical focus: Norway and the Nordic Region, The UK, Germany

A four year project directly related to the ongoing CEDREN activities GOVREP and OPTIPOL

Audun Ruud, SINTEF Energi

Norsk vannkraft som batteri for Europa

- Energy storage and support from Norwegian hydropower reservoirs to Europe
  - A new CEDREN project “HydroBattery”

Vision: Norwegian hydro – the green rechargeable battery for Europe

Tema for FoU:

- Marked: Hvordan blir mulige markeder?
- Politikk: Rammer og regelverk i Norge og Europa, RES-direktivet
- Teknologi: Pumpekraftverk, vannveier, overføringslinjer, kabler
- Miljø: Effekter i magasiner og miljøvirkning av nye linjer
- Samfunn: Samfunnsaksept, turisme, friluftsliv, lokalt og nasjonalt
- Utnytte all kompetanse i CEDREN sammen med aktive brukere

Atle Harby, SINTEF Energi

www.cedren.no

Contact: atle.harby@sintef.no

SINTEF NTNU 100 skapende år NINA Norsk institutt for naturforskning NATURHISTORISK MUSEUM UNIVERSITETET I OSLO NIVA uni Research

Appendix 2

Statkraft in Germany

Stefan Jörg Göbel, Statkraft Markets GmbH

STATKRAFT IN GERMANY

AND HOW WE SEE RENEWABLES INTEGRATING CURRENTLY

DECEMBER 2010

Statkraft
PURE ENERGY

KEY AREAS

Flexible European generation and market operations

International hydro power

Wind power

District heating

Regional companies

Statkraft

GAS-TO-POWER

- **Knapsack** – Germany
  - 100 % ownership
  - Installed capacity: 800 MW
- **Herdecke** – Germany
  - 50 % ownership
  - Installed capacity: 400 MW
- **Robert Frank** – Germany
  - 100 % ownership
  - Installed capacity: 487 MW
- **Emden** – Germany
  - 100 % ownership
  - Installed capacity: 452 MW
- **Kårstø** – Norway
  - 50 % ownership
  - Installed capacity: 420 MW

Statkraft

OUR GERM

- Head office
- Offices

Statkraft

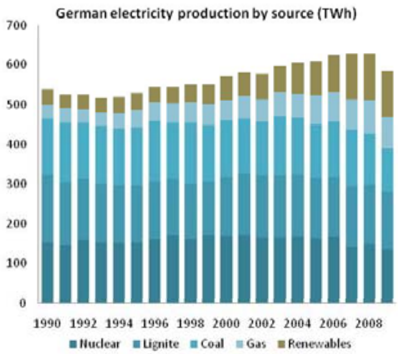
PUMPSTORAGE ERZHAUSEN

220 MW turbines/pumps, 1035 MWh storage

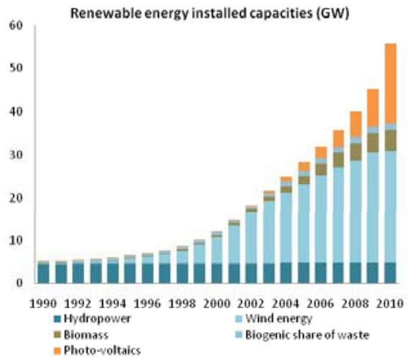
TRADING IN EUROPE

- > 70 persons
- 50m EUR risk capital
- >30% return on capital
- Active in 25 countries, 28 borders, 20 exchanges!

RENEWABLE ENERGY IN GERMANY



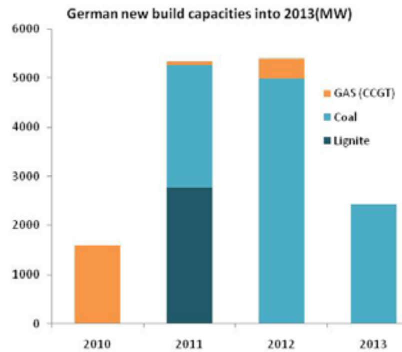
Renewable energy reached 93.5 TWh production in 2009, equivalent of 16% of total electricity consumption.



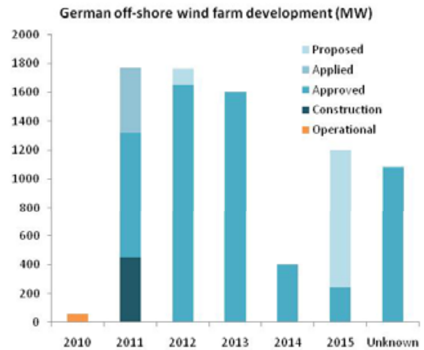
Wind & solar are among the fastest developing renewable energy sources.

Source: BDEW, AG Energiebilanzen e.V.

EXPECTED ADDITIONS IN GERMANY



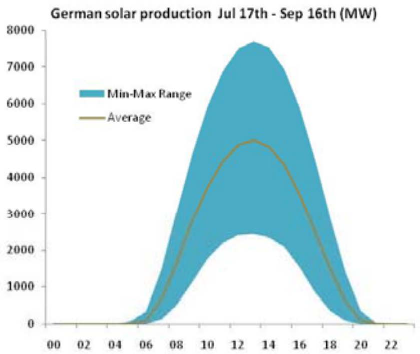
1300MW new gas fired capacity was added in 2010. (E.ON & RWE). More of coal to come.

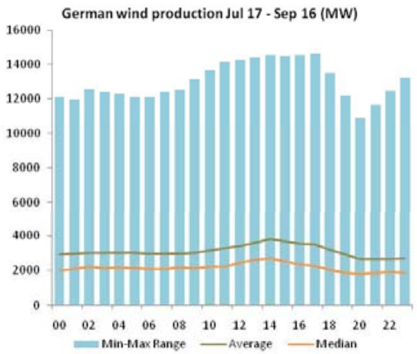


Offshore wind farm is one of the biggest uncertainties…

Source: Statkraft.

IMPACT OF SOLAR & WIND ON SPOT PRICE: SUMMER SCENARIO (I)



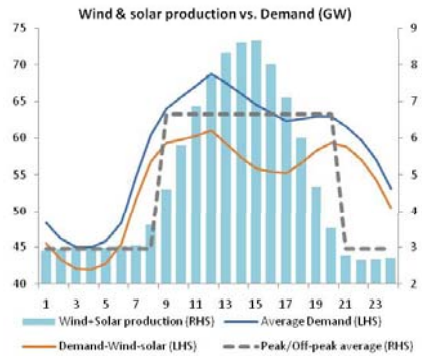


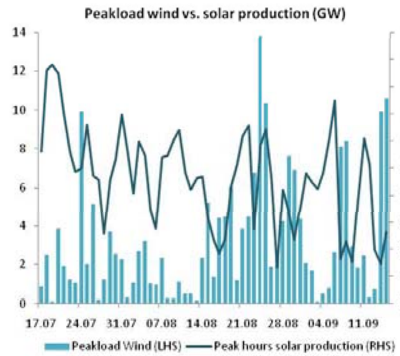
EEX started reporting solar production/forecast since July 2010.

Wind production is much less predictable than solar.

Source: EEX, Statkraft.

IMPACT OF SOLAR & WIND ON SPOT PRICE: SUMMER SCENARIO (II)





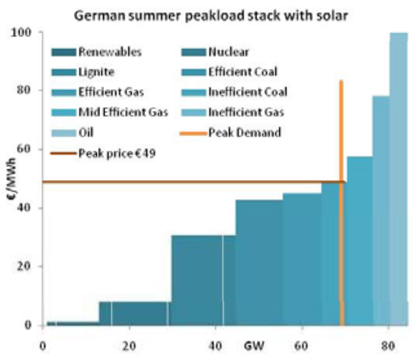
Solar + wind production averaged 6.7GW during peak hours in the past 2 months.

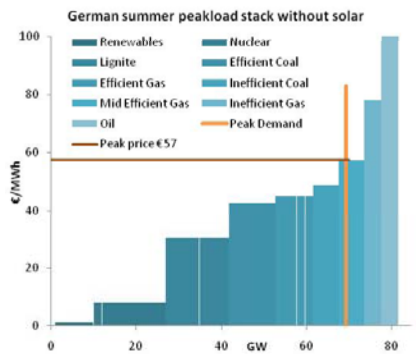
	Wind	Solar	Wind+Solar
"Volatility"	1.39	0.29	0.47

Solar production mitigated volatile behavior of wind production.

Source: EEX, Statkraft.

IMPACT OF SOLAR POWER ON SPOT PRICE: SUMMER SCENARIO



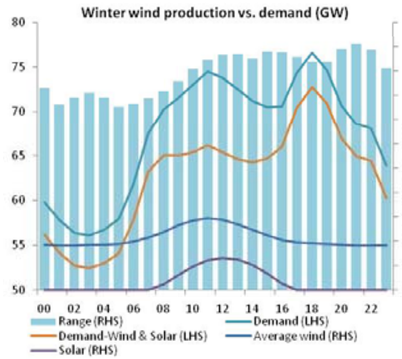


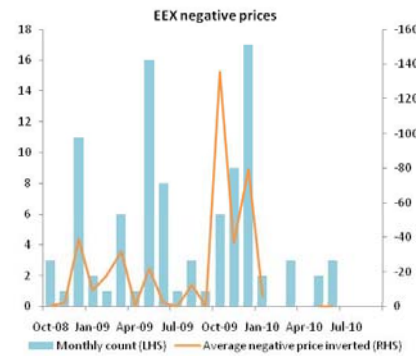
By adding **3.3**GW of peak-load solar production, a simple stack model shows €8 reduction in peak-load price. Actual delivery for the observation period was at €50.8

	Coal (€/GJ)	Gas (€/GJ)	Base	Peak	Peak/ Base
2009	1.95	2.53	35.8	47.1	1.32
2010	2.87	5.22	42.8	52.7	1.23

Source: EEX, Statkraft.

IMPACT OF WIND & SOLAR ON SPOT PRICE: WINTER SCENARIO





The drop of solar power after short daylight hours creates tension in supply-demand balance for second peak of winter times.

Negative price is becoming far less frequent this year.

Source: EEX, Statkraft.

PURE ENERGY

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Mobile +49 163 430 1224
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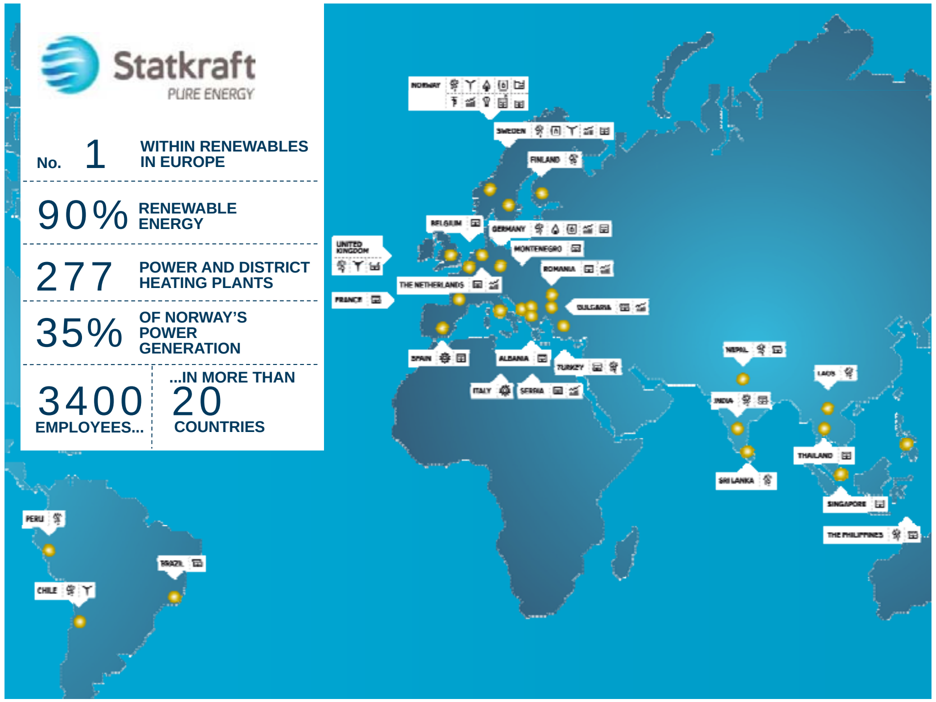
www.statkraft.de

THE STATKRAFT GROUP

- --> Environment-friendly power generation: 56.9 TWh*
- --> Total assets 2009: NOK 144 billion
- --> 3,400 employees in more then 20 countries
- --> Gross operating revenues 2009: NOK 25,7 billion
- --> EBITDA 2009: NOK 9,8 billion
- --> Net profit 2009: NOK 6,5 billion

Statkraft

*Annual average



Appendix 3

Realization of energy and climate policies in Europe. What works where, when and how

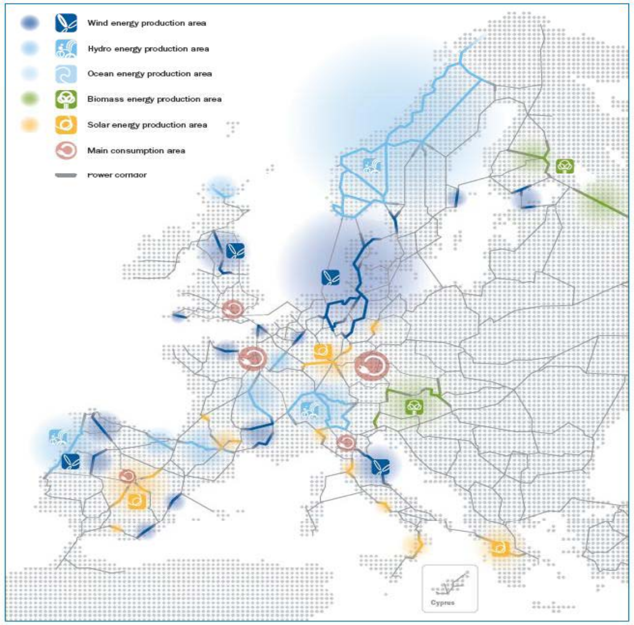
Audun Ruud, SINTEF Energy

Realization of energy and climate policies in Europe: What works where, when and how?

Hydropeak workshop, Düsseldorf
15 December 2010

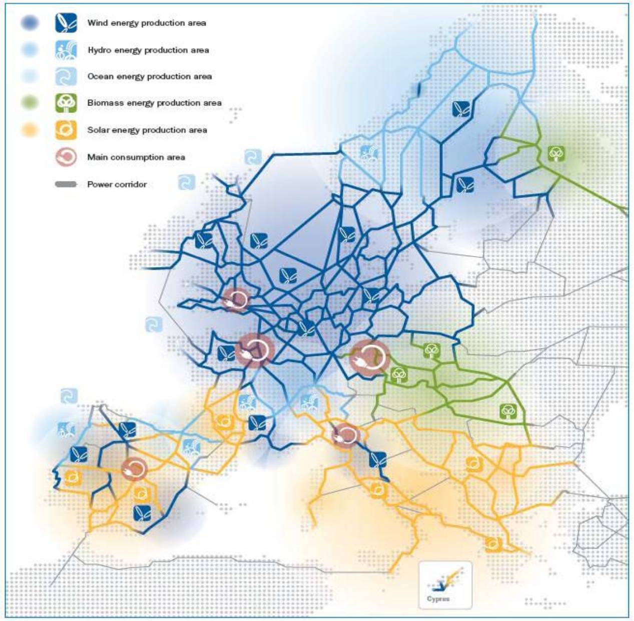
Audun Ruud,
Research Manager,
SINTEF Energy Research,
Policy and governance

Status in 2010
according to EWEA



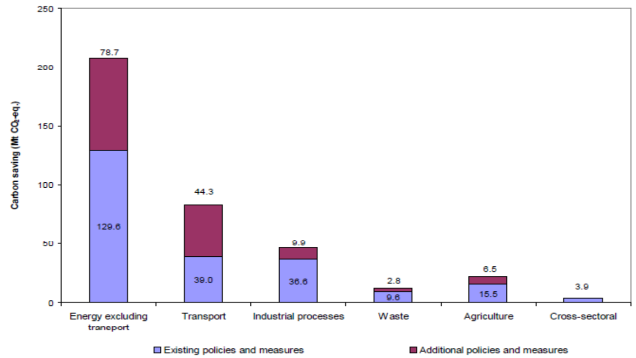
Status in 2050
according to EWEA

How can we get there?



More than 80% of EU greenhouse gas emissions caused by production and use of energy

Figure 91 EU-15 Projected annual greenhouse gas emission savings by sector in 2010



Note: Projected savings from policies and measures in 2010 are estimated by comparison with a hypothetical reference case in which no measures were implemented since the base year.

Source: See Sources of Information (Chapter 7). Details on individual Member States can be found in Table 4 of the Country Profiles (Annex 8).

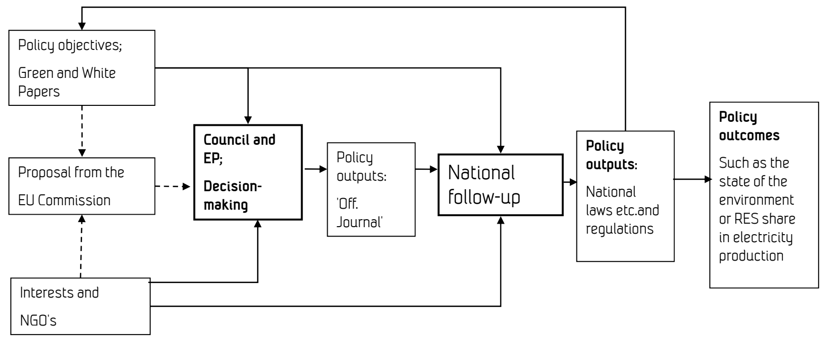
Source: EEA 2008

How does the EU decide and follow up a specific policy area?

- **In general, the following steps *may* apply:**

1. Green Paper formulated by the Commission, with inputs from various stakeholders.
2. Public consultation
3. White Paper/Communication formulated by the Commission.
4. Public consultation
5. **Proposal for legislation from the Commission**
6. Public consultation
7. **Council and Parliament; reading and deciding the proposals, in *co-decision*.**
8. Final decision of the co-decision process as ***output*** is published by the *Official Journal* by which the deadline for national follow-up ('transposition') is communicated.
9. **Follow-up by national authorities/governments**, in accordance with national parliaments: National legislation and other follow-up processes as ***outputs*** at the national level.
10. National reports of status of implementation, addressed to the Commission
11. In cases of lacking implementation the Commission and/or other actors can summon the national government to the European Court of Justice (ECJ) (Infringement procedures).
12. **The ECJ can rule out sanctions in the cases of lacking implementation**; e.g. fines.
13. Monitoring and evaluation of EU policy outputs; the assessment of the eventual ***outcomes*** (results).

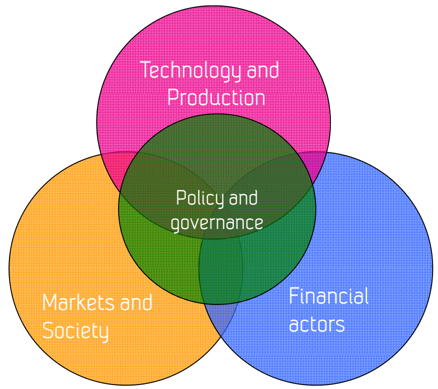
Decision-making and implementation in the EU: From policy formulation via policy outputs to policy outcomes (results)



What can be decided by the EU? The constitutional basis for climate and energy

- **The Lisbon Treaty (2009):** For the first time, a specific chapter on energy in the EU Treaty (article 194), in addition to an explicit mentioning of climate-change. However, no new political power transferred to member states to the EU in energy matters.
- **The EU can decide on energy issues only if they are related to the development of the internal market and/or the environment.**
  - In the latter cases, the EU can apply decisions by qualified majorities in the Council, in *co-decision* with the Parliament. That is, a certain degree of supra-nationalism can apply on energy.
- **In contrast, all decisions pertaining to the national energy mix and fiscal incentives require unanimity (all Member States must agree).**

What is actually influencing development of the energy system:



Scenario
20 GW in 2030

	2010	2020	2030
Policy	Policy headlines	Relevant changes/policy implementation 2020	Relevant changes/policy implementation 2030
Market	Present market situation	Relevant market developments	Relevant market developments
Transmission	Existing transmission capacity	New transmission lines 2020	New transmission lines 2030
Generation	Total capacity Balancing services	Total capacity Balancing services	Total capacity Balancing services

Elements on 'policies' from the Hydropeak 2030-scenario

- **20 GW balancing delivered from Norway.**
- **Towards 2030:**
  - Energy security as a stable and basic driving force for policy making.
  - The EU-targets 20/20/20 fulfilled by the mid-20's.
  - Increased shares of Renewables have caused a stronger need for balancing hydropower from Norway.
  - North Sea grid established, UK as the leading nation.
  - European market exchange systems mainly harmonized, but
  - still strong resistance towards common EU market regulation and
  - no effective supra-national authority over energy supply questions.

Status of the Renewable Energy Sources (RES) Directive of 2009 (based on the submitted National Energy Action Plans*)

- **Technologies:**
  - *Electricity generally more substantially and concretely accounted for than heating/cooling and transport.*
  - *Wind power the most prevalent technology, both on- and off-shore.*
- **Economy:**
  - *Financing a key challenge in all countries, but mostly sketchy estimates and lacking assessments of impacts on end use, industrial activity and employment.*
  - *Cost estimates provided by the Member States not standardized, and hence not directly comparable.*
- **Policy instruments:**
  - *Strongest reliance on feed-in tariffs, investment grants and tax incentives. Despite the recent anouncement between Norway and Sweden, less enthusiasm on tradable green certificates (TGCs)*
  - *Most Member States address the challenges of grid connection, planning/licensing and public acceptance. However, few stipulate new instruments in this regard!*

*Source: ENDS Environmental Data Services (2010): 'Renewable Energy Europe'

Where is the EU moving? (1)

✓ EU on track towards its common Kyoto commitment, by 2012.

The EU Commission recently (11 Nov) forwarded a ***Strategic EU energy plan for 2011-20***

- **Main priorities** of the strategy are:
  - increased energy efficiency that translates into 20% savings by 2010,
  - a more integrated market providing competitive prices, choice and security of supply
  - European technological leadership, delivering innovative and cost-efficient solutions
  - reinforced energy security for citizens and businesses
  - stronger international partnerships, notable with our neighbours

➢ **The energy plan to be discussed at the EU Summit February 2011; as a basis for a 'Roadmap towards 2050' (expected in 2011).**

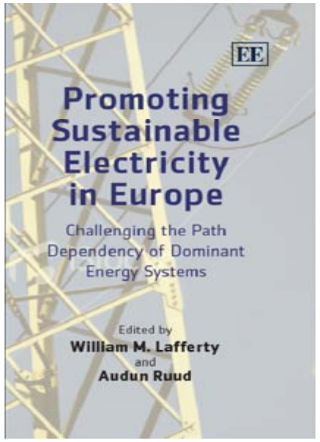
Where is the EU moving? (2)

The Commission also recently (17 Nov) presented its priorities on ***energy Infrastructure:***

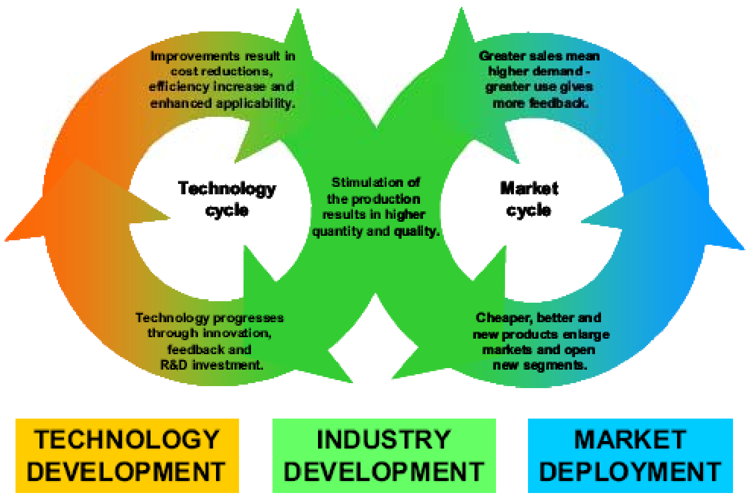
- **Spesific maps are to be drawn**
- **Priorities are to be formulated**
  - Offshore grid North Sea and related connection to Northern and Central Europe is included as priority.
- **Spesific projects to realize the priorities are to be selected**
- **New tools to be developed:**
  - **Improved regional cooperation**
  - **Permitting procedures**
  - **Better methods and information for decision makers**
  - **Innovative financial instruments**

However, still EU energy policy depends ultimately on the Member States' follow-up and approval.

Can we learn by taking a look at the Susten project analysing the implementation of the RES-E Directive from 2001?

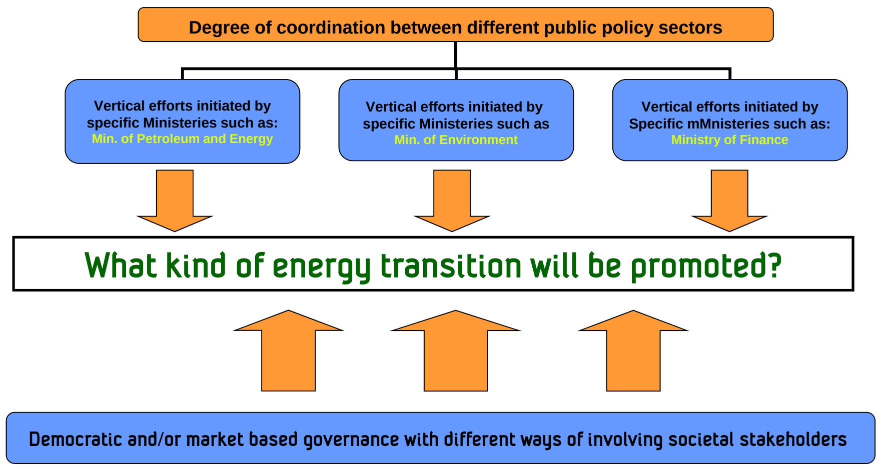


Standard model for perceiving the "virtuous cycle for a supportive policy environment":

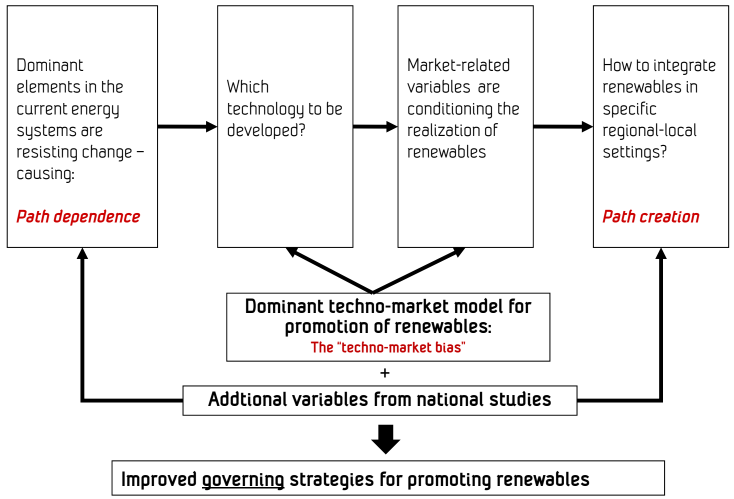


Source: *Renewables for Power Generation* (2003: IEA-OECD, p. 14)

How does energy policy making actually function?



The expanded "virtuous cycle" applied in the SUSTEN project:



Selective national figures for achievement of renewable targets

SUSTEN results

	Percent RES-E of total *El consumption (1990 – 2004)* IEA/OECD data		Percent RES-E achieved EU data ("normalized")	Indicative target from RES-E Directive	Gap to be closed by 2010 EU figures	Gap to be closed by 2010 SUSTEN figures
	1990	2004	2005	2010	2005 > 2010	2004 > 2010
Denmark	2.8	29.9	27.3	29.0	+ 1.7 ☺☺	- 0.9
Finland	18.3	30.8	25.4	31.5	+ 6.1 ☺	+ 0.7
Netherlands	1.7	6.2	6.5	9.0	+ 2.5 ☺	+ 2.8
Sweden	56.9	51.8	52.0	55.2*	+ 6.1 ☺	+ 3.4
Spain	20.2	22.7	21.6	29.4	+ 7.8 ☺	+ 6.7
Ireland	5.8	6.0	8.0	13.2	+ 5.2 ☺	+ 7.2
Austria	75.0	67.0	57.5	78.1*	+ 20.6 ☹☹	+ 11.1
Norway	125.0	98.7	99.0	90.0		- 8.7

Drawn on insight from the Susten project:

Will current energy and climate policies in Europe be realized?

Norwegian Hydropower has a potentially central role in balancing the increasingly intermittent European energy system, however:

- How to handle path dependence and resistance to change?
- Who should be in charge to stimulate necessary path creation to realize energy and climate policies of Europe?
- Will instrastructure for distribution of natural gas be developed complementary or in competition to electricity grids?
- More specifically:
  - How to reconcile economic, social and environmental concerns?
  - How to strengthen social acceptance for electricity grid development?
- Hopefully these questions will also be covered in the plenary discussion!

Appendix 4

Perspectives on the role(s) of storage seen from a German utility

Bernd Calaminus, EnBW AG

Perspectives on the role(s) of storage seen from a German utility

Workshop:
"Perspectives on hydropower's role to balance non-regulated renewable power production in Northern Europe"

Düsseldorf, 15/16-12-2010
Dr. Bernd Calaminus
Head of Generation Technology
Conventional/Hydro at Holding of EnBW AG

EnBW
Energie braucht Impulse

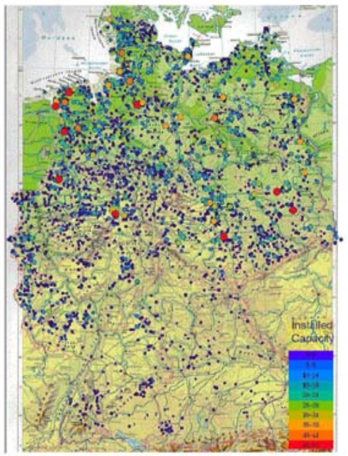
Three Words on EnBW
Vertically integrated, but of course unbundled

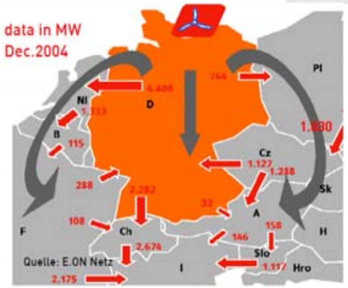
- Third biggest, fully integrated utility company in Germany with about 6 Mio clients and 15.8 GW of installed power
- One of the biggest TSO / DSO (south-west of Germany)
- About 16 Billion € turnover, > 20.000 employees (in 2009)

EnBW Home Market in Baden-Württemberg
Nuclear – coal (hard, brown) – hydro (run of river, pumped) - renewables

¹ Leistungsbetrieb als Folge des Atomkonsenses am 11. Mai 2005 eingestellt

Wind Power in Germany – Impact on Physical Load Fluxes



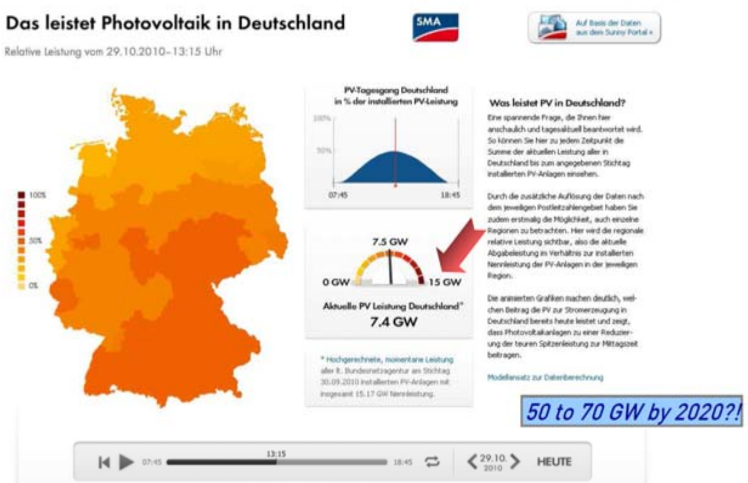


- North to South gradient
- secured power 5-10%
- grid congestion
- storage for excess uptake?
- storage for constant delivery?

Source: ISET today ca. **27 GW** inst. wind power

PV in Germany

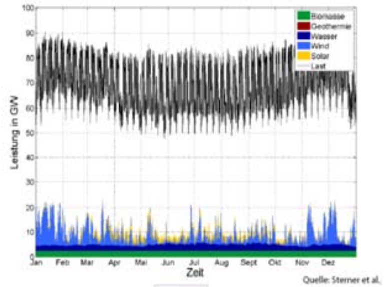
As of today 15 GW / ca. 1.000 h Fullloadhours / Investment based on "EEG" / hardly dispatchable / high share in regions with comparatively weak grids



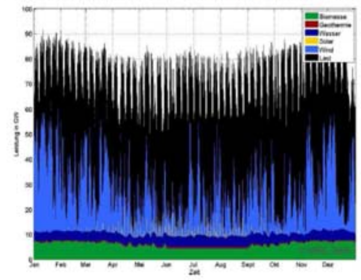
50 to 70 GW by 2020?!

Impact on Thermal Residual Load - Increased Need for Flexibilty

Simulation von 2007: 15% EE - one year – hourly resolution

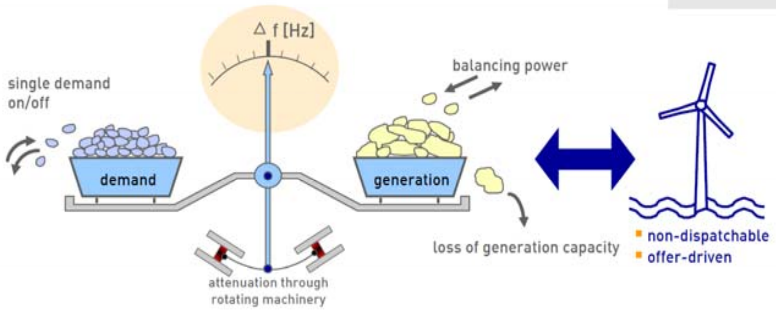


BEE-Szenario 2020: 47% EE - one year – hourly resolution



- › thermal residual load decreases significantly
- › base load driven out
- › untrue operation of conventional plants

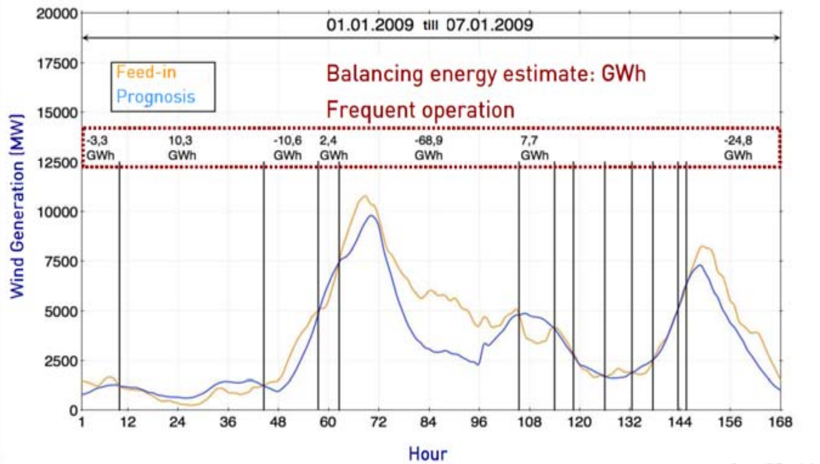
Strong Increase of Non-dispatchable Generation



- demand and offer have to be balanced out at any time
- shares of non-dispatchable, offer-driven generation increase
- at high wind load and low demand, energy management can be required (loss of ren. energy)
- future high-end generation plants (700°C) provide lower flexibility
- grid congestion situations occur more frequently

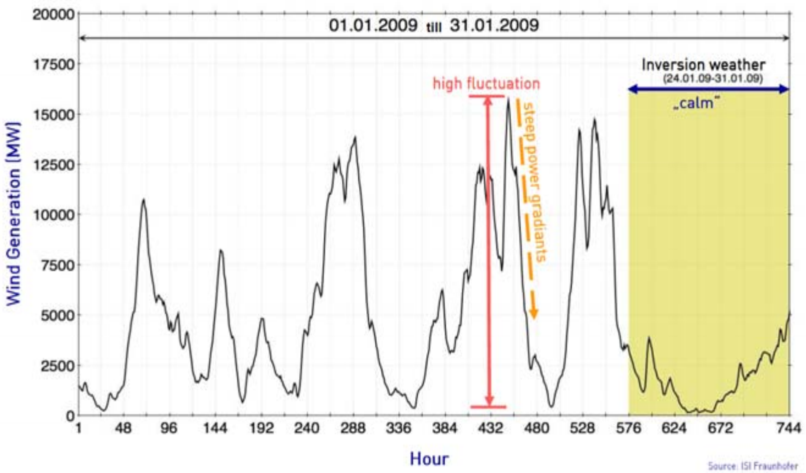
Short-term Use of Storage

Prognosis Error over Week 01.01.2009 – 07.01.2009



Source: ISI Fraunhofer

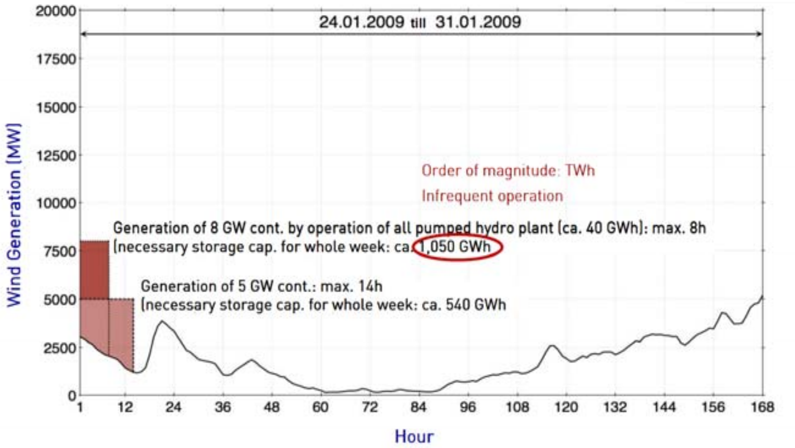
Wind Feed-in January 2009



Source: ISI Fraunhofer

Multiple Day Storage

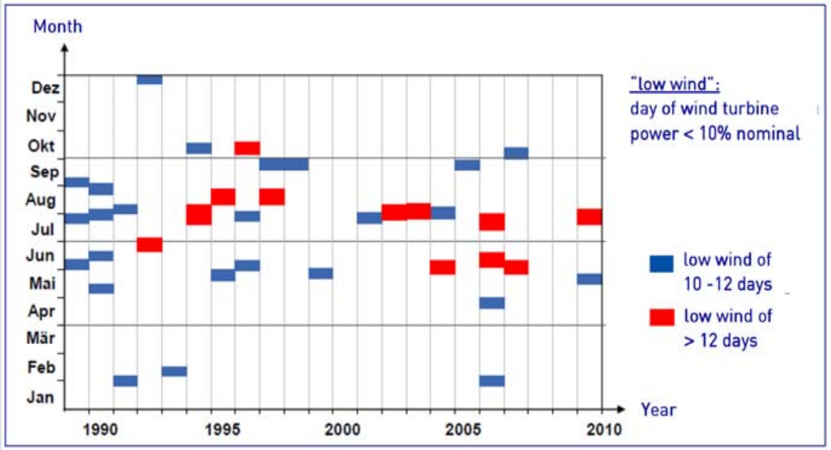
Inversion Weather Conditions 24.01.09 – 31.01.09



Source: ISI Fraunhofer

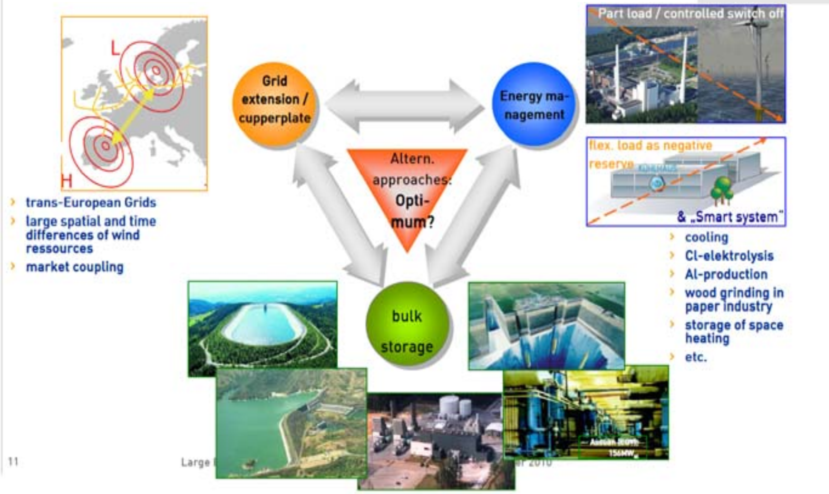
Periods of Low Wind Feed-in

(< 10% of Installed Power)



Source: RWE/Vahrenhold, VGB-Tagung 2010

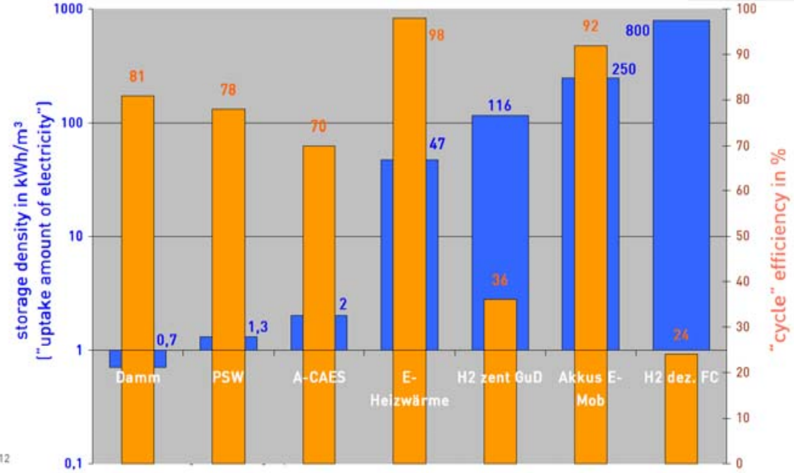
Alternative Approaches for Equilibrating Demand and Generation (...or Generation and Demand) in Balancing Zones



Rough Comparison of Storage Options

Approach: How to store large amounts of electricity?

[for dam, el. space heating and decentral. H2 no closed electricity storage cycle]



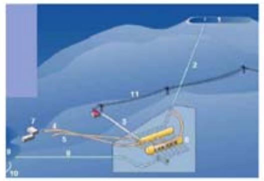
Balancing Power Example: Pumped Hydro Plant

[„Wehr", 50% owned by EnBW, +/-1,000MW]

EnBW total PHS: 1,720 MW (D: ≈ 7,500 MW, ≈ 40 GWh)

- powerful, proven technology
- high storage efficiency (~80%)...
- ...but new sites are hard to find
- hilly topology is needed
- specific costs for new plants are strongly increasing

→ adiabatic CAES potentially competitive as further OPTION



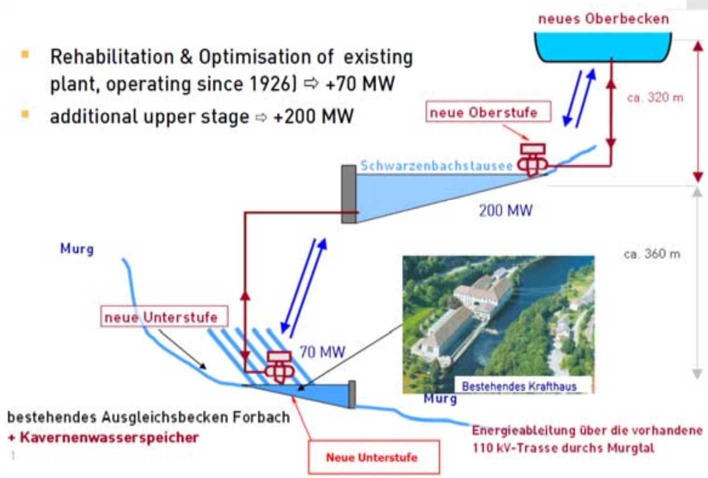
Pumped Hydro Project: ATDORF

(EnBW share 50%)

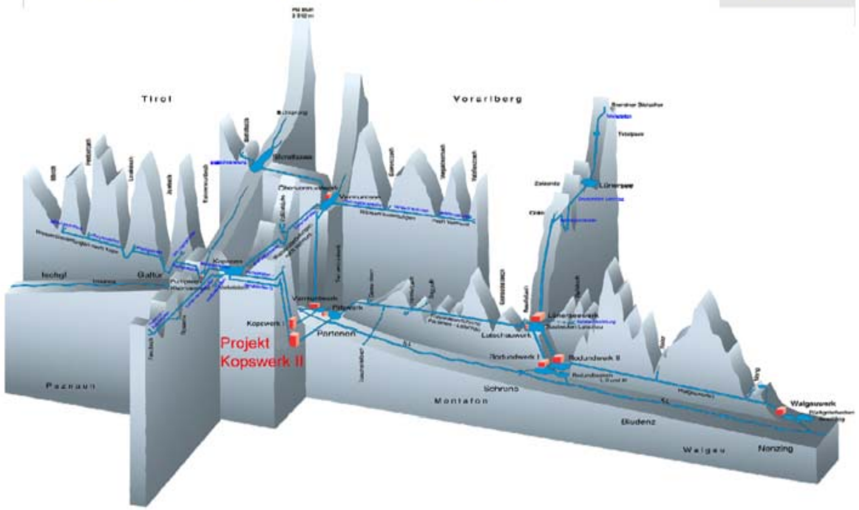
- Active volume 9 Mio m³ (T_{Pump}≈12h, $T_{Turbine}$≈ 9h)
- Head 600 m
- Power 1,400 MW (e.g. 6 pump/turbine units of about 234 MW each)

Pumped Hydro Project: FORBACH

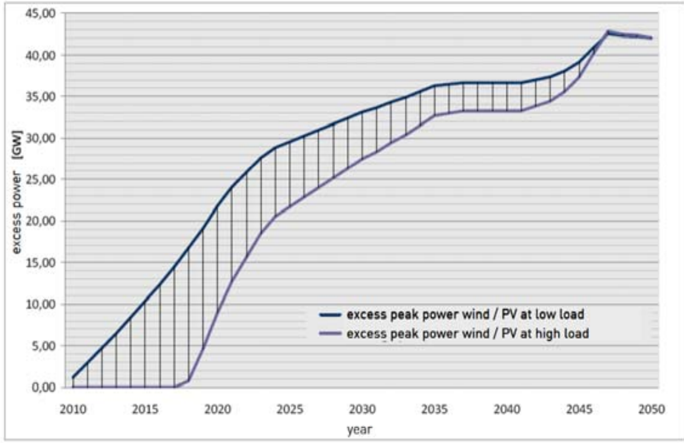
- Rehabilitation & Optimisation of existing plant, operating since 1926) ⇨ +70 MW
- additional upper stage ⇨ +200 MW



Illwerke Schematic Plant Concept
Highly flexible peak and mid power in the Vorarlberg Alps



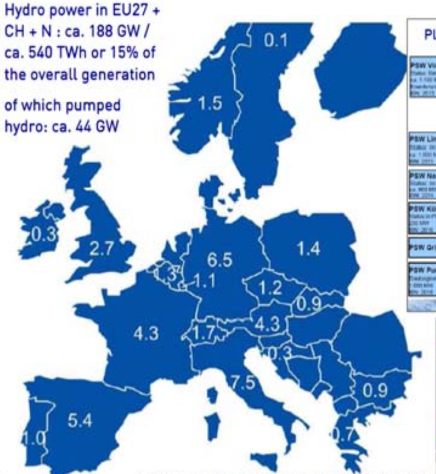
Development of Excess Power from Wind and PV in Germany
(Scenario 2.1.a; SRU-Bulletin No.15-2010)



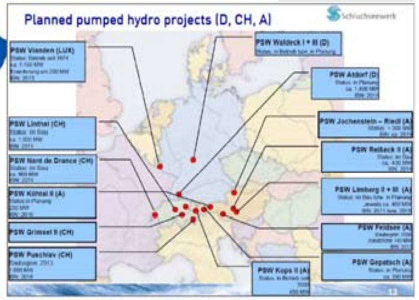
Maximum transport power for the region DE–DK–NO 2050

Pumped Hydro in Europe
Some Figures

- Hydro power in EU27 + CH + N : ca. 188 GW / ca. 540 TWh or 15% of the overall generation
- of which pumped hydro: ca. 44 GW



PSP power in Europe: data: EUROSTAT 2008



D – L – CH – A:

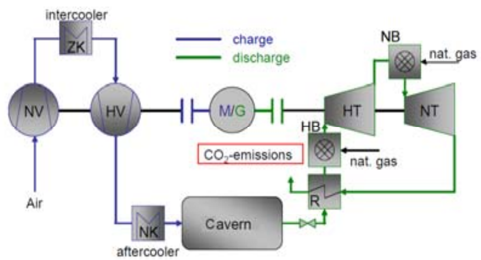
today:	ca. 7,5 GW at D-grid
	ca. 40 GWh energy
under constr. / in pipeline:	ca. 8,4 GW
„potentials":	ca. 7 GW

Norway following Statkraft:

„potentials": ca. 15-20 GW; 1,8–2,4 TWh

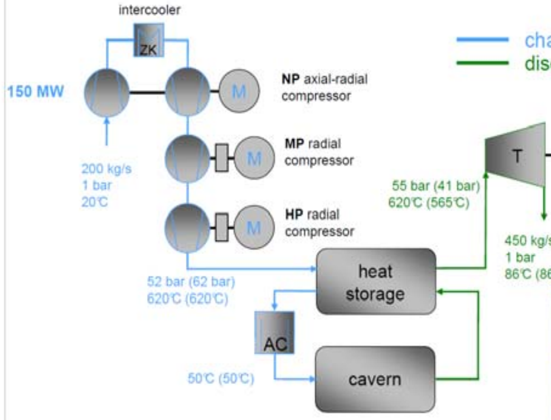
Technical Status Quo:
Gas Fired Diabatic Compressed Air Energy Storage

„McIntosh/Alabama (USA) 1991" [110MW over 26h, η = 54%]

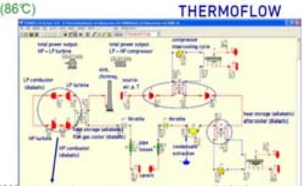


- Analogue to Huntorf [320MW over 3h, η = 42%, 1978], but without recuperator
- 2nd CAES-plant worldwide, both diabatic and therefore linked to CO_2-emissions for the reheat

Possible Technical OPTION for final design: Advanced Adiabatic Compressed Air Energy Storage



Thermodynamic modelling with THERMOFLOW



The Innovative Components of AA-CAES - Challenges

overall system optimization needed

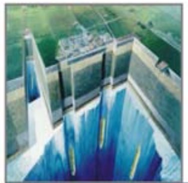
innovative component no. 1: highly-efficient air turbine
- steep temperature gradients
- high efficiency combined with wide operational range
- broad variation of volume flow and pressure (adaptive stages, inlet and outlet guide vanes)
- quick-start ability (concept for the pre-heating and design)
- pressure and temperature ranges of middle-pressure steam turbines

innovative component no. 2: highly-efficient compressor
- high pressure and temperatures in the last stage
- wide operational range (variable counter-pressure) with high efficiency
- short start-up time and frequent starts (high pressure and temperature gradients, hollow axis and preheating concept)
- combination of axial and radial (centrifugal) stages

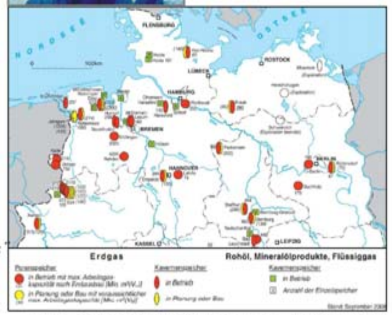
innovative component no. 3: large-capacity heat storage
- high thermal power and storage capacity / pressurized containment design
- low pressure and heat losses
- low output temperature difference during unload, operating temperature range from ambient to 620°C
- material´s durability at high temperatures, high pressure and humid atmosphere
- avoidance of material discharge into turbine (PM)
- condensing water drainage system

Salt Dome Cavern Sites in Germany

- Actual use for NG-Storage: ~9 bill. $m^3(V_n)$ in operation
- Sites: North of Germany → high wind areas
- Planned or under constr.: 7,4 bill. $m^3(V_n)$
- Hypothesis: use of 10% of the planned NG-storage for CAES or H_2:
  ↔ 21 GWh (CAES) — „Balancing of prognosis errors"
  ↔ 1200 GWh (H_2) — „Compensation of calm periods"
- Pumped hydro power Germ. grid: 40 GWh



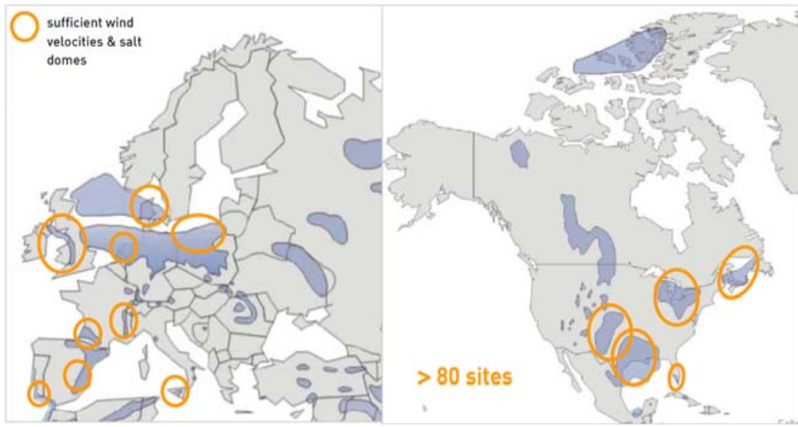
Source: KBB Deep Underground



Source: Landesamt für Bergbau, Energie und Geologie (Niedersachsen)

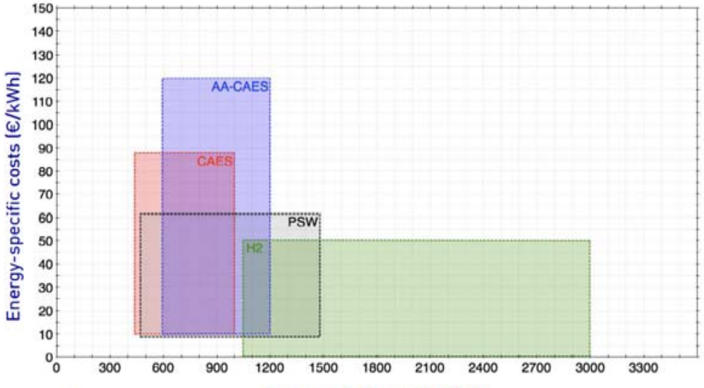
Potential Sites for CAES in the EU and the US

Coincidence of High Wind Potential and Salt Domes



CAPEX Ranges
From Literature Studies; Filtering of Extreme Values

EnBW

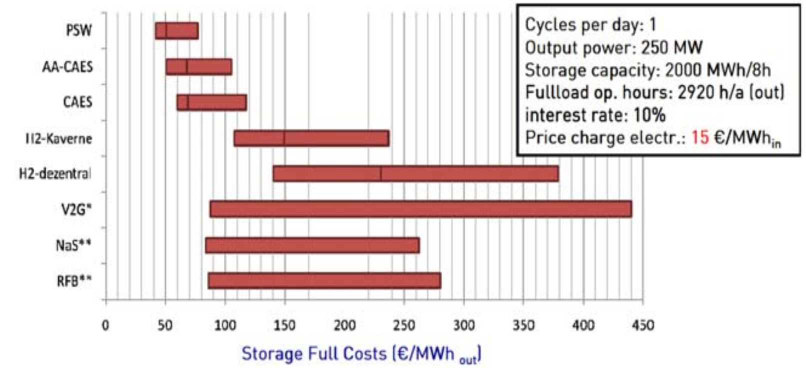


Filtering: 1-2 extreme values per technology

Source: ISI Fraunhofer

One-day Storage
Comparison of Full Costs at 15 €/MWh$_{in}$

EnBW



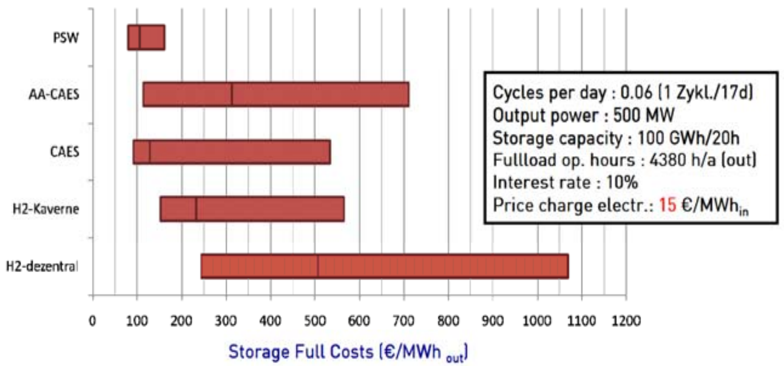
* Costs of the additional batterie usage for feeding back
** Cost span taken from source „Energietechnologien 2050"

Discount period:
Pumped hydro: 30a, RFB: 30a, H_2: 15a, NaS: 10a, others: 20a

Source: ISI Fraunhofer

Multiple-day Storage ("Week Storage")
Comparison of Full Costs at 15 €/MWh$_{in}$

EnBW



Discount period
Pumped hydro: 30a, (AA-)CAES: 20a, H_2: 15a

Source: ISI Fraunhofer

Main Conclusions

EnBW

1. Securing reliable and economically viable supply of electricity including renewable power is the **fundamental basis** for prosper industrialised countries
2. Large penetration of fluctuating non-dispatchable renewable power (mainly wind, PV) request for **broad adaptation and change of existing electricity systems** (generation – transport - demand side)
3. **Efficient CO_2-free bulk buffer capacities** showing fast ramp rates and good part-load operation will play an increasingly important role for various services (wind integration, balancing power, grid relief, etc.)
4. **Pumped hydro projects** should be supported; **innovative concepts** like adiabatic CAES, Hydrogen, large Redox-Flow and NaS should be further developed

⇨ REN-driven system requires flexible power (+/-) and energy capacity
⇨ policy makers should assure that favourable frame work conditions are met (e.g. grid extension, connection exemption for storage, clear business models, investment aids, public acceptance,...)

Appendix 5

Connecting markets – the value of new transmission lines

Arndt von Schemde, THEMA Consulting Group

THEMA
CONSULTING GROUP

CEDREN Workshop
Düsseldorf, December 15th/16th 2010

CONNECTING MARKETS

THE VALUE OF NEW TRANSMISSION LINES TO AND FROM NORWAY

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+47 9826 3986

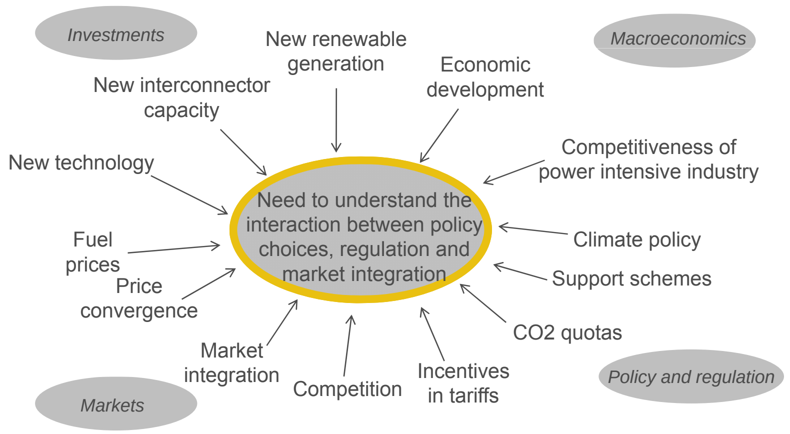
The Value of New Transmission Lines from Norway to the Continent is Substantial

Large cable income	Increase value of Nordic hydro resources	Substantial additional benefits
• Markets are physically different • Lower prices in the Nordics than in Germany • In addition, large hourly price differences remain	• Power surplus for Nordics due to new renewables • Nordic power market effect: Prices decrease • Cables partly offset renewable effect, and improve terms of trade • Likelihood of spill decreases with cables	• Other substantial benefits of transmission cables than congestion rent, such as security of supply, increased competition, etc.

Some Background on the Multi-Client Study

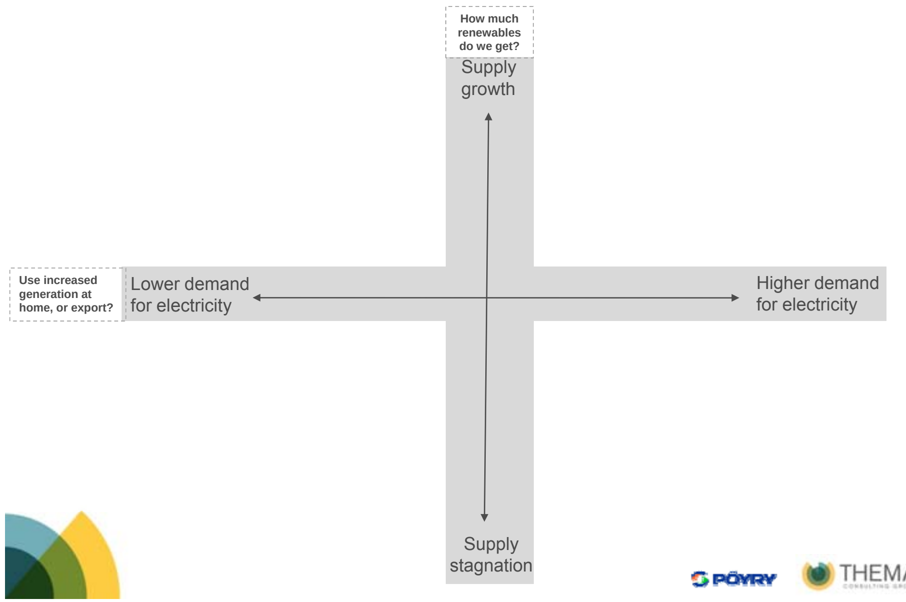
- Outlook for *Northern European* supply/demand over the next 20 years under various assumptions on policy, macroeconomic conditions and fuel prices?
- What are the benefits of new interconnectors?
- How are Nordic prices affected by investments in renewable generation and interconnectors?
- Sponsored by Nordic entities such as generators, consumers, stakeholder organisations, TSOs, regulators and with ministries in an observer role.
- Joined project with Econ Pöyry

Aim of Study



Study long-term effects on energy balance and electricity prices in the Nordics

Aggregating Trends Into a Scenario Cross



Creating Four Scenarios for the Future

How much renewables do we get?
Supply growth

1. Politics work

Globally, moderate economic growth and moderate fuel prices
European supply side shock: Large investments in renewables
Nordics: slow recovery of energy intensive industry in spite of compensation for carbon leakage; Substantial increase in interconnector capacity from Nordic area to Continent, UK and Baltics

2.Green growth

Globally, high economic growth and high fuel prices
European supply side shock: Large investments in renewables
Nordics: Sharp recovery and high growth for industry (global climate agreement); new areas for electricity – transport, petroleum sector, district heating; Substantial increase interconnector capacity to the Continent, UK and Baltics

Use increased generation at home, or export?
Lower demand for electricity
Higher demand for electricity

3. Stagnation

Globally, low economic growth and low fuel prices
In Europe, reduced RES ambitions
Nordics: Demand side stagnation; phase out of some Swedish nuclear capacity; moderate cable investments

4. Supply worries

Globally, high economic growth and high fuel prices
In Europe, NIMBY issues around RES and infrastructure, and nuclear phase-out
Nordics: Reduction of nuclear capacity; Energy intensive industry growth – compensation for carbon leakage; new areas for electricity (el-cars)

Supply stagnation

The Value of New Transmission Lines from Norway to the Continent is Substantial

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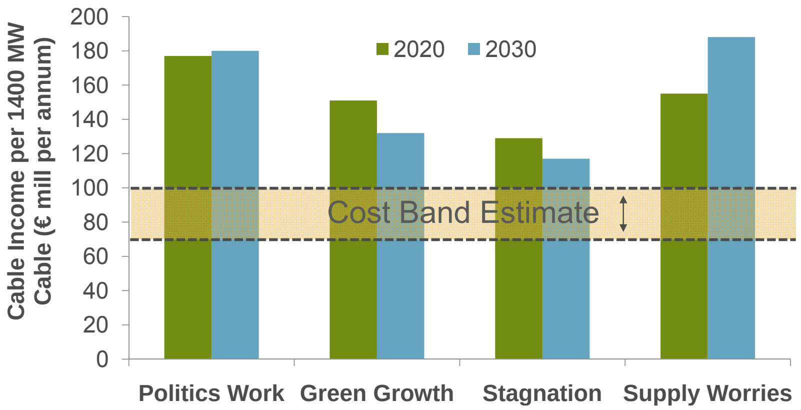
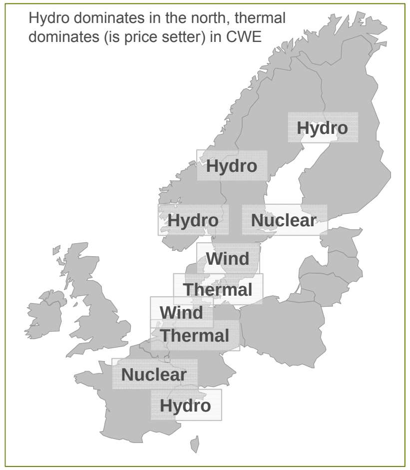
The Cable Income for Cables is Robust and Substantial in All Scenario, and exceeds Costs



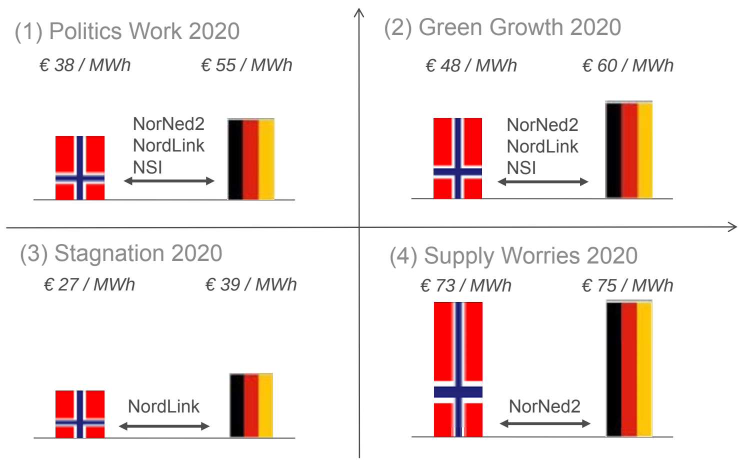
The revenues are likely to cover costs for internal grid investments within Norway

High Value of Coupling Regions that are Physically Different



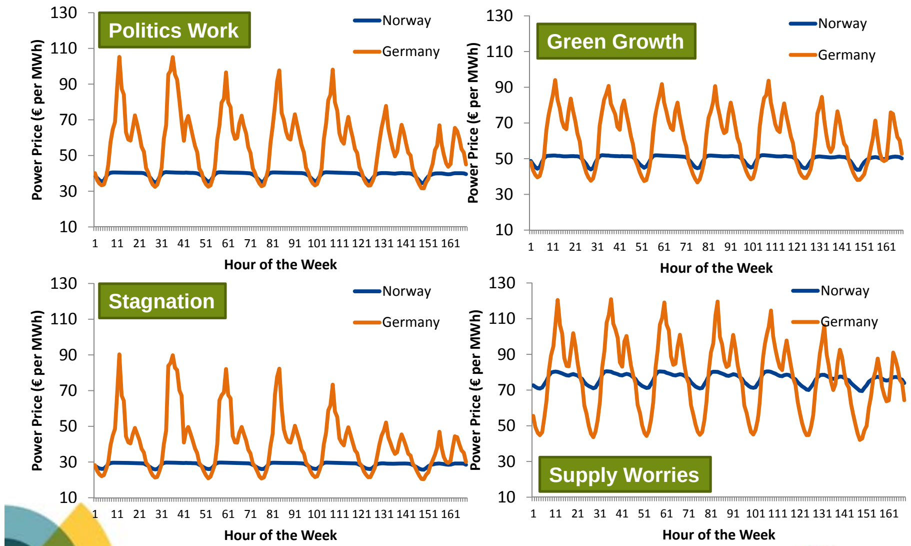
High value of coupling regions that are physically very different

Price Differences Remain Despite new Cables



And, in all cases: NorNed, SK4, SweLit, Estlink2, etc. are included;

Hourly Price Differences Remain and Secure Revenues also if Price Levels are similar



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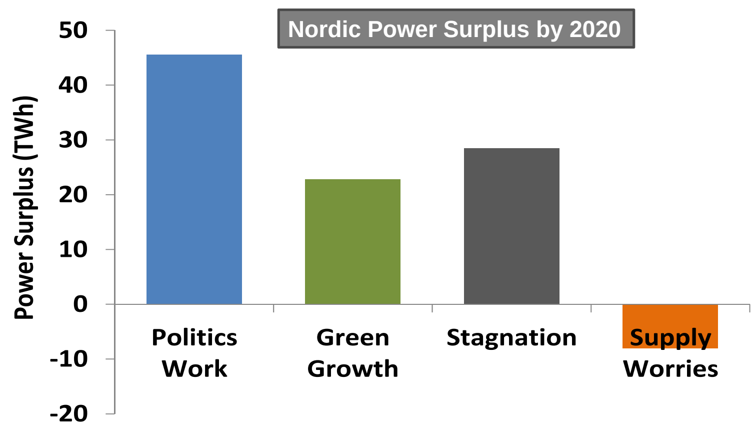
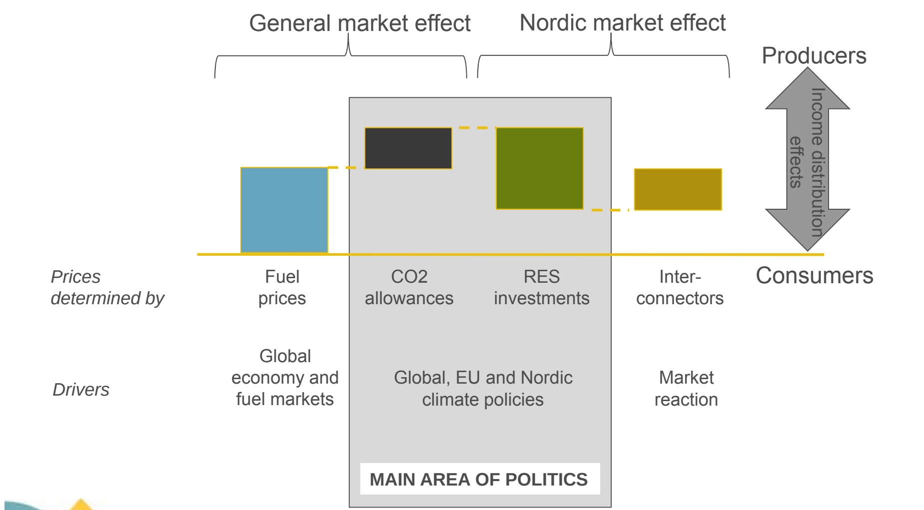
The Nordics are likely to Experience a Large Surplus in the Coming Years (Results for 2020)



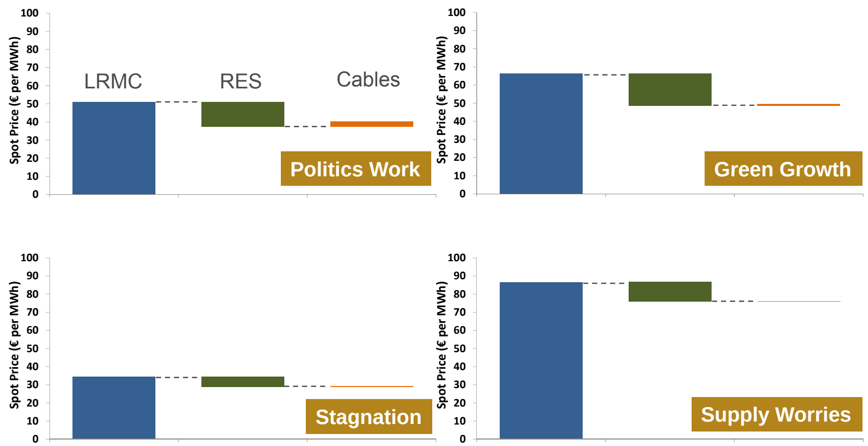
- *Nordic Market Effect: The higher the surplus, the lower the prices*
- *Results from this study: 10 TWh of new renewables decrease prices by € 4 per MWh in Nordics*

Nordic Market Effects: Renewables Decrease Spot prices; Cables partly offset Decrease

Illustrative

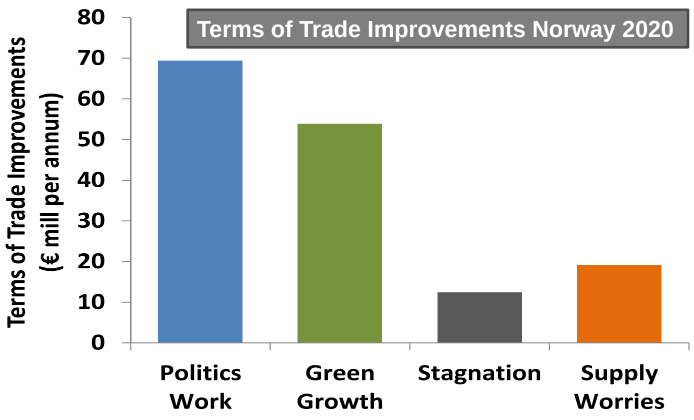


Cables partly offset the Renewable Price Effect, but the Price Increase is Moderate



- *Cable effect dependent on power balance: The higher the surplus, the higher the price effect*

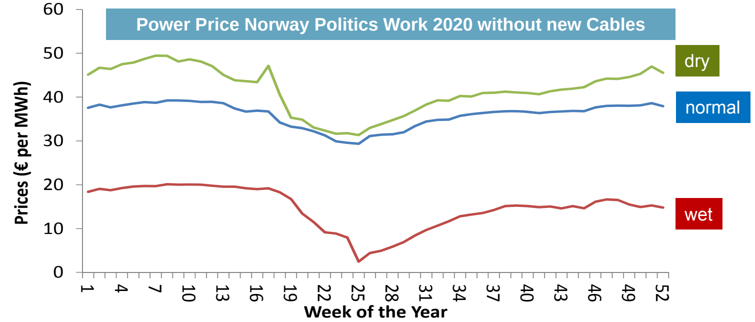
Terms of Trade Improvements Increase Benefits of Cables – Results for Norway 2020



- ***Terms of Trade****: Changes in values for exports and imports*
  → Difference between Consumer and Producer Surplus
- *In surplus cases, cables increase the value of exports*

PÖYRY THEMA

High Likelihood of Spill without New Cables



- In Politics Work, we estimate a *normal year* surplus of around 45 TWh per annum.
  - Inflow in Norway alone can vary with +/- 30 TWh per annum
  - Means that the power surplus can be 75 TWh in a wet year

Without new cables, spill in a wet year could be as high as 25 TWh (with a normal year value of € 1 bn)

PÖYRY THEMA

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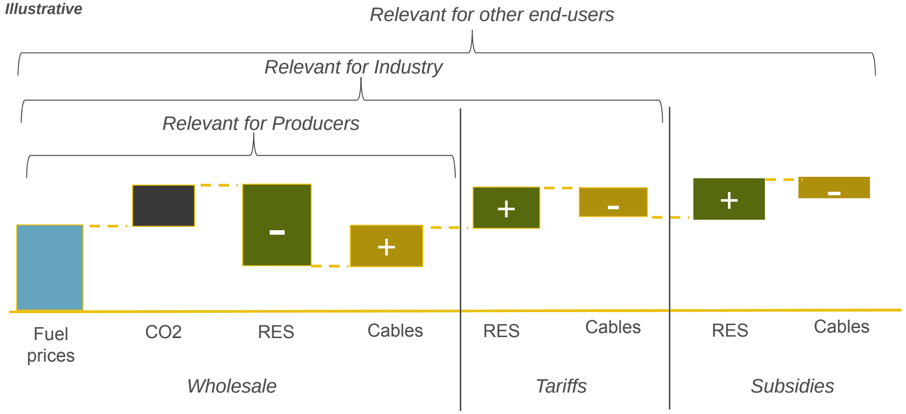
PÖYRY THEMA

THEMA CONSULTING GROUP

In Norway Redistribution of Benefits via Tariffs, Subsidy Reduction, and (Public) Ownership

Illustrative



- While RES lowers prices on the spot market, it will increase tariffs and subsidies
  - RES is not for free!
- While cables increase prices on the spot market, they are likely to lower tariffs (as surplus is re-distributed) and subsidies for renewables (as they increase spot market price)

Some Thoughts around "Norway as Battery"

- In our analysis, we focused on congestion rent from day-ahead trading (spot market)
  - Other benefits from delivering "flexibility" on other markets
- "Flexibility" arises from existing reservoirs
- Moderate cable assumptions by 2030: NorGer, NorNed2, NSI, etc.
- In the debate, there is talk about completely different cable ambitions
  - See, for example, Sachverständigenrat für Umweltfragen, *Stellungnahme 15-2010*
  - *16 GW by 2020, 100 GW by 2050*
  - This would imply a paradigm shift in the power markets

Implications and Challenges for "Norway as Battery"

- How would "markets" work?
- How to give incentives to build pumped storage
  - Initially, existing reservoirs sufficient
  - Pump storage need "exposure" to fluctuating prices
- What flexibility is needed?
  - Spot?
  - Regulating power?
  - Intraday?
- Gigantic distributional effect!
- How is this financed?
- "Market" Solutions?
- Etc.

Source: SRU; 100% erneuerbare Stromversorgung bis 2050: klimaverträglich, sicher, bezahlbar

The Value of New Transmission Lines from Norway to the Continent is Substantial

Thank you

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Appendix 6

Commercial challenges regarding exchange of flexibility from a Norwegian TSOs point of view

Bernt Anders Hoff, Statnett SF

Statnett

Commercial challenges regarding exchange of flexibility – seen from a Norwegian TSO

Bernt Anders Hoff
CEDREN Workshop, Dusseldorf 15. December 2010

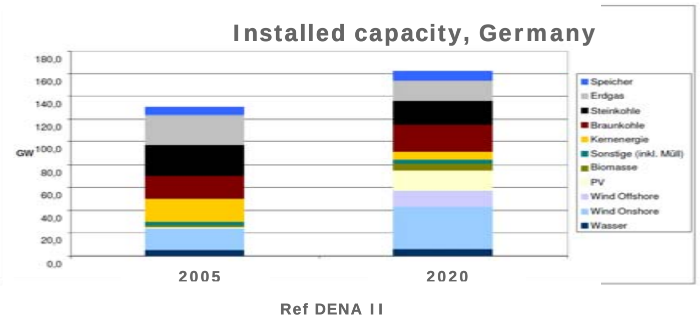
Statnett

Agenda

- A power system in change
- Exchange of flexibility in different time frames
- Market design challenges
- Regulatory challenges
- Conclusions

Statnett

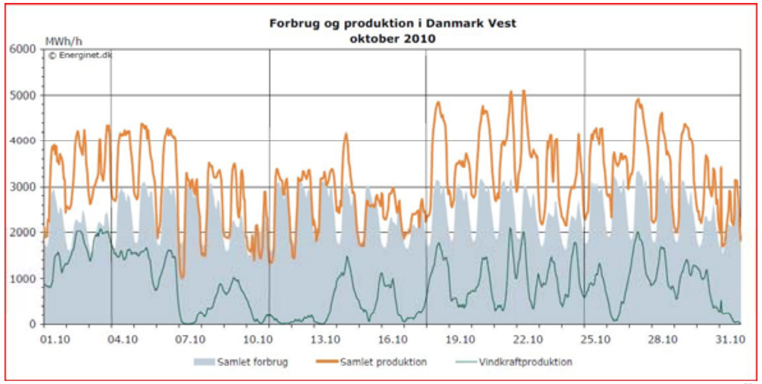
A power system in change



Plan to introduce secondary reserves in Nordic Synchronuos area during 2011

Statnett

High penetration of intermittent production challenge flexibility in several time frames



Source: Energinet.dk

- Flexible energy production needed
- Adjustable energy production needed to adjust for improved prognosis
- Reserve providers needed

Statnett

Agenda

- A power system in change
- Exchange of flexibility in different time frames
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Statnett

Flexibility can be exchanged in different time frames

- The spotmarket will still be the most important market
  - Operational MC CWE – Nordic
  - A challenge to include costs related to exchange of flexibility in spotmarket
  - More volatile prices expected
- Intraday market will develop
  - Important tool to reduce imbalance cost of intermittent production
  - Push from EU Commision and national regulators to develop market coupling
  - Challenge to price capacity
- Ancillary services market will develop
  - National markets with variable designs today
  - German TSO co operation
  - SK4 agreement
  - Who will provide reserves in periodes when spot energy is produced by intermittent production?
  - More volatile prices expected

Statnett

Agenda

- A power system in change
- Exchange of flexibility in different time frames
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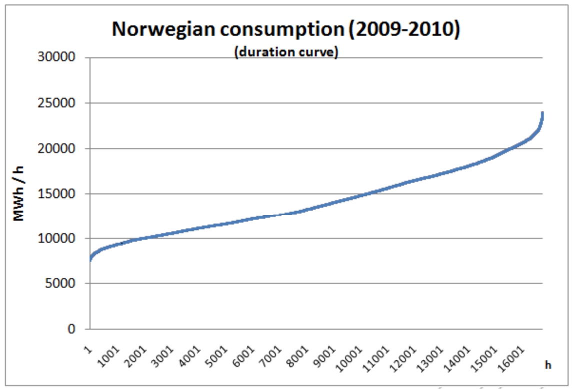
Statnett

Costs related to exchange of flexibility in the spot market

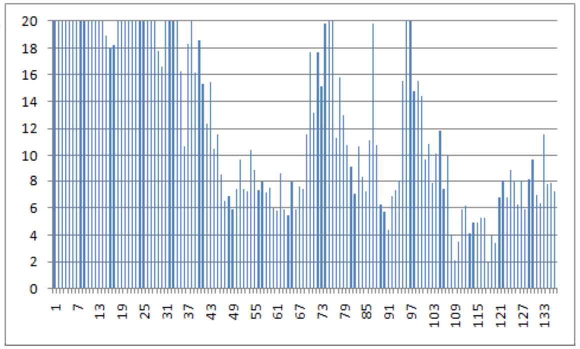
- Energy losses not included
- Cost of changing power flow direction – ramping
  - Increased need of ancillary services
- Import at low load
  - System operational challenge
  - Rotating reserves
  - Short current capacity



Statnett

Spot price difference Germany-Kristiansand
Weekly average, absolute values (May 2008 – Nov 2010)

€/MWh

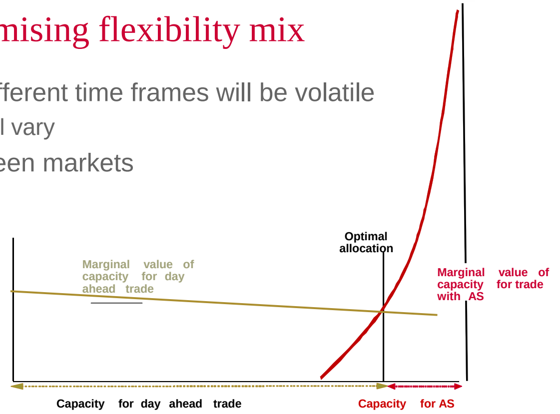


- Varying price differences
- Decreased spot differences in the future with market coupling and interconnections?

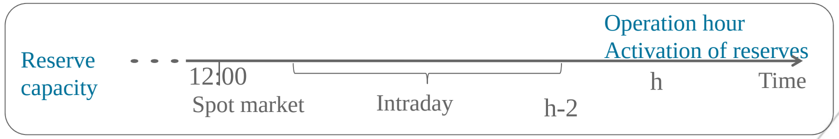
Statnett

Challenges of optimising flexibility mix

- Price difference in different time frames will be volatile
  - Optimal allocation will vary
- Interdependicy between markets



- Market time line



Statnett

Challenging to initate investments?

- More dynamic markets
- More volatile prices
- Long term contracts should be considered when investments are needed

Statnett

Agenda

- A power system in change
- Exchange of flexibility in different time frames
- Market design challenges
- Regulatory challenges
- Conclusions

Regulatory challenges

- ERGEG guideline allows allocation to different time frames
  - Need to prove socio economic efficiency
  - Only on HVDC –links
- Danish national regulator gives permission for exchanging ancillary services
  - Evaluation will be done
- ENTSO-E has turned to be positive to exchange of ancillary services
- Further development of market solutions is necessary to optimise hydropowers role in Northern Europe
- Regulators seems to reduce possible development

Conclusions

Flexibility should be exchanged in different time frames

Challenge to optimise flexibility mix

Regulatory introducing prohibitions is a challenge

Need for developing market design further - stepwise

Appendix 7

Storage needs for 100% renewable electricity in Germany and Europe. Scenario analyses

Amany von Oehsen, Fraunhofer IWES

Storage needs for 100% renewable electricity in Germany and Europe - scenario analyses

Speaker: Amany von Oehsen

Fraunhofer Institute for Wind Energy and Energy Systems Technology

Aim of the talk

Presenation of balancing needs in two 100% renewable electricity scenarios:

100% renewable electricity in Europe by only wind and PV energy (SIEMENS)

100% renewable electricty for Germany (German Federal Ministry of the Environment) based on national generation

Scenario 1: Large Scale Integration of Wind and Solar Energy in Europe Requirements on Transmission and Storage

Dr. Kurt Rohrig[1],

Dr. Lüder von Bremen[3] ,Dr. Clemens Hoffmann[3]

1) Fraunhofer IWES

2) ForWind, 3) SIEMENS AG

Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power

European Wind Energy Technology Platform

TradeWind

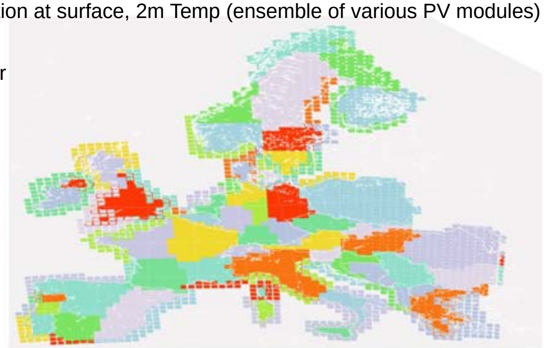
ewis

Model and input data

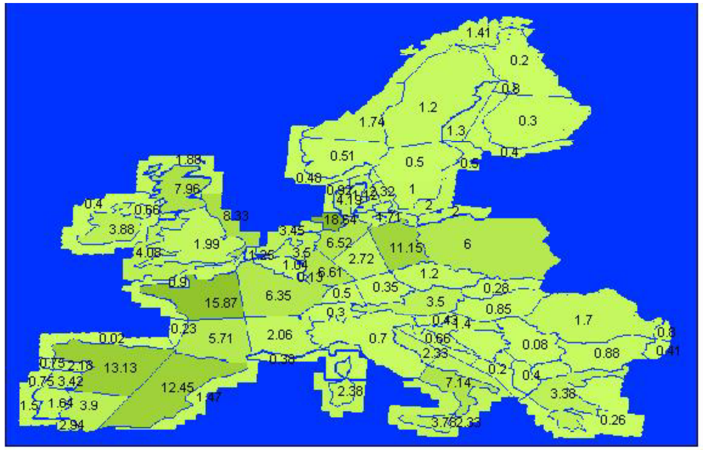
- Domain: UCTE + Nordel + UK/IR
- Study period: 2000-2007
- Data: 1hourly, 50km horizontal resolution
- Wind Power: Wind speed (~100m), standard power curves for on/offshore, losses (wake, availability, el. losses) are considered
- PV: cloud cover, net short wave radiation at surface, 2m Temp (ensemble of various PV modules)
- 83 regions (50 onshore, 33 offshore)
- Hourly time series of consumption for each region (partly reconstructed)

1 a) no transport only regional storage

1 b) perfect transport, one common European storage

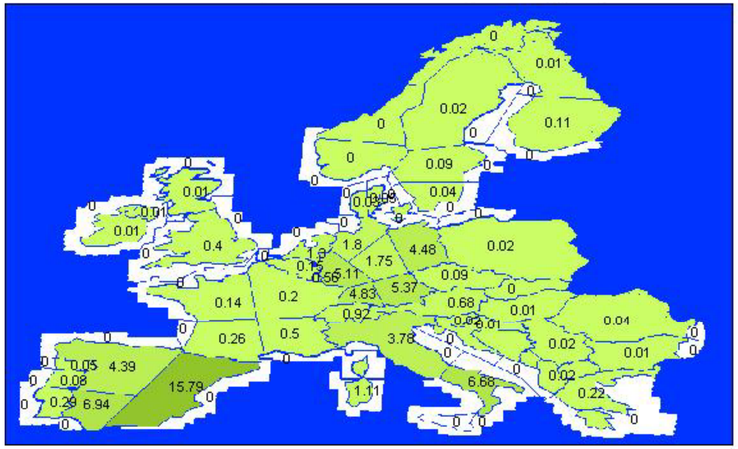


Distribution of wind power in 2020 (political targets)



sum of all installed Wind- power: 227 GW

Distribution of PV in 2020 (political targets)



sum of all installed PV- power: 68 GW

Scaling up of planned capacities for the 100% RES scenario

Average power demand in the domain: 357 GW

Assuming that demand remains the same as today about 23% of the consumption would be met by wind and PV power if political targets are realised

Therefore: scaling up of wind and PV targets by a factor of ~4

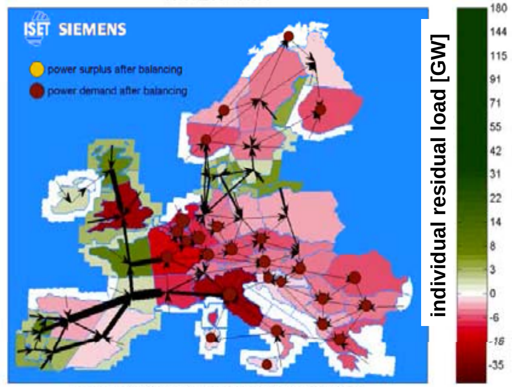
for a 100% scenario

i.e. :	908 GW wind	&	272 GW PV

Power flow calculation

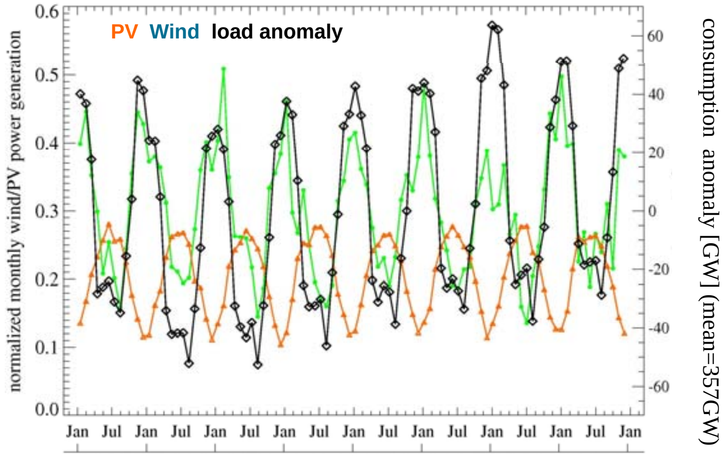
- Full interconnection between neighbours
- Offshore regions are only connected to a single onshore region
- no transport limits, no losses
- DC flow equation solved assuming equal resistence on all lines
- single & perfect European power market
- each time step (~70000) is computed individually (no storage)
- after each time step unbalanced regions will remain

09.07.2007 00:00

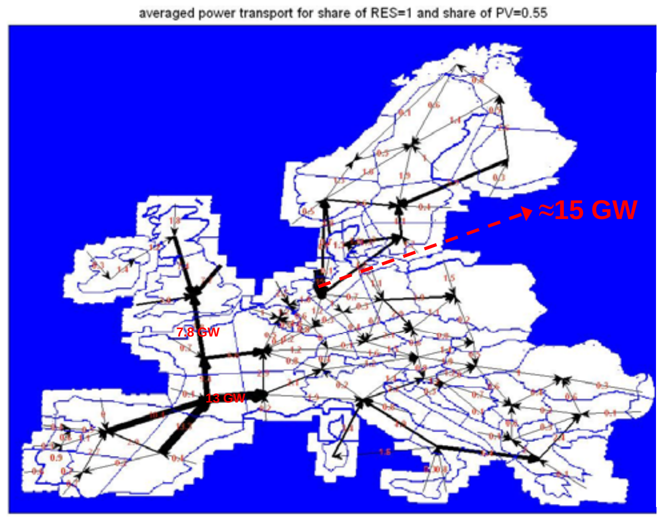


Wind: 170 GW, PV: 0 GW, demand: 264 GW

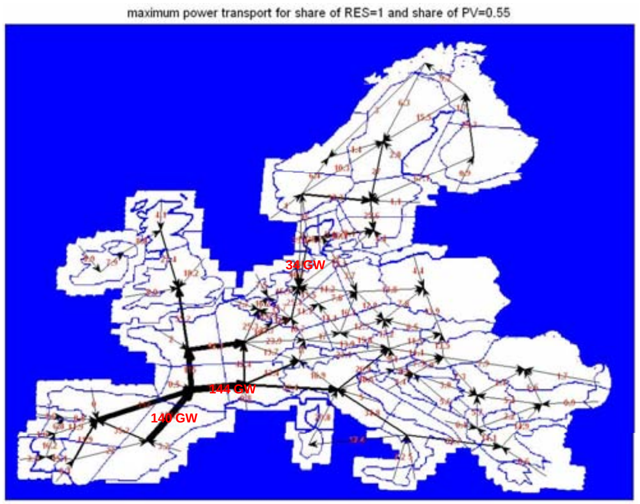
Monthly PV, Wind generation and consumption anomalies



Average Transports in 100% supply scenario

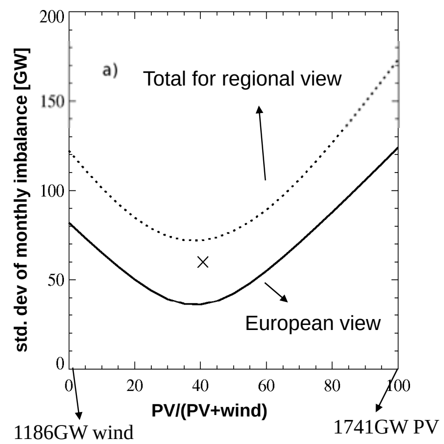


Maximum power transports in the 100% scenario



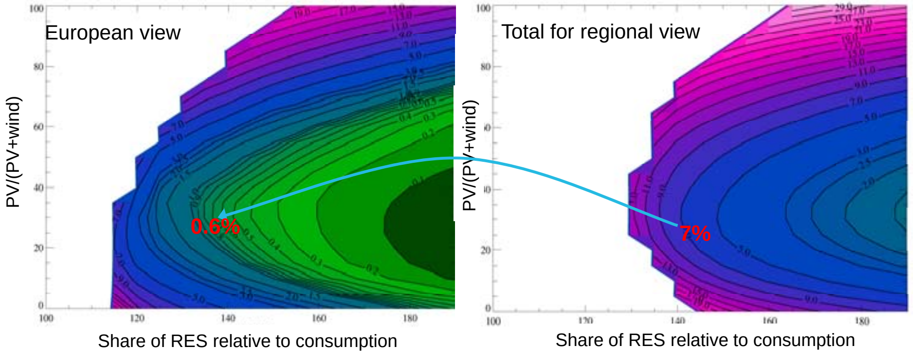
Finding the optimal ratio between PV and wind power via minimal fluctuations

- Fluctuation of monthly residual load (RES-consumption) in a 100% renewables scenario



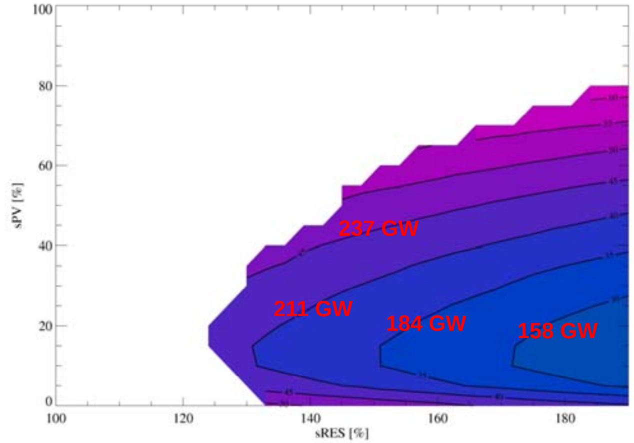
Finding the optimal ratio between PV and wind power via required storage capacity

- Storage capacity relative to annual consumption (= 3127 TWh) (in %)



- Example:140%RES, PV=30% → required storage capacity = 2.2 days of avg. consumption
- European balancing reduces storage capacity by factor of 11!

Required storage power



Peak load: 527 GW

Candidates for needed large scale storage technologies

Needed storage capacity in TWh for different technologies

Technology	Capacity in TWh for storage of 2% of annual consumption	Capacity in TWh for 8%
Hydrogen	100	400
Pump hydro	67	267
AA-CAES	80	320

Needed storage power: ~ 190 GW !!

Hydro storage plants in Nordel

Storage plants	Norway	Sweden	Finland	Sum
Capacity [TWh]	81,7	33,8	5,5	**121**
Power [GW]	29	16	3	**48**

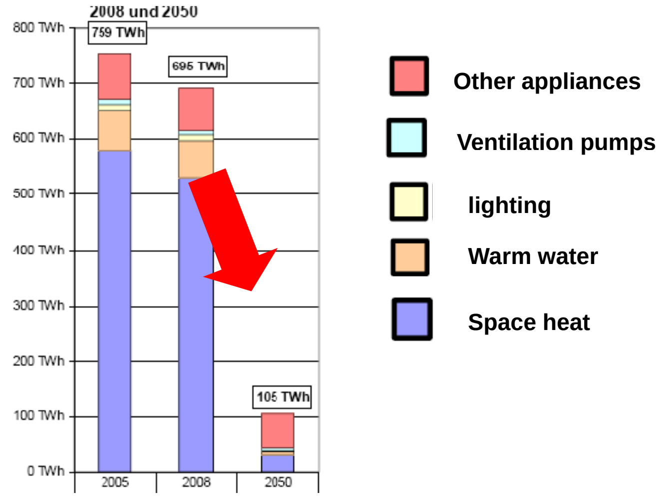
Conclusions

- very high transport capacities occur in a 100% scenario
- demand for storage decreases on the European level (factor of 9!!)
- required storage capacities can be <5 days
- required storage power is extremely high
- optimal mix between PV and wind power exists to reduce fluctuations, power transports and storage capacity
- wind and PV do not care about national interest → aim for unified European integration
- deployment of different renewables must be coordinated in Europe, otherwise unnecessary losses and investments (storage, etc) might happen

German Federal Minstry of the Environment Study: 100% renewable electricity in Germany for the year 2050

	Conservative ecolocgical potential	Installed power	Share in electricity production
Wind		**105 GW**	**62 %**
onshore	60	60 GW	30.5 %
offshore	45	45 GW	31.5 %
PV	**275**	**120 GW**	**18.6 %**
bioenergy	**-**	**23.3 GW**	**2 %**
hydro	**5.2**	**5.2 GW**	**4 %**
geothermal	**6.4**	**6.4 GW**	**9 %**
import	**-**	**Maximum 10 GW**	**~ 5 %**

End energy use of households 2005, 2008 and 2050



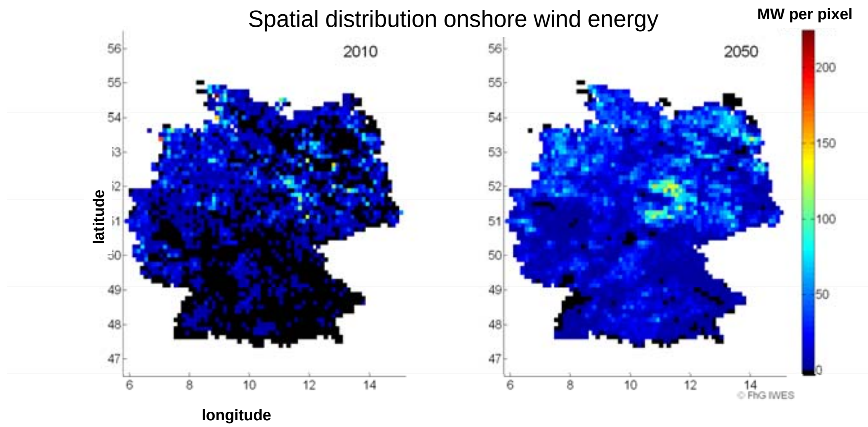
Simulation methodology

4 years of meteo and hydro data: 2006-2009

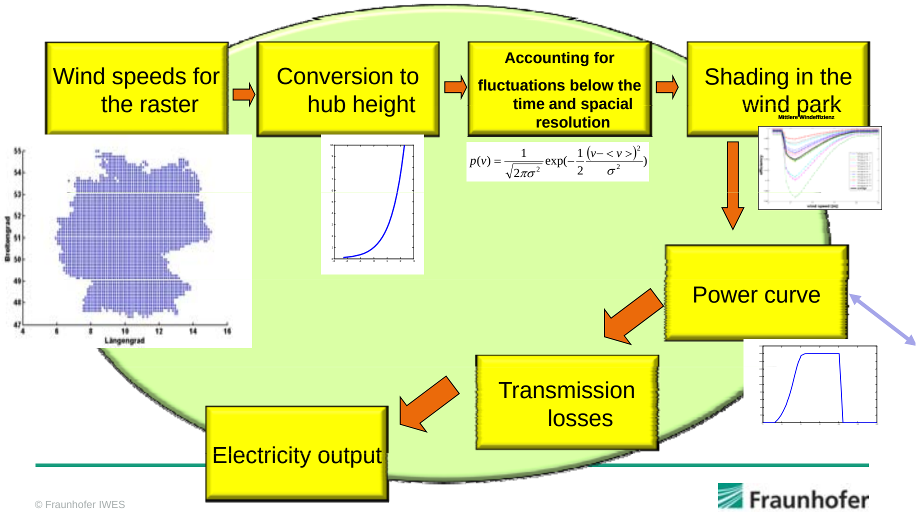
- Wind speeds (resolution: 1 hour , 14 x 14 km^2)
- Global horizontal irradiation (resolution: 1 hour , 14 x 14 km^2)
- Temperature (resolution: 1 hour , 14 x 14 km^2)
- River run-off (resolution: daily)

- 4 years of hourly electrical load data (ENTSO-E)

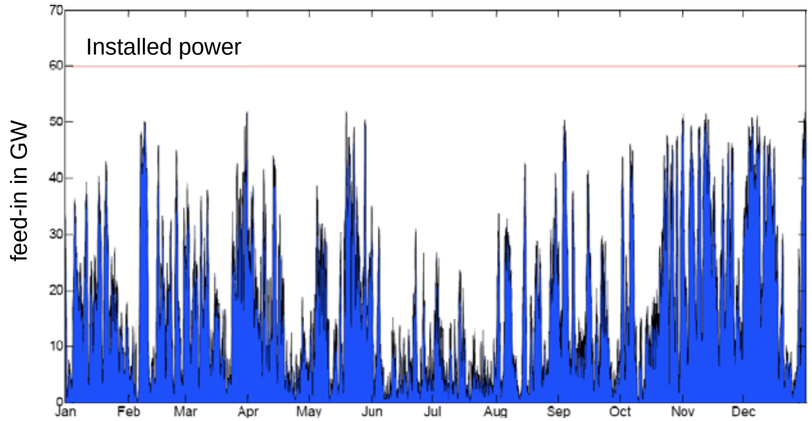
Simulation of wind energy feed-in: methodology



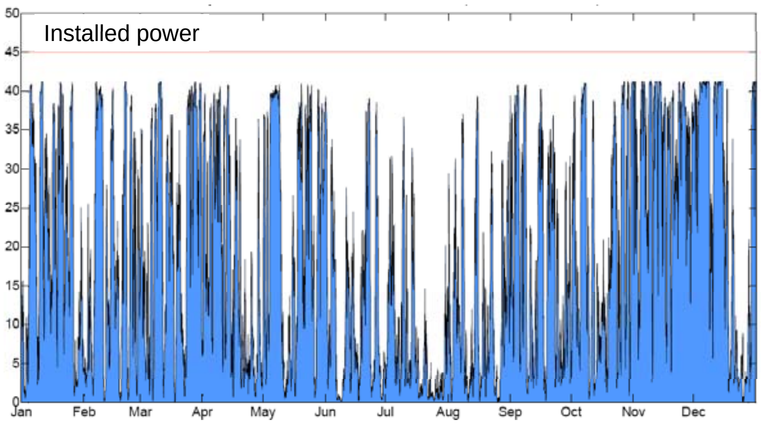
Simulation of wind energy feed-in: methodology



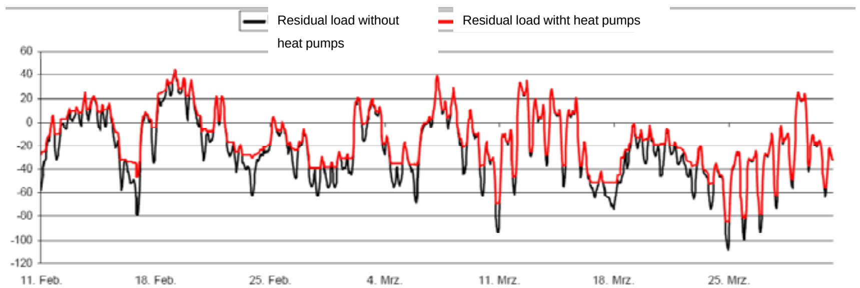
Onshore feed-in meteo year 2006



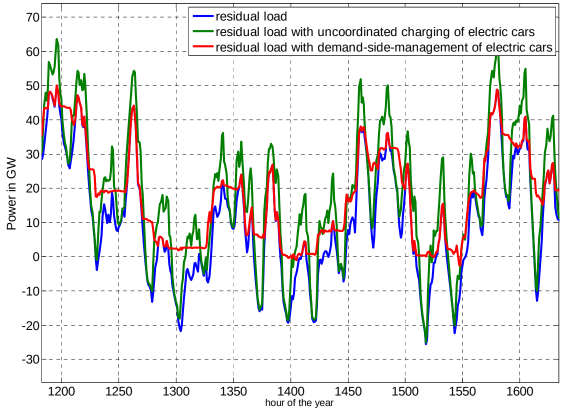
Offshore wind energy feed-in meteo year 2006



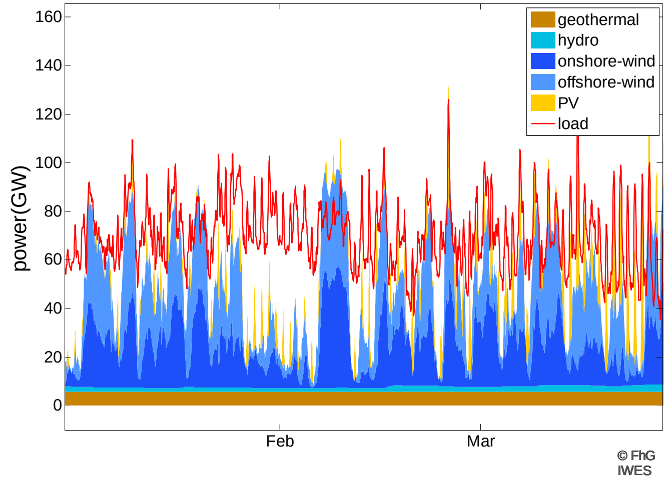
Demand-Side Management with electric heat pumps



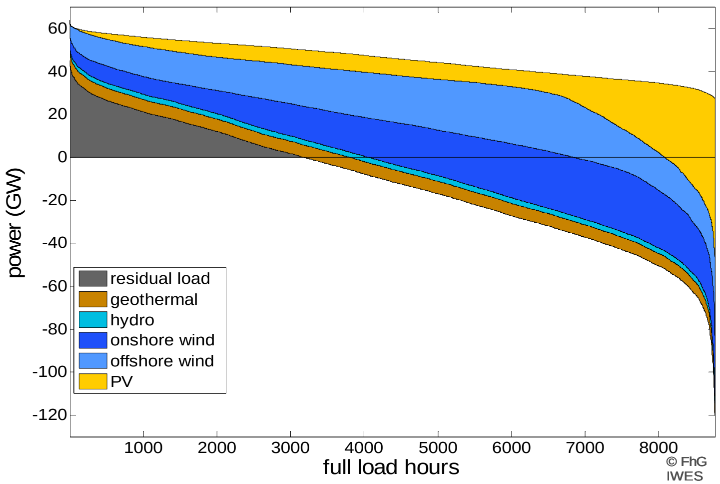
Demand Side management with electric cars



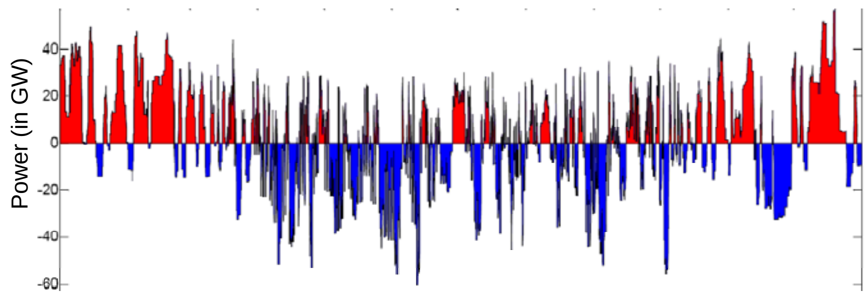
Renewable power feed-in and electric load 2050 for the meteo year 20



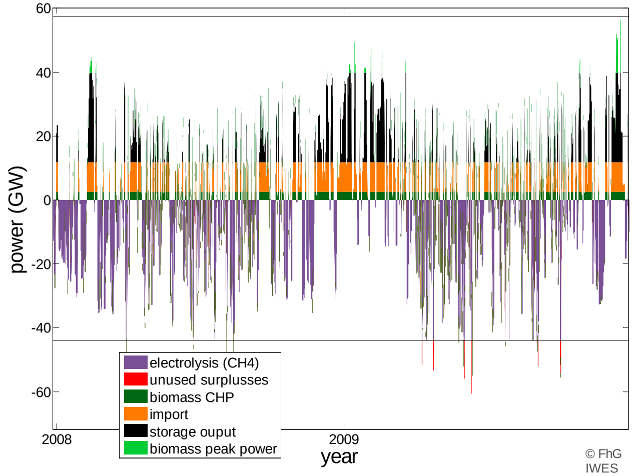
Load duration curve residual load 2006



Residual load: deficits and surplusses: balancing power needs



Load balancing with CH4 Storage, biomass peak power and electricity import



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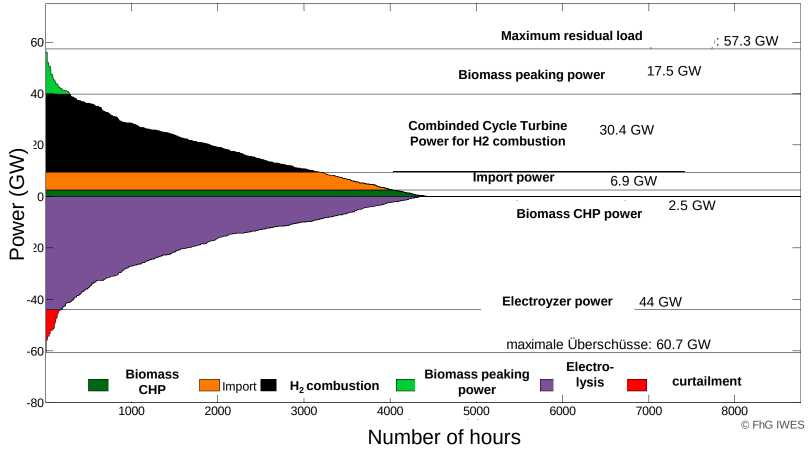
Residual load balancing: load duration curve of balancing measures



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Storage Potential in salt caverns and pore storage in Germany

	Total potential	Required amount
Hydrogen	110 TWh_{th}	84 TWh_{th}
Methane	514 TWh_{th}	75 TWh_{th}

Fraunhofer IWES

Simulation of large scale gas storage

Electrolysis efficiency : 82%

Conversion back to electricity with Combined Cycle Gas Turbines with efficiency 57%

Fraunhofer IWES

Storage level of the simulated large scale CH_4 Storage

Conclusions

- 100 % renewable electricity in Germany is technically possible

However a high amount of balancing power and a large storage capacity is required

The available storage capacity for underground storage of hydrogen or methane is sufficient

The costs for the simulated scenario are likely to be higher than a scenario with international cooperation in RE energy generation

Appendix 8

Modeling an Integrated Northern European Regulated Power Market based on a common day-ahead market

Gerard Doorman, NTNU

NTNU
Norwegian University of Science and Technology

Modelling an Integrated Northern European Regulating Power Market Based on a Common Day-Ahead Market

Stefan Jaehnert, Gerard L. Doorman

IAEE International Conference, Rio de Janeiro, 07.06.2010

Outline

- Introduction
- Integrated regulating power market model
  - Day-ahead market
  - Regulating reserve procurement
  - System balancing
- Case studies
- Conclusion

NTNU Norwegian University of Science and Technology

"Balance Management in Multinational Power Markets"

- Sustainable (intermittent) electricity production => need for regulating resources
- Cross boarder trade => integration of national regulating energy markets
- Aim to integrate northern European regulating power markets

NTNU Norwegian University of Science and Technology

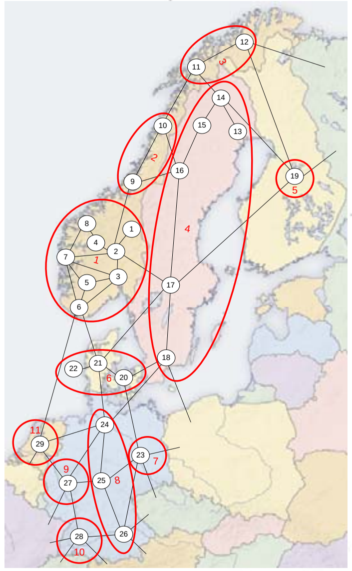
Modelling objective

- Increasing intermittent power generation => utilization balancing capabilities of Nordic hydro-based power system
- Investigation of:
  - Possibility of foreign regulating reserve procurement
  - System wide regulating resource exchange (real-time system balancing)
  - Transmission reservation for reserve procurement and system balancing
  - Regulating reserve and resource pricing
- Estimation of socio-economic benefit of integrating multinational regulating power markets
- Analysis of different regulating power market integration steps

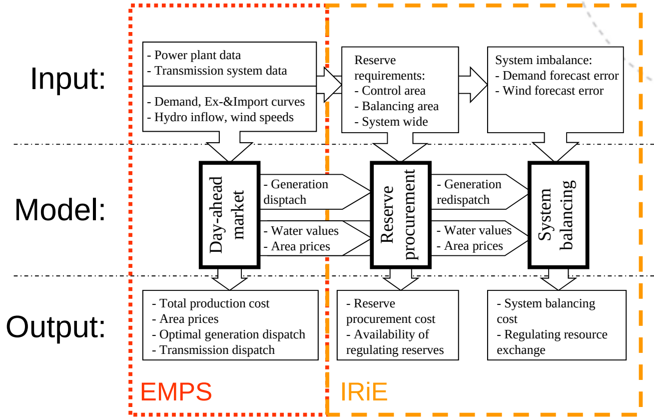
NTNU Norwegian University of Science and Technology

Overview

- Integrated regulating power market based on a common day-ahead market
- Covers Denmark, Finland, Norway, Sweden, Germany, Netherlands (Northern Europe)
- Fundamental model
- Perfect market assumption
- Hydro system inflow / wind production scenarios: 1951-1990



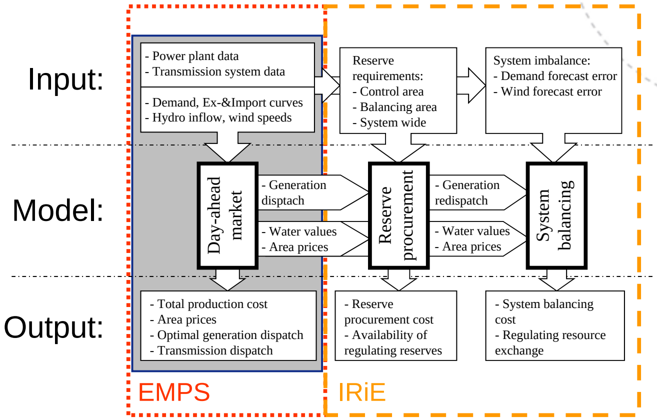
Structure



EMPS – EFI's Multi-area Power-market Simulator

IRiE – Integrated Regulating power market in Europe

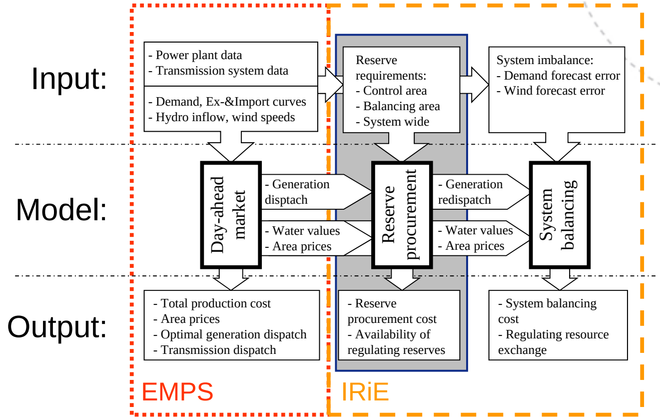
Day-ahead market



EMPS – Common day-ahead market

- Mid- and long-term optimisation of system operation on weekly basis (containing several periods)
- Developed at SINTEF Energy Research
- Key points:
  - Transmission system (NTCs, linear losses)
  - Nordic hydro system (reservoirs, power plants and water course)
  - Thermal scheduled production & dispatchable production (power plants with marginal production- & start up costs)
  - Wind power generation
  - Consumption (temperature dependent)
- Results:
  - Optimal unit commitment and generation dispatch
  - Area prices, water values

Reserve procurement

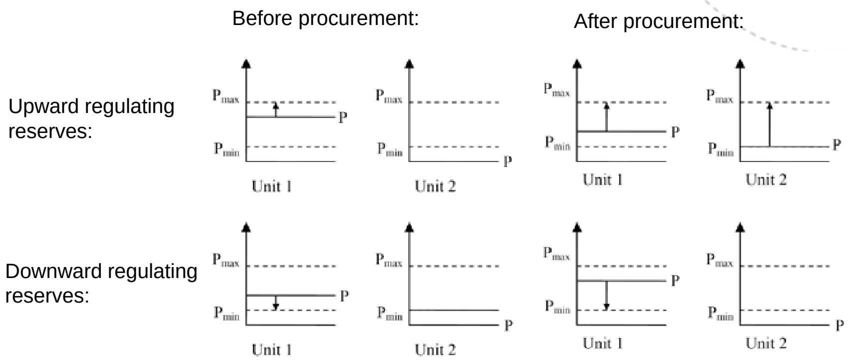


IRiE - Reserve procurement

Objective: least cost redispatch of generation and transmission capacity in order to fulfil given reserve requirements

- Procurement of up- & downward regulating reserves
- Reserve procurement cost includes:
  - Production decrease on infra marginal units / Production increase on ultra marginal units
  - Efficiency loss for thermal units at partial load
  - Start up- / shut down costs of thermal units

Reserve procurement strategy

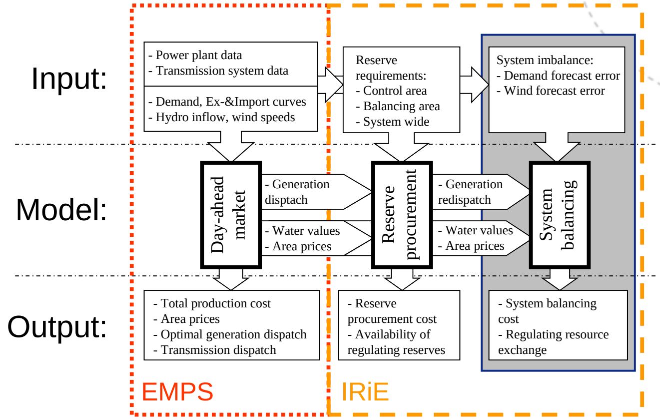


Reserve requirements

- Requirements for secondary reserves (UCTE) and Frequency restoration reserves (Nordel)
- Aggregation of control areas into balancing areas (Nordel, DE, NL)

	Control Area		Balancing Area		Total system	
	Up	Down	Up	Down	Up	Down
NO1						
NO2	1200	-1200				
NO3						
SWE	1220	-1220	3865	-3865		
FI	865	-865				
DK	580+620	-580-620			7175	-6210
VET	640	-400				
EON	830	-590				
RWE	1000	-725	3010	-2045		
EnBW	540	-330				
Netherland	300	-300	300	-300		

System balancing



IRiE - System balancing

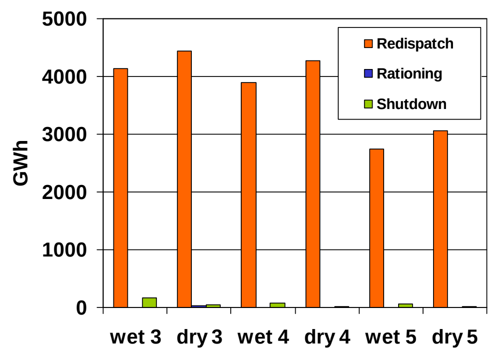
Objective: least cost system wide generation and transmission redispatch to settle real-time system imbalances in each PTU

- Input: imbalance records (quarter hourly)
- No time dependencies (ramping, start up / shut down of units)
- Definition of non-spinning in addition to spinning regulating reserves
  => all installed generation capacity available for system balancing

Case studies
Integration of regulating power markets

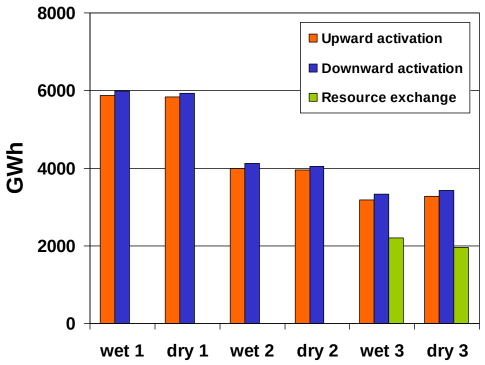
- Studied years:
  - Wet year – hydro inflow = 244 TWh
  - Dry year – hydro inflow = 146 TWh
- Exchange of regulating resources: Case:
  - No exchange between control areas in Germany (I)
  - Exchange only in balancing areas (II)
  - System wide exchange (III – V)
- Regulating reserve procurement:
  - Procurement only in own control area (I – III)
  - Procurement in whole balancing area (IV)
  - Reserve procurement system wide (V)

Regulating reserve procurement



- Significant reduction of necessary redispatch for reserve procurement approx. 30%
- Procurement costs:
  - wet dry
  - 3: 91,92 436,1 M€
  - 4: 70,71 110,8 M€
  - 5: 49,81 88,12 M€

Reserve activation



- Reduction rationing / shutdown to nearly zero with exchange of regulating resources
- Imbalance settlement costs:
  - wet dry
  - 1: 180 207 M€
  - 2: 96 113 M€
  - 3: 60 73 M€

Conclusion

- Decrease redispatch during reserve procurement by 30% => ample regulating reserves available in Nordic system
- Reduction reserve activation by 30% (imbalance netting)
- Gross exchange of balancing energy approx. 2 TWh – 40% of activated regulating reserves
- Significant reduction of reserve procurement and reserve activation costs
- Further work
  - Model with better grid representation
  - Improvement in description of reserve costs
  - Modelling of future scenarios – 2020/2030

Appendix 9

Climate-friendly, reliable, affordable: 100 `% RES-E supply by 2050

Olav Hohmeyer, University of Flensburg & German Council of Environmental Advisors (SRU)

Climate –friendly, reliable, affordable:
100% renewable electricity supply by 2050

Prof. Dr. Olav Hohmeyer

German Council of Environmental Advisors (SRU)

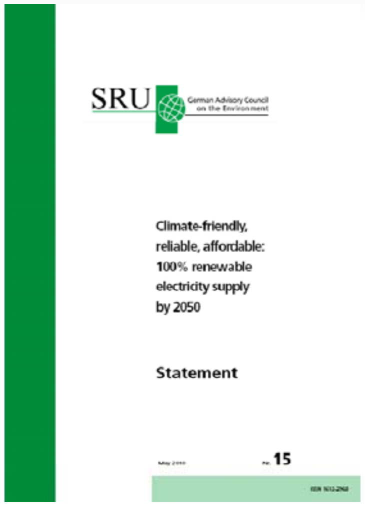
CDREN workshop

Perspectives on hydropower's role to balance non-regulated renewable power production in Northern Europe

Düsseldorf, December 15th – 16th, 2010

Structure of the presentation

100% renewable electricity in Germany and Europe by 2050


SRU German Advisory Council on the Environment

Climate-friendly, reliable, affordable: 100% renewable electricity supply by 2050

Statement

15

100% renewable electricity The eight SRU scenarios

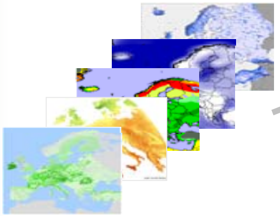
	Demand DE 2050: 500 TWh/a	Demand DE 2050: 700 TWh/a
Autonomous Germany	Scenario 1.a DE-100 % SV-500	Scenario 1.b DE-100 % SV-700
100% REN production in Germany Exchange with DK/NO	Scenario 2.1.a DE-NO/DK-100 % SV-500	Scenario 2.1.b DE-NO/DK-100 % SV-700
15% Net import max. from DK/NO	Scenario 2.2.a DE-NO/DK-85 % SV-500	Scenario 2.2.b DE-NO/DK-85 % SV-700
15 % Net import from EU-North Africa	Scenario 3.a DE-EUNA-85 % SV-500	Scenario 3.b DE-EUNA-85 % SV-700

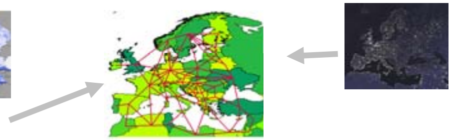
The REMix-Europe model of DLR

REMix-Europe
(**R**enewable **E**nergy **Mix** for Sustainable Electricity Supply in Europe)

Inventory of REN-resources
GIS, C

Electricity demand
GIS, C

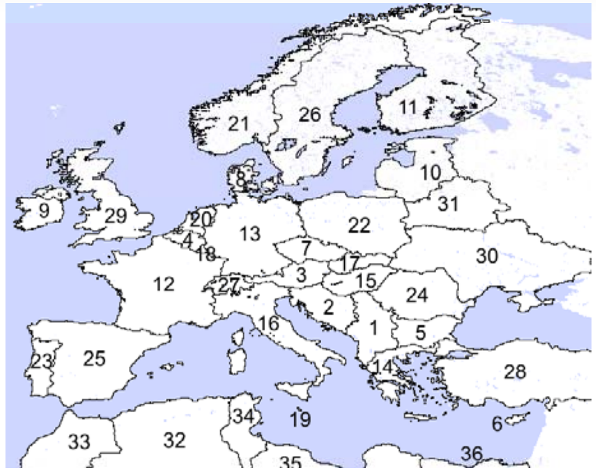




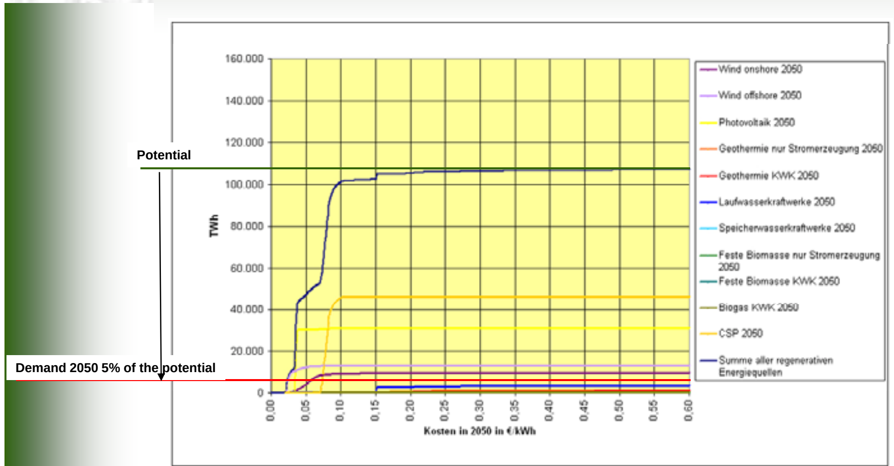
Linear optimization model
GAMS (General Algebraic Modeling System)

Source: Krewitt 2009

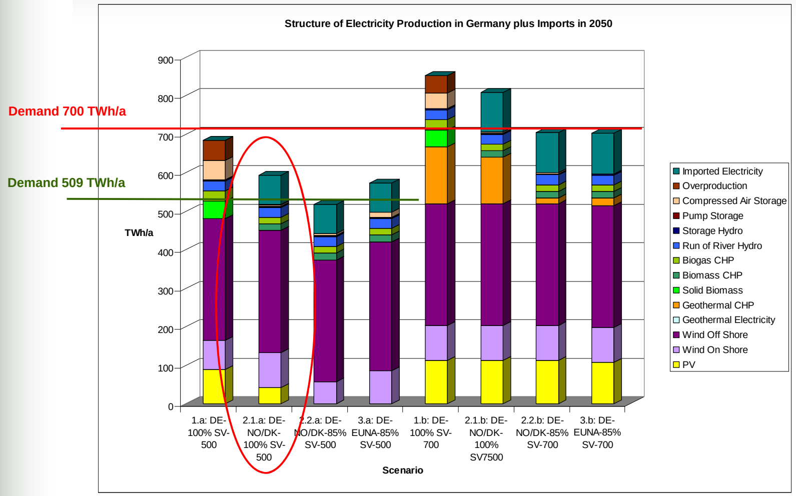
The analyzed region Europe-North Africa



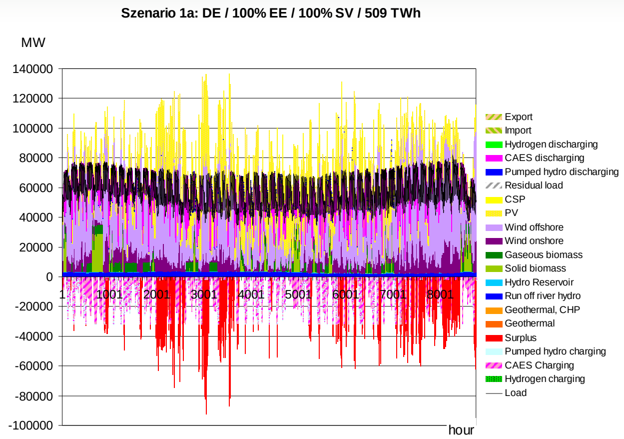
The potential for renewable electricity production in EU-North Africa (TWh/a)



100% renewable electricity is possible under all scenarios (example Germany)



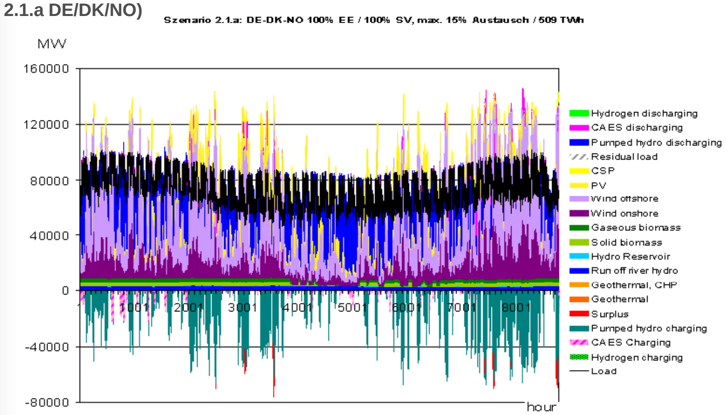
Overproduction in isolation (Szenario 1.a)



Even an isolated German system ist possible, but it needs 262 GW of capacity for 81 GW peak load. It leads to 53 TWh/a of overproduction.

Electricity production and storage in DE-DK-NO

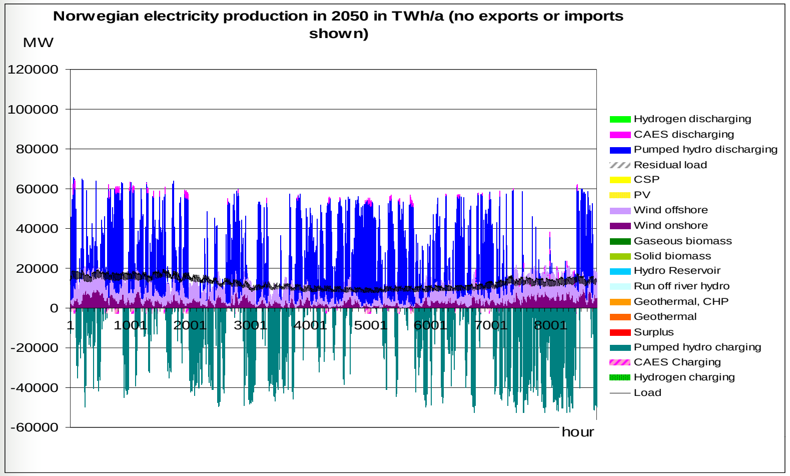
(Scenario 2.1.a DE/DK/NO)



The Norwegian system supplies the necessary storage! Practically no overproduction remaining!

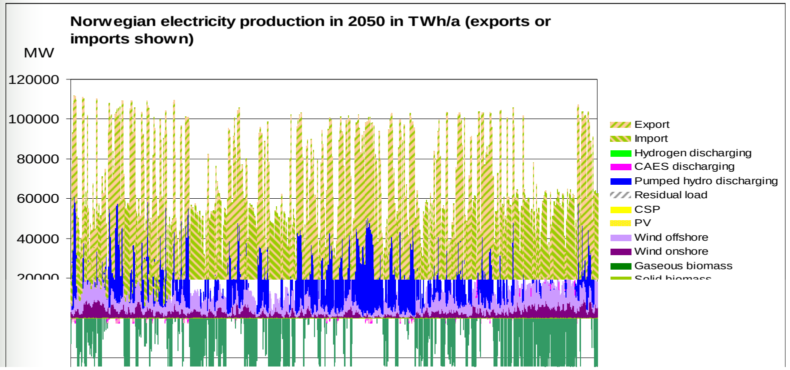
The Norwegian situation in 2050 with 100% national renewable electricity

Scenario 2.1.a (ex- and imports not shown)

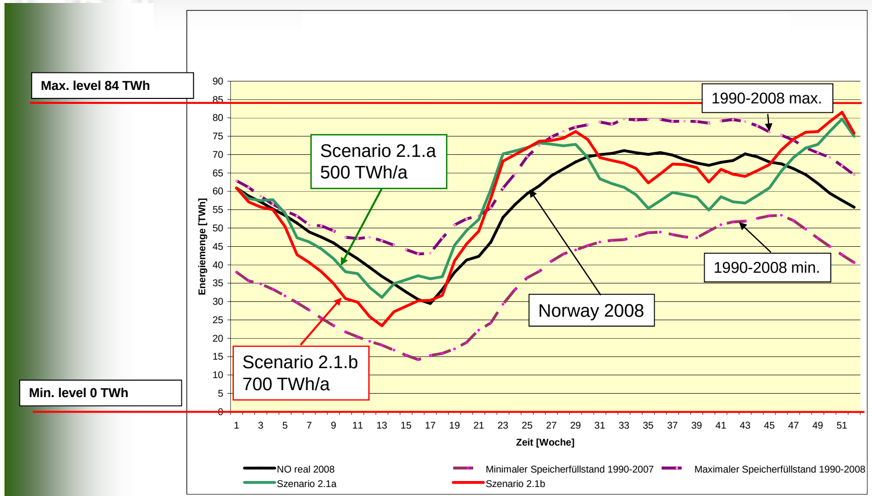


The Norwegian situation in 2050 with exports and imports shown

Scenario 2.1.a

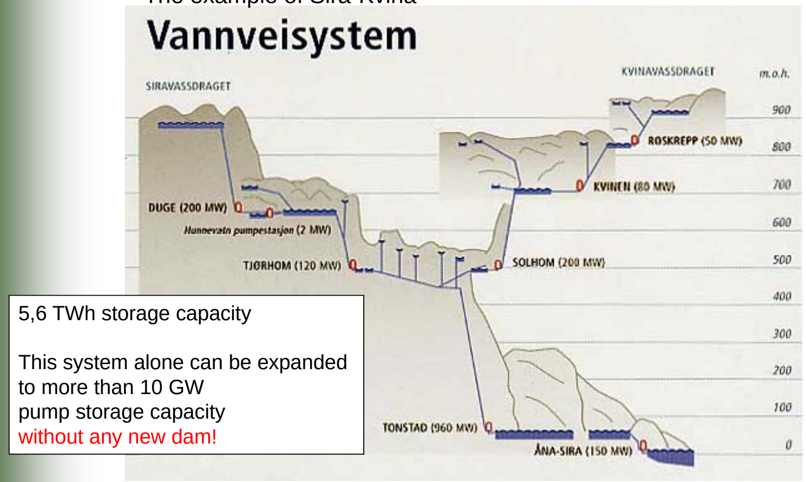


Impact on Norwegian hydro storage in 2050 (Scenario 2.1.a compared to 2008)



Only minimal changes to the Norwegian hydro power system are required

The example of Sira-Kvina



5,6 TWh storage capacity

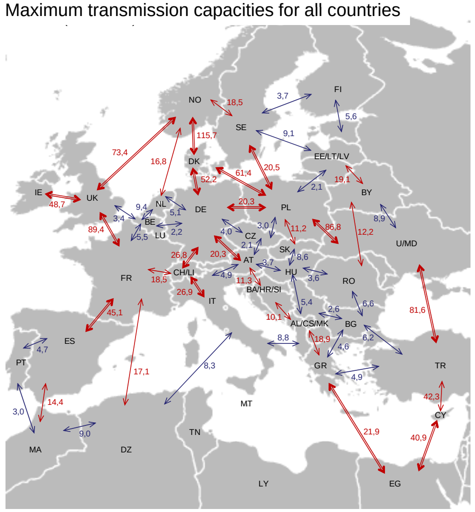
This system alone can be expanded to more than 10 GW pump storage capacity without any new dam!

The necessary grid capacity for a cooperation DE-DK-NO

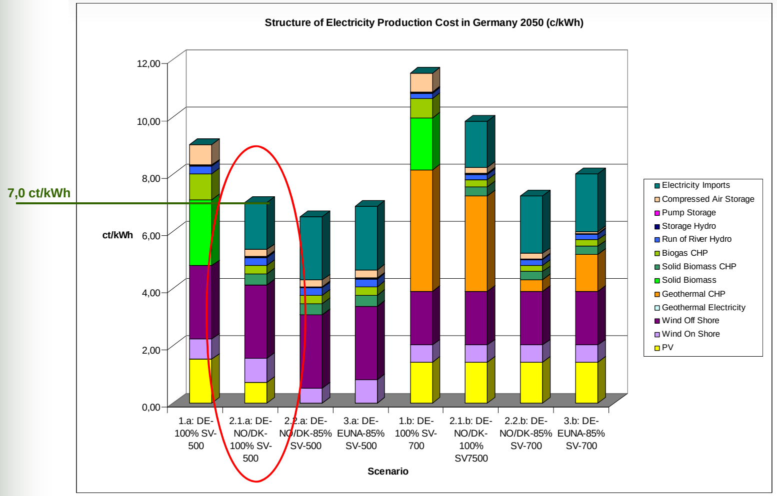
Scenario 2.1.a Maximum transmission capacities between DE – DK -NO

The necessary grid capacity The larger picture in 2050

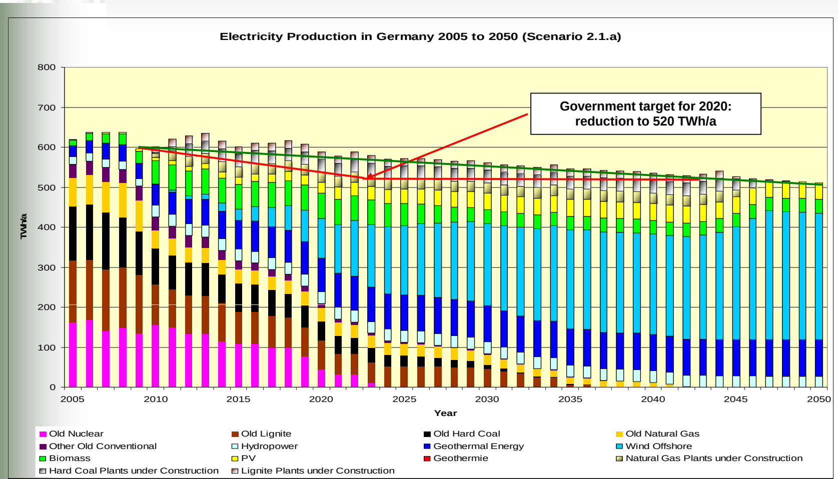
Scenario 3.a Maximum transmission capacities for all countries



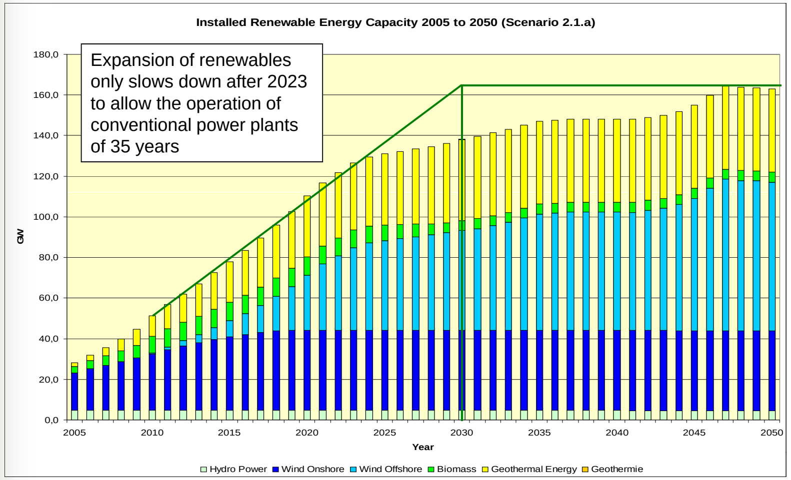
Electricity costs of less than 7 Cent per kWh in 2050 (Germany)



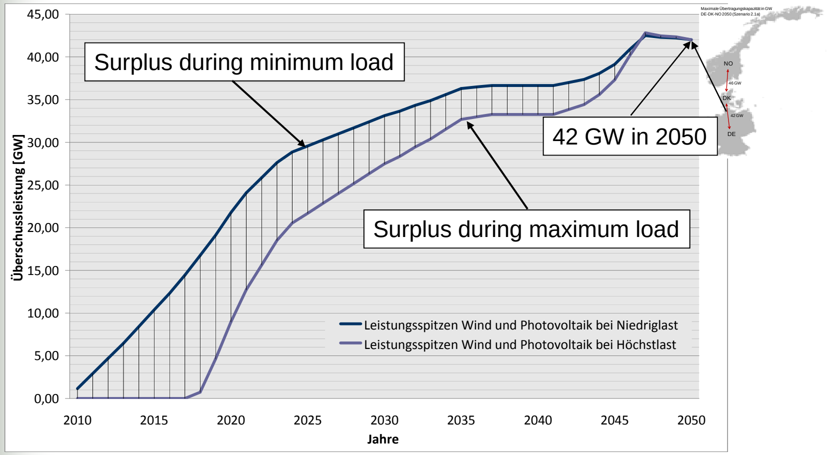
The German pathway 2010 to 2050
No additional conventional plants



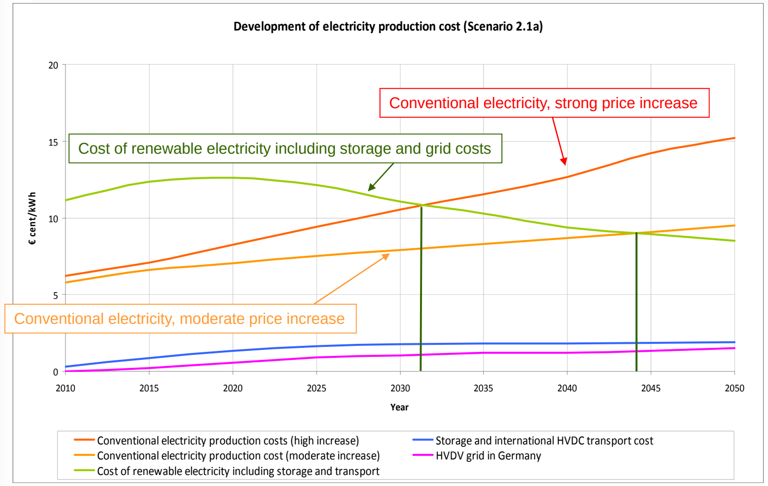
100% REN is possible by 2030
(based on scenario 2.1.a for Germany)



Development of surplus production in Germany in GW (wind and PV)



Renewable electricity is the lowest cost long term solution (2.1.a Germany)



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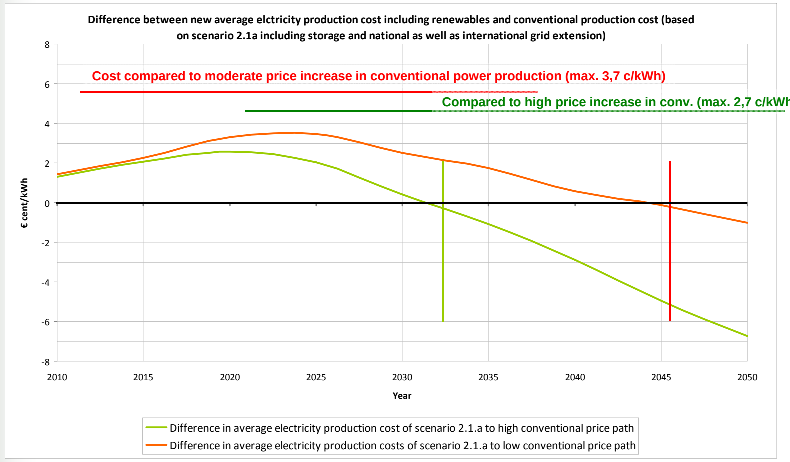
Cost of climate protection 2,7-3,7 €c/kWh during the most expensive years

The cost changes in Germany



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Conclusions

- **100% renewable electricity supply for Germany and Europe is possible by 2050 (2030 if needed)**
- **The system will mainly be based on wind and solar**
- **Storage and transmission will be crucial**
- **Pump storage will be in great demand**
- **Norway will become a unique swing provider for the European system due to its hydro resource**
- **We can start with bilateral cooperation**

11

The sooner we start a cooperation, the sooner we will be able to solve the climate problem!

Thank you very much for your attention

12

Appendix 10

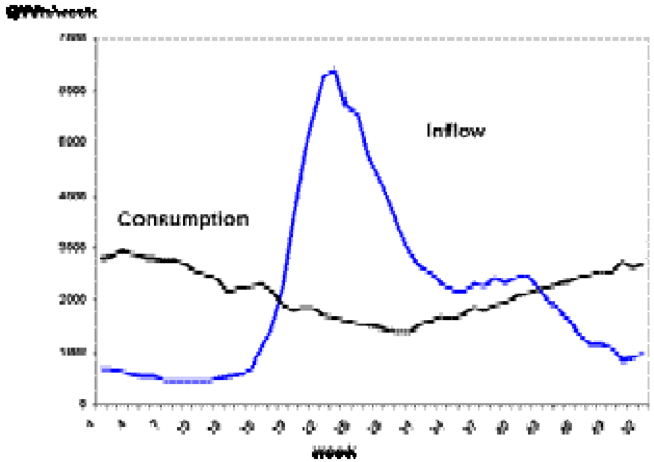
Potential for pumped storage plants in Norway

Jon Ulrik Haaheim, Statkraft

Potential for Pumped storage plants in Norway

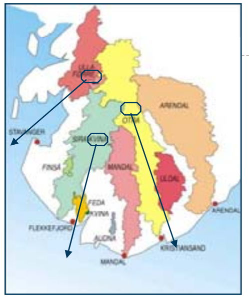
Oslo December 2010
Jon Ulrik Haaheim

NORWEGIAN HYDROPOWER



Reservoirs established to secure domestic consumption
Yearly consumption in average approx.120 TWh

NORWEGIAN POSSIBILITIES



- Reservoir capacity 82 TWh
- Increasing capacity in existing plants
- Establishing pumped storage plants between existing reservoirs

Location for capacity increase and PSP near potential location for new cables.

STATKRAFT STUDY.

- **Statkraft initiated a project mapping technical possibilities for capacity increase and PSP in southern part of Norway.**
- **Further identifying possibilities and challenges in supplying balancing power to Europe.**

- **Project**
  - Technical potential
  - Market assessment and modelling
  - Legal issues
  - Environmental consequences
  - Business models
  - etc

TECHNICAL POTENTIAL

PSP possibilities depend on limitations in the change of water level in reservoirs and duration for pump period

Øvre begrensning i vannstandsendring	Pumpekraftverk (MW) med svingperiode (hver fase)			Effektverk (MW)
	1 døgn 24 t	5 døgn 5x24 t = 120 t	60 døgn 60x24 t = 1440 t	65 - 120 døgn 7x24x9 t= 1500 t
				7 500
0,50 m/time	05 000	30 000	2 600	
0,10 m/time	30 000	16 000	2 600	
0,01 m/time	3 200	3 200	1 500	

Statkraft

The reservoir capacity of Lake Blåsjø is 7.8 TWh

CHALLENGES

- Political and public acceptance
- Domestic supply situation / safety of supply and price structure
- Environmental issues
- Legal issues
- Cables and transmission system
- Business models and economic viability

Statkraft

CONCLUSION

- **Significant possibilities for capacity increase and pumped storage plants**
- **Requires cables and increased transmission capacity**
- **Public and political acceptance**
- **Environmental solutions**
- **Economic viability**

Statkraft

Appendix 11

TSO experiences with EEG (feed-in of RES-E) and future outlook

André S. Estermann, 50Hertz Transmission

TSOs‘ EEG experience and future outlook

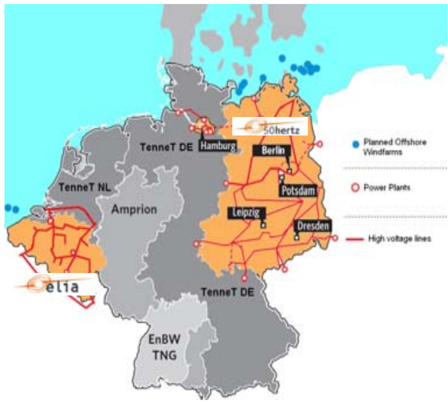
Perspectives on hydropower’s role to balance non-regulated renewable power production in Northern Europe, CEDREN Research Center, December 15th – 16th , Düsseldorf

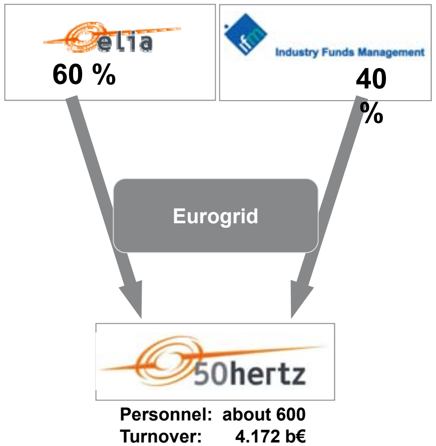
André S. Estermann, 50Hertz Transmission, Germany

Overview

- Development of renewables in Germany
- Feed-in characteristics of wind and solar power
- German renewables support scheme
- Challenges of renewables market integration for TSOs
- Outlook on market integration of renewables
- Conclusions

50Hertz Transmission as part of the elia group





Key figures 50Hertz Transmission – 2009

Area:	**109,000 km²**	(~31%)*
Inhabitants:	**18.2 Mio.**	(~22%)*
Demand:	**95 TWh**	(~20%)* [1]
Max. vertical Load:	**10,330 MW**	
Grid length:	**9,750 km**	(in operation)
Coupling lines to:	**TenneT, energinet.dk, PSE Operator, CEPS**	

Power stations and storage in control area ($P_{install.}$ in MW)	**Grid connection 380/220 kV**	**Grid connection ≤ 110 kV**
Thermal	12.860	7,100
Pump storage, Water (~43%)* [1]	2,400	500
Wind power (~41%)* [1]	910	9,590
Bio mass, **PV** etc. [1]	30	1,970
Sum	**16,200**	**19,200**
Total	**35,400**	
RES infeed	**25.4 TWh**[1] (2008: 22.7 TWh)	
Wind infeed	**16.9 TWh**[1] (2008: 16.5 TWh)	
$P_{install}$ Wind	**10,500 MW**[1] (2008: 9,680MW)	

!

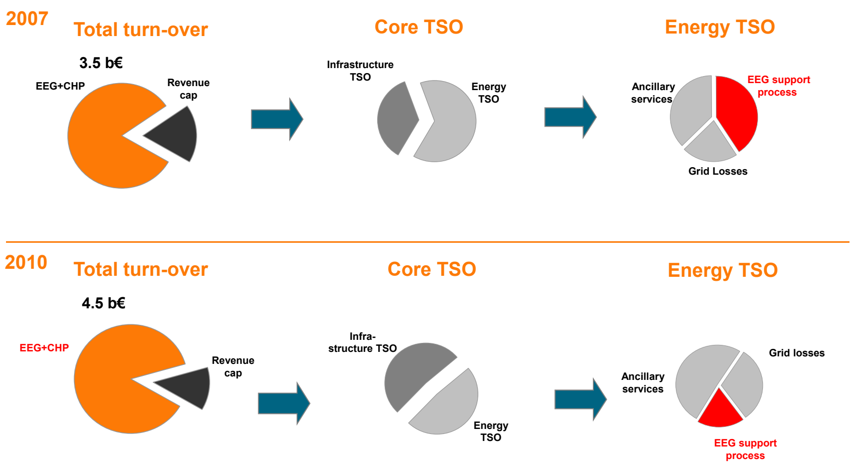
Peak load in grid area	**17,592 MW**
Peak grid load	**10,330 MW**
Minimum grid load	**– 3,303 MW**

!

* Percentage of whole Germany
[1] Preliminary information

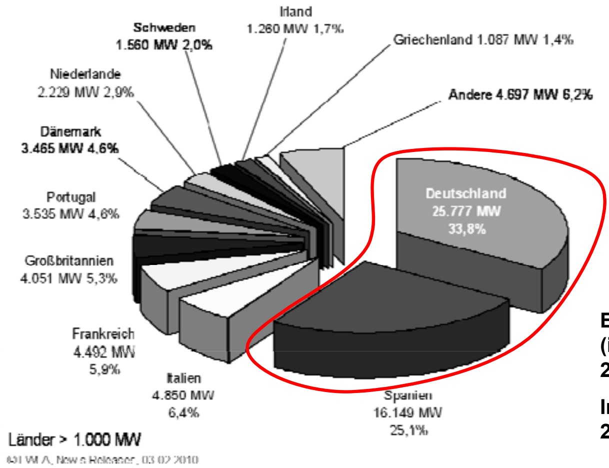
TSO business areas

Non-infrastructure business with increasing importance



Installed wind power in Europe (2009)

A major challenge for German TSOs



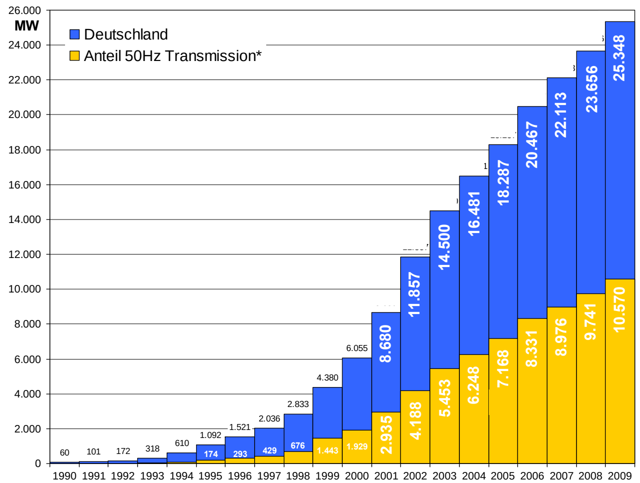
(Angaben für D vom DEWI, Deutsches Windenergie-Institut)

Major wind power share in Germany and Spain

Europe (2009) 76,152 MW (incl. off- and near shore 2,016 MW)

Increase of 10,526 MW to 2008 (DE + 1,917 MW)

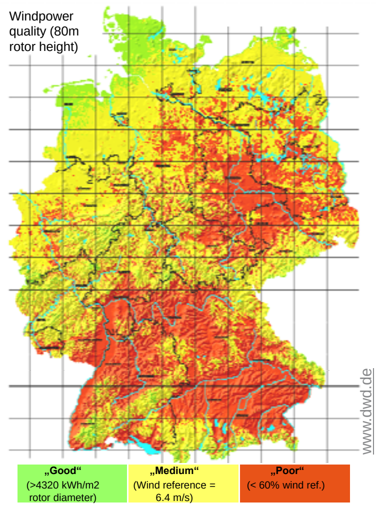
Development of installed wind power in Germany



* bzw. Anteil der ostdeutschen Bundesländer plus Berlin und Hamburg

Wind power characteristics

Control area 50Hertz in 2009

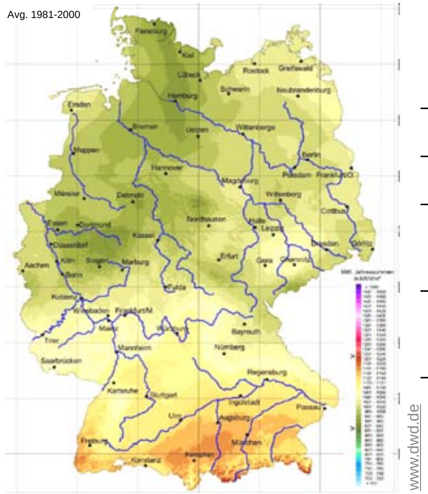


Average installed wind power	**10,126 MW**
Maximum feed-in	**9,094 MW**
Minimum feed-in	**0 MW**
Maximum 15-minutes change of feed-in	**+ 785 MW* / - 769 MW***
Maximum 1-hour change of feed-in	**+ 1,723 MW* / - 1,727 MW*** !
Maximum 1-day change of feed-in	**7,692 MW**

*) No major slopes from storms occurred in 50Hertz control area in 2009

Solar power characteristics

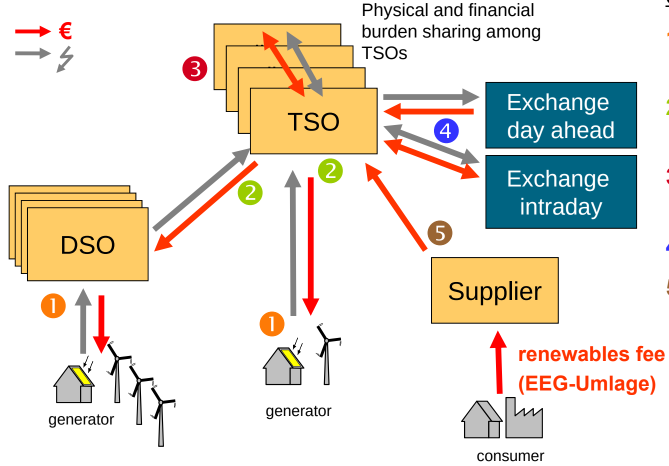
Germany



Installed solar power	ca. 13,000 MW !
Maximum feed-in	ca. 9,000 MW
Minimum feed-in	0 MW
Maximum 15-minutes change of feed-in	+ ca. 700 MW / - ca. 600 MW
Maximum 1-hour change of feed-in	+ ca. 2,200 MW / - ca. 2,200 MW !

German renewables support scheme

Since January 2010



5 Steps:

1. Integration of RES
2. EEG feed-in tariff
3. Inter TSO exchange
4. EEG Marketing
5. Recovery of costs

Challenges: Balancing Renewable Energy feed-in

According to German Regulation the "renewables balancing group" is to be operated like all other balancing groups with the obligation to level out any imbalance as far as possible.

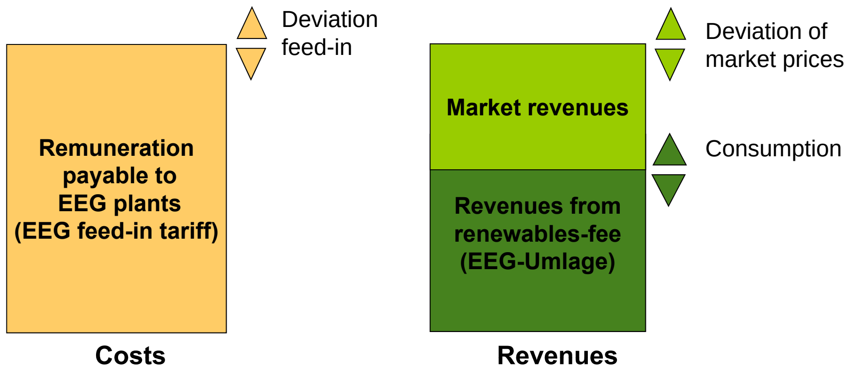
TSOs are responsible for the renewables balancing by:

- Day-Ahead Spot Trading at a Spot Exchange (EPEX Spot)
- Intraday-Trading at a Spot Exchange (EPEX Spot)
- EEG-Reserve power from public tendering
  (only until the end 2010 according to German regulation)
- Balancing energy within balancing group management

Additional new tools for balancing are needed

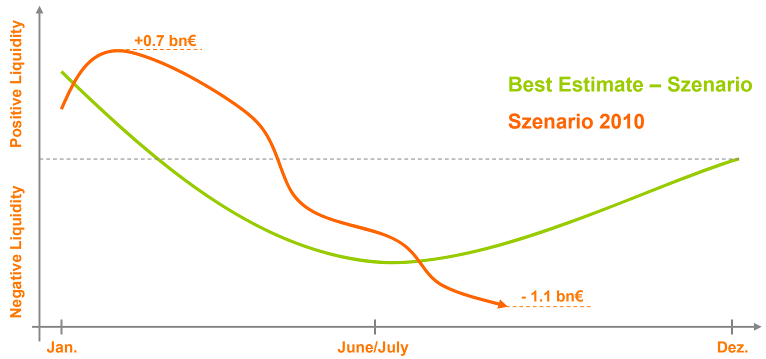
Cost recovery in renewables support scheme

Renewables fee shall cover the gap between costs for renewables remuneration and revenues from selling renewable energy to the spot exchange.



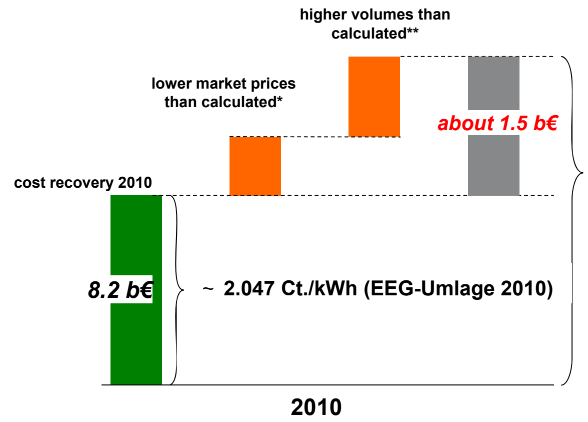
Challenges: TSOs‘ Liquidity needs

Renewables support scheme liquidity development in 2010



The current liquidity level (**-1,116 b€** in 09/2010) will be carried forward to the renewables fee (EEG-Umlage) in 2011

Differences between renewables costs and revenues for German TSOs end 2010

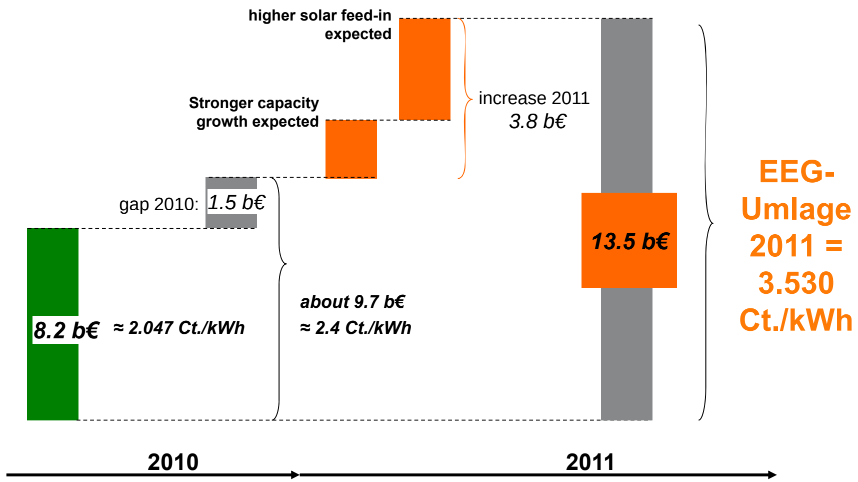


for cost recovery about 2.4 Ct./kWh (+17% compared to 2.047 Ct./kWh) would have been needed in 2010

* Spot market price assumption for renewables fee calculation: 53.65 €/MWh; average spot market price 2010 (until 09/10): 42.1 €/MWh

** in particular **solar power** increase in 2010

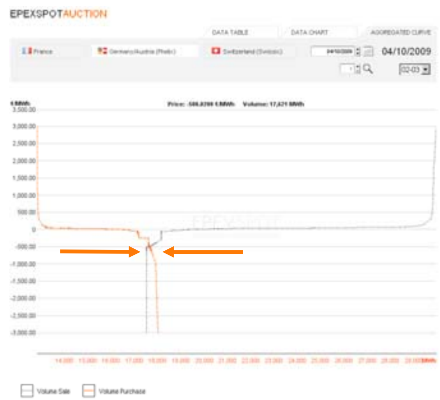
Outlook on renewables costs 2011



EEG-Umlage 2011 = 3.530 Ct./kWh

Challenges: Negative price peaks (I)

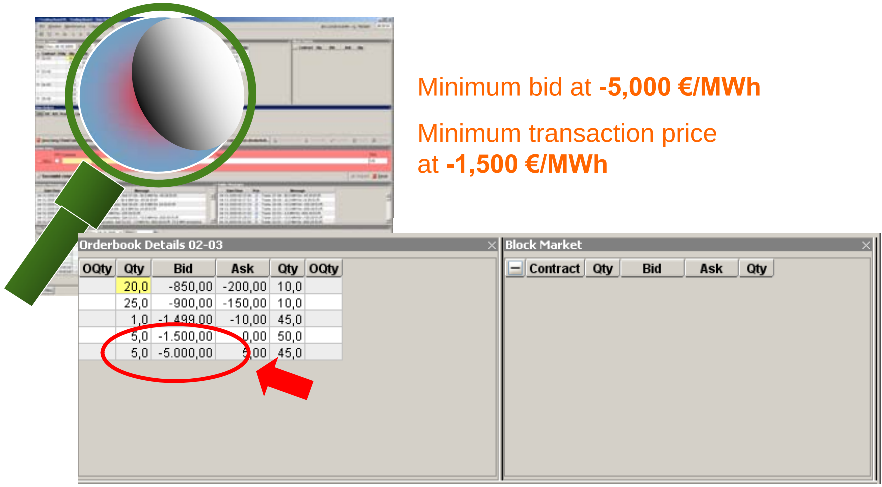
Day-ahead market 4 October 2009 between 2 am and 3 am



About 500 MWh additional market order volume would have driven market clearing price from -500 €/MWh down to the **technical Power Exchange limit of -3,000 €/MWh**.

Challenges: Negative price peaks (II)

Intraday market snapshot 4 October, 0:33 am for 2 to 3 am



Minimum bid at **-5,000 €/MWh**

Minimum transaction price at **-1,500 €/MWh**

Limititation rules

2010

- **Individual Limitation mechanisms** used by the 4 TSO (according to AusglMechAV)
  - Limitation only under exceptional circumstances possible
  - Max. 100h pro ½ year
  - ➢ **So far limits had not any impact on the market price!**
  - **Short term balancing possible by using the EEG-Reserve**

2011ff.

- **Standardized Limitation mechanism** for all TSO (according to updated AusglMechAV)
  - Limitation only possible in 2nd EPEX Auction
    - 10 bid steps per TSO
    - -150 to -350 €/MWh
  - **EEG-Reserve canceled!**

Outlook on market integration of renewables

German renewables development scenarios

year	Renewables share of electricity consumption	Electricity consumption	Resulting renewables production	Other scenarios	thereof wind	thereof solar
2008	15%	615 TWh*	92 TWh			
2020	**35%**	**554 TWh** (-10% vs. 2008)	**194 TWh**	**217 TWh** 111 GW	**104 TWh** 46 GW	**41 TWh** 52 GW
2050	**80%**	**461 TWh** (-25% vs. 2008)	**369 TWh**	**534 TWh** 260 GW	**347 TWh** 105 GW	**104 TWh** 120 GW

Document 1: **Energy concept 2010 of federal government**

Document 2: **National action plan 2010 for renewables**

Document 3: **Scenario from Umweltbundesamt 2010** (federal environmental agency, scenario with 100% renewables and some imports)

*) Statistisches Bundesamt

Outlook on market integration of renewables (II)

Prerequisites for full integration

- ➢ **Reinforcement of the grids**
- ➢ **Market development**
  - ➢ Integration of European markets
  - ➢ Harmonisation of renewables support schemes in Europe
  - ➢ Transparency and price signals
  - ➢ Liquid intraday market
  - ➢ Well functioning balancing tools
  - ➢ Contribution of renewables to ancillary services and balancing
- ➢ **Additional energy storage facilities needed**

Conclusions

- **Full integration of renewables** – will in future only be achievable with further grid extension, market development and additional storage facilities.
- **Renewables balancing** – TSO face great challenges due to renewables feed-in characteristics. There is an urgent need for new tools.
- **Liquidity** – TSO have to manage liquidity needs from renewables support scheme: credit lines, cash management, regulatory acceptance.
- **Negative prices** – For 2011 a successor rule for price limitations (§ 8 AusglMechAV) is needed. Reasonable negative prices create necessary price signals, while extreme prices must be avoided.
- **Market transparency** – Bring market participants into a position to understand renewables impact on markets and new flexibility demands.

At the End …

50Hertz keeps the Lights On!

André S. Estermann
Marktentwicklung und Verfahrensgestaltung
50Hertz Transmission GmbH

andre.estermann@50hertz-transmission.net

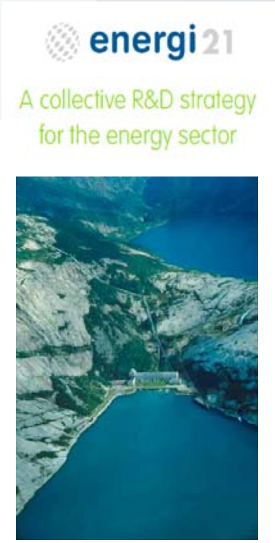
Appendix 12

Energi 21 strategy and work on Pump and Storage Demo and pilot plant

Bjarne Børresen, Energy Norway

Energi21

Energi21 sets out the desired course for research, development and demonstration of new technology for the 21st century.
The Energi21 initiative was launched with a mandate from the Ministry of Petroleum and Energy, which has now requested that the strategy be revised.
Efforts are currently underway in Energy21 to revamp the original strategy, giving it a more concrete, target-oriented focus. A revised version is planned to be completed in the course of 2011.



Hydropower group - highest priority project:

Pumped storage demonstration and pilot plant

PS R&D challenges - The need for a PS demo plant

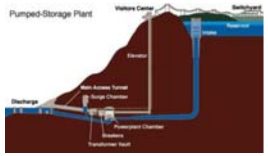
Old	New
Thermal dominated system	Intermittent production
Diurnal cycling	Stochastic cycling

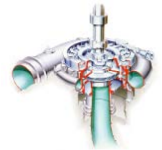
System challenges
System modelling
- Integration
- Type of support
- Storage requirements
- Time scales

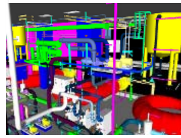
System optimization

Component challenges
Variable pumping power
Flexibility (operating range)
Mode change time
Bus based control & protection

Operational opportunities
Wind-water scheduling
Scaling issues
Training
Accelerated life testing





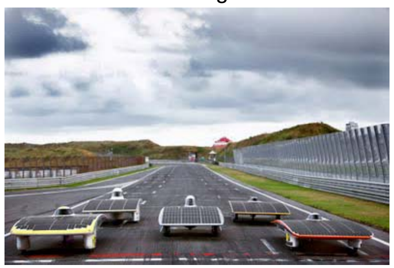


Why is PS a good idea

1. PS is the best technology for integration intermittent, renewable energy
2. PS is the best technology for increased usage of storage for balancing power.
3. PS is an excellent engine for hydropower development
4. PS is an excellent engine for international R&D collaboration
5. PS gives increased knowledge about operation and maintenance of ordinary hydropower.
6. PS is an excellent driver for research driven education within hydropower
7. PS is an excellent platform for training of power plant personnel
8. PS can be an excellent ”grand challenge” project which can increase the interest for hydropower among the youth
9. PS can spur the interest for hydropower in new scientific communities
10. PS promotes collaboration between power companies, academia and the research institutes
11. PS can be a partial answer to national bottleneck issues

X-challenge model

World solare challenge



Example (RPT runner development)
Day -90: Nominate scientific comitee
Day 0: Competition rules are published
Day0-5: International workshop: development of RPT runner.
Day 270: Submission of proposals
Day 360: Internationonal workshop: review of submissions and jury decission
(select 3 finalists, to be built and tested in lab)
Day 540: International workshop – model test results , jury decission of winner.

Open only for university teams (can have an industrial sponsor)
All geometries and computations freely available in public domain *)
All model test results freely available in public domain *)

*) Possible to add condition that further development directly based on the public results must also be made available to the public domain.

Appendix 13

Perspectives on Hydro Power's Role to Balance non-Regulated Renewable Power Production in Northern Europe. Reflections on European Initiatives

Peter Støa, SINTEF Energy Research

Perspectives on Hydro Power's Role to Balance non-Regulated Renewable Power Production in Northern Europe

Reflections on European Initiatives

Dusseldorf 15-16 Dec 2010

Dr. Petter Støa
Research Director
SINTEF Energy Research

SET Plan

Drivers
Climate Change
Security og Supply
Economic Recovery
Innovation

Themes
PV
Wind
Bio
CCS
SmartGrids
...

EU Infrastructure
Power/ Gas / CCS
1000 million Euro
Priority connections
North Sea
...

EII
SET Plan Themes
Grid Initiatives
Roadmaps

EERA
SET Plan Themes
Large Tech Research Institutes
R&D Roadmap

North Sea Countries Grid Initiative
MOU
Policy/ Market/ Regulation

North Sea Grid

Interconnections

Split ? Or One Issue?

Joint Programming
JU/ TP/ JTI/ EIT-KIC
FP8

UK, I, D — EU, E, N

National and/or EU

Europe
Commision
Regulators
Entso-E
...

UK
Goverment
DECC
Ofgem
National Grid
...

Norway
Goverment
OED
NVE
Statnett
Produsenter
...

Germany
...

UK Business Case (ex SKM report)
Interconnections
North Sea Grid
Renewable Directive
Security of Supply
Balancing
- Norway
- Ireland
- Iceland
- Netherland/...

N Business Case
Interconnections
Renewable Directive
North Sea Grid
Green Sertificates

Appendix 14

Perspectives on hydropower's role to balance non-regulated renewable power production in Northern Europe

Hans Olav Ween, Energy Norway

Perspectives on hydropower's role to balance non-regulated renewable power production in Northern Europa

Hans Olav Ween, Energy Norway - CEDREN WS 15. – 16.12.2010

EnergiNorge

Reflections on the way forward (1)

- Who will finance the investments?
  - 20 GW by 2030 – 28 cables of 700 MW (NorNed)
  - Total cost of appr. 16 bill. euro
  - In addition internal grid and production investments are needed.
- What are the price consequences ?
  - In the wholesale and retail markets
  - Network charges for producers and consumers.
  - How is industrial competiveness influenced?
- How shall costs and benefits be allocated
  - Who takes the investment risk and who reaps the benefit.
- Do we have the necessary governmental and regulatory support in and between countries, do we need it and how can we achieve it?

EnergiNorge

Reflections on the way forward (2)

- Procurement issues
  - Cable and converter production capacity
  - Cable ships
- Technical issues
  - Ramping and voltage issues
  - Conventional HVDC or VSC technology
- Environmental issues
  - Building new transmission lines
  - New regulation of waterways and reservoirs
- Market design and commercial business issues

EnergiNorge

Appendix 15

Summing up the workshop

Atle Harby, SINTEF Energy Research

Summing up

- It is more flexibility in the German system than previously expected
- Don't forget the politics
- Many storage techniques under development
- Good payback in cable investments and still lower prices in Norway than in Europe when surplus production and not too many cables
- Flexibility at different time scales. New markets needed
- Available modelling tools for balancing services at multiple time scales
- Supergrid may be very valuable in a "science fiction" future. Storage needs may then be reduced. Requires European energy politics

Summing up

- 100 % renewable Germany by 2050: Cheapest and most secure to use Norwegian hydro
- Southern Norway can technically provide 30 GW pumped storage for 5 days (80 GW for 24 hours)
- Full integration of renewables requires grid reinforcements, market development and additional storage
- Pumped turbine pilot – careful in the way this is marketed
- European perspective – North Sea grid – interconnections
- 20 GW + 28 cables: Financing, prices, how fast ?

Discussion I

- North Sea Grid – problem or solution?
  - Additional power lines over land in Germany
  - No need for pumping for the first 10 GW between Norway and Germany
- Multinational (European) or bilateral (Norway-Germany)?
- 100 % renewable will not happen, but a system strongly dependent on renewable energy is very likely
- Germany and Norway can show how things can be done
- Changes in German price formation will also impact other countries
- Fixed contracts for gas pipes – why not the same for power cables? A lot to learn from the gas negociations

Discussion II

- Address the issue at a high political level – show challenges for 2030 and 2050. Make Europe ask Norway!
  - Bring the money back to the end users, local society, etc
- Expert group for 2050 energy in 2011
- Trade-off between economics, environment, policy – a larger picture

Norwegian hydropower – the rechargeable battery for Europe

- Energy storage and balancing from Norwegian hydropower reservoirs to Europe

Visions: Norwegian hydro – the green rechargeable battery for Europe
Germany 100 per cent renewable by 2050

Topics for further R&D:

- Market: How to design and develop markets?
- Politics: EU, Norway, Germany, RES-directive, collaborations between countries, governmental and regulatory support
- Technology: Pumped storage, tunnels, cables, grid
- Environm.: Impacts in reservoirs, power line corridors, sub-sea
- Society: Public acceptance, compensations, tourism, aesthetics – local and national

Further work

- Workshop in the UK
- Workshop in Brussels ?
- Discussion forum – to be continued ? (YES !)
- Include governmental bodies and politicians ?
- Design applied research program - outline
  - Market, technology, environment, policy, society

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Renewable energy respecting nature

CEDREN
Centre for Environmental Design of Renewable Energy

FME
CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH