

CEDREN Hydrobalance

WP 2: Demand for energy balancing and storage

Trondheim, 15/9 - 2015

Prof. Magnus Korpås

Dept. of Electric Power Engineering

NTNU

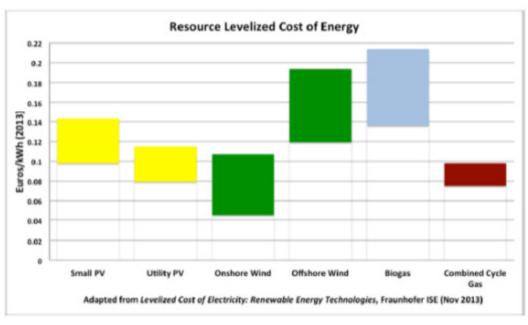


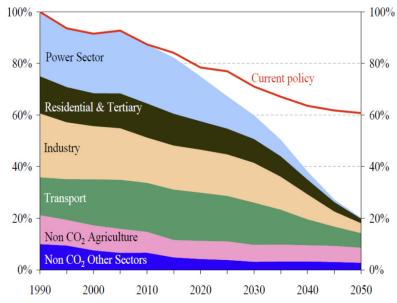
WP 2 in brief so far

- Balancing cost comparison PHS vs Gas
 - EEM 2015 paper by Korpås, Wolfgang, Aam
 - MSc Thesis Hanne Ommedal
- Cost comparison of energy storage options in progress
 - PHS, Batteries, Power2Gas, Flywheels, Compressed Air
- PhD-candidate Ingeborg Graabak started sep 2014
 - 2 papers submitted
 - "Variability Characteristics of wind and solar power resources a review with focus on Europe"
 - "Balancing of variable wind and solar production in Continental Europe with Nordic hydropower A review of simulation studies"
- Simulation study of PHS wind power smoothing
 - Guest researcher Nicola Destro, Univ. of Padova
- Several media contributions and public presentations on the role of Norwegian (pumped) hydro in the future European energy system



Renewables are «on track»

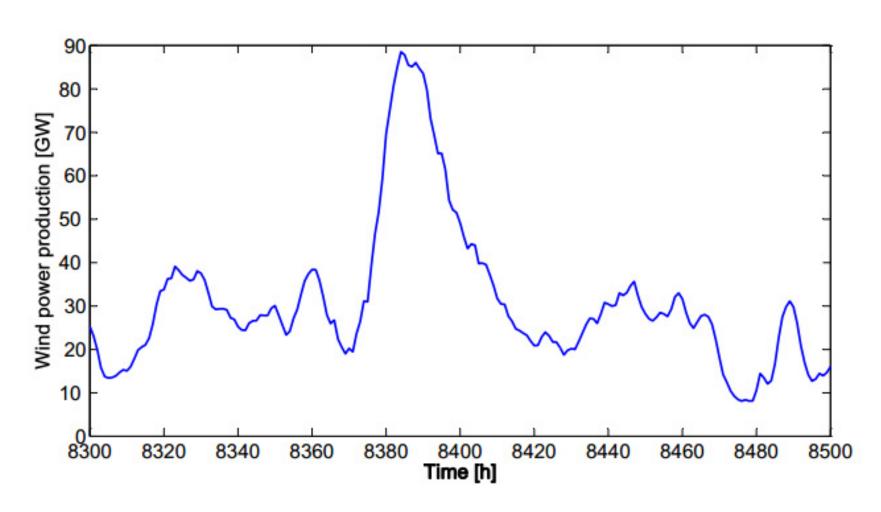






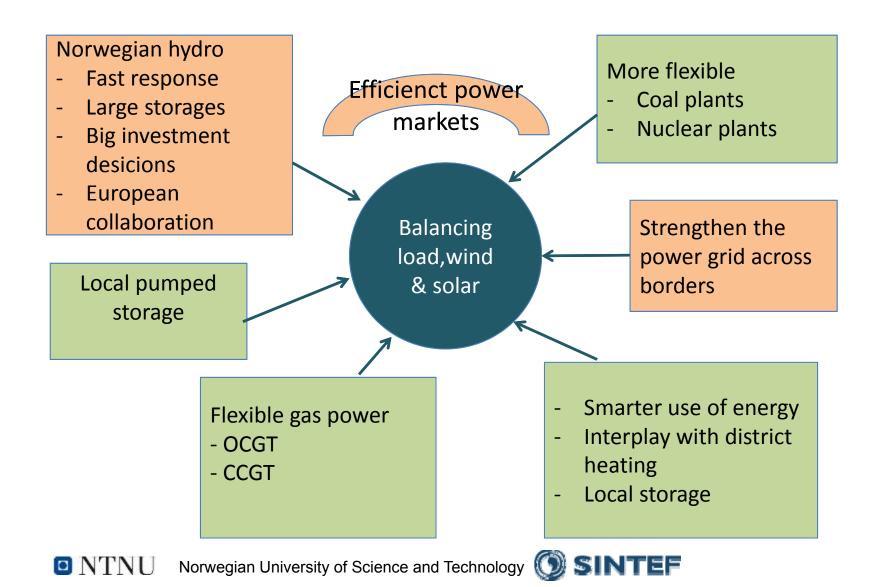


Houston, we have a prolem ...challenge!





...and a whole lotta solutions!



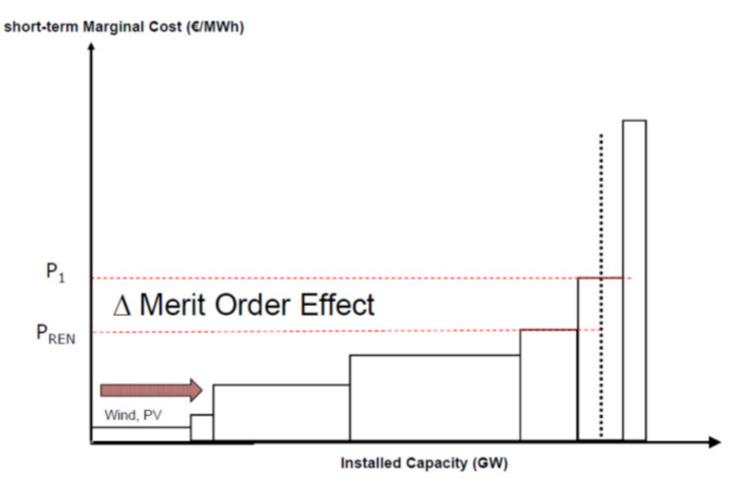
Characteristics of a RES-based power market

- Common markets for spot, balancing and ancilliary services across borders
- More rapid update of production plans
- Market clearing closer to operation
- Demand-side participation
- Allow extreme prices OR establish capacity markets
 - The «Merit order effect»



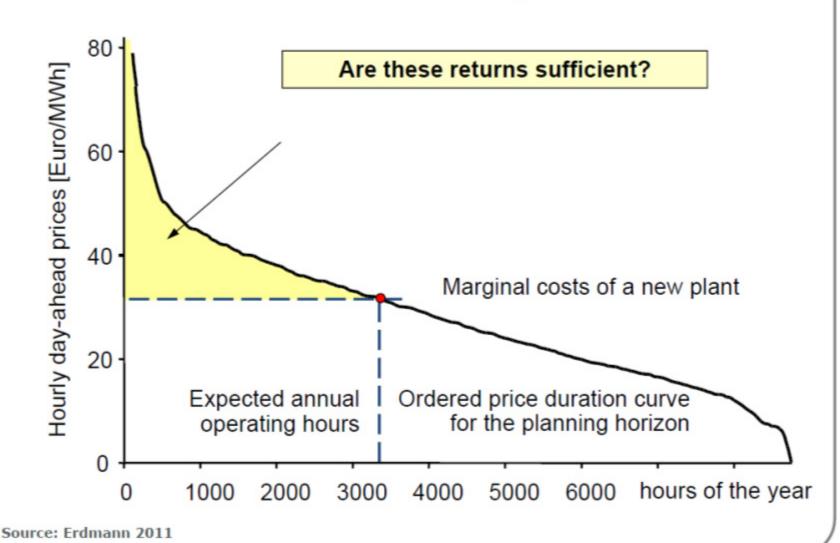


Variable Renewables and Implications for Market Prices: Merit Order Effect



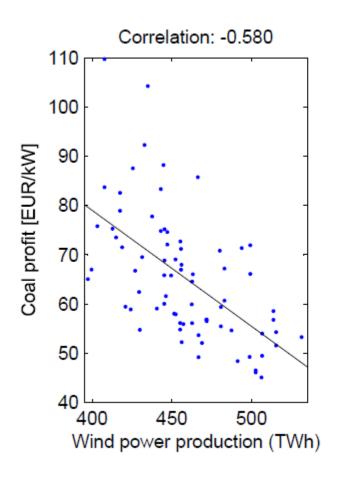


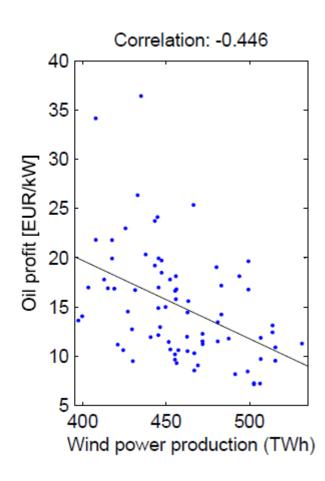
Price-Duration-Curve: Power Plant Investments on Competitive Markets



Lars Dittmar | 25

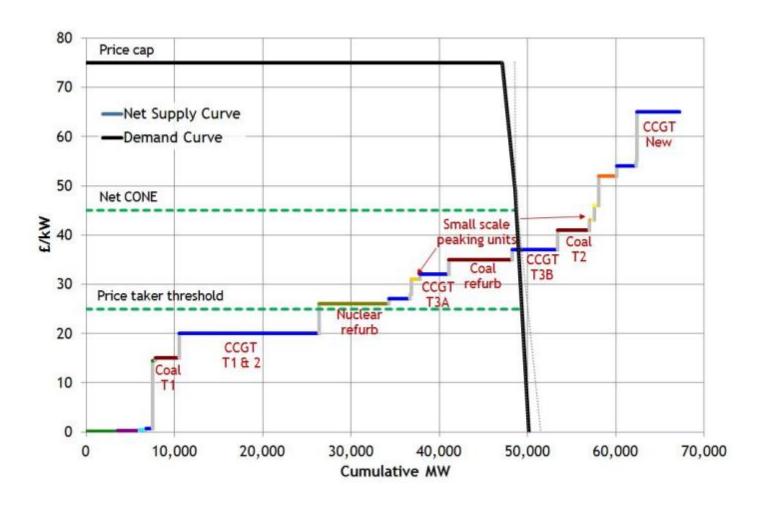
Wind and solar pushes fossils out of the spot market...







...and into the (emerging) capacity markets

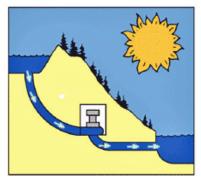




Norwegian hydropower for balancing

- The reservoirs are natural lakes
 - Multi-year reservoirs
 - Largest lake stores 8 TWh
 - Total 84 TWh reservior capacity
- Balancing capacity estimates 2030
 - 29 GW installed at present
 - + 10 GW with larger tunnels and generators
 - + 20 GW pumped storage
 - 30 GW total new capacity
 - Within todays environmental limits
 - Requires more transmission capacity











What is the value of the lake Blåsjø??





	BLÅSJØ	POWERWALL
Capacity (kWh)	8 000 000 000	10
Installation cost (\$)	-	3,500
Lifetime (years)	∞	10



8 TWh of Powerwalls cost 2800 Billion \$...



Isolated wind-storage systems

Increasing the renewable fraction beyond 75-80% results in an exponential increase in the marginal cost of energy

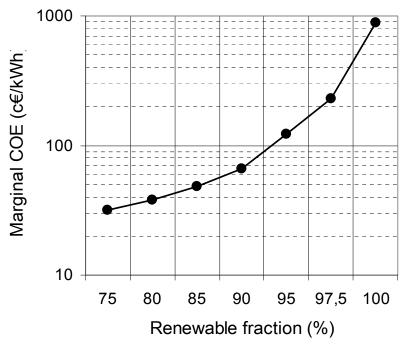


Figure 3: Marginal cost of energy of increasing renewable fraction. Wind power with 3500 full load hours.

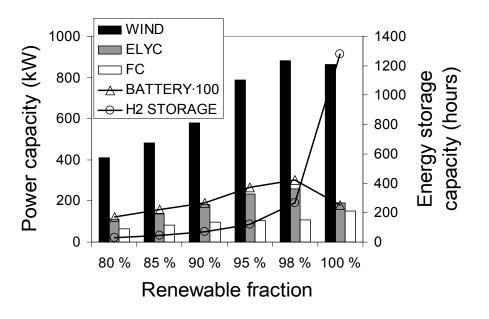


Figure 4: Optimal system configuration for various renewable fractions. Battery capacity is multiplied with a factor of 100 for graphical reasons.

Aurland Bergen Mauranger/Oksla/Tysso Dramm Kvilldal Haugesund Jøsenfjorden Holen Porsgrunn Stavanger Lysebotn Kragerø **Tonstad** Kristiansand

Case study 2030

10-20 GW new pumping and generation capacity using existing reservoirs





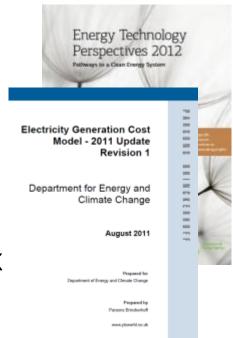


Overview of study

- Only cost is considered
 - Market operation "translated" to load factors
 - Assessment of the most cost-effective flexibility options in the near term

Input data

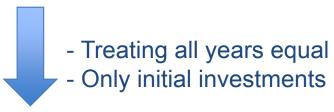
- Time period 2030-2040
- Based on IEA WEO scenarios and figures
- Gas plant models and costs according to report for UK Dept. of Energy and Climate Change
- Pumped hydro storage and grid data based on Norwegian figures; Producers, Regulator, TSO, Univ.





Levelised Cost of Electricity (LCOE)

 $LCOE = \frac{Discounted total investment costs}{Discounted total investment costs}$ Discounted total generation



$$LCOE = \frac{\text{Specific InvCost} \cdot (\text{AnnuityFactor} + \text{O\&Mpct})}{\text{Availability} \cdot \text{FullLoadHours}} + \sum \text{VariableCosts}$$

$$LCOE = \frac{i \cdot (\delta_{n,r} + OM)}{\alpha \cdot T_{fl}} + \sum_{j=1}^{J} c_{var,j}$$
Natural gas
$$(p_{ng} + p_{CO_2} \cdot e_{ng}) / \eta_{ng}$$

$$p_{pump} / \eta_{ph}$$
Pumped hydro



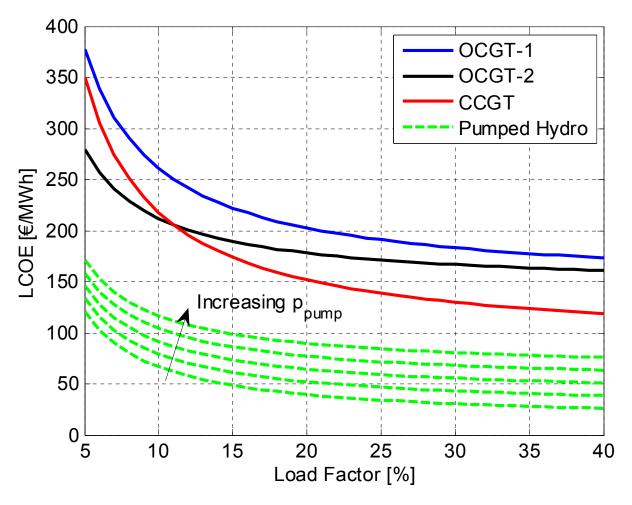


Parameter	CCGT	OCGT-1 (Aeroderivativ e)	OCGT-2 (F-class)
i _{ng} [€/kW]	718	705	377
n _{ng} [yr]	25	40	25
OM _{ng} [%]	3.9	3.5	3.4
η _{ng} [%]	59	35	35
α _{ng} [%]	92.8	94.7	91.9

Pumped	hydro plant	Subsea cable and grid		
i _{ph} [€/kW]	400	i _{cable} [€/kW]	1153	
n _{ph} [yr]	30	n _{cable} [yr]	40	
OM _{ph} [%]	0.75	α _{cable} [%]	95.0	
η _{ph} [%]	80	GR [%]	30	
α _{ph} [%]	95.7	n _{grid} [yr]	70	



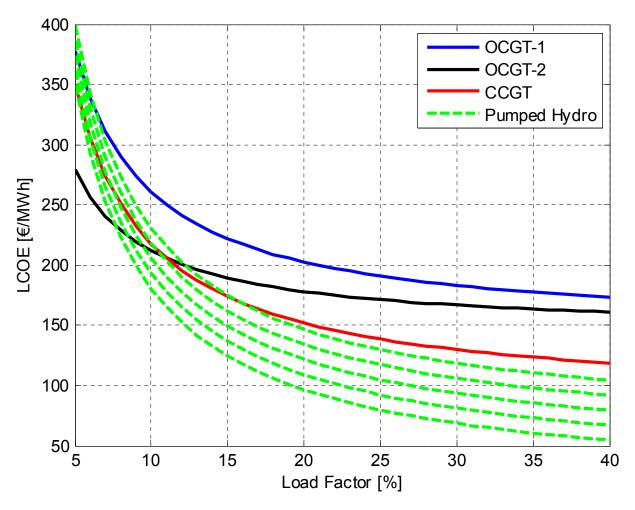
Norwegian pumped hydro has a relatively low LCOE...







...even when grid and cable costs are included





Levelised Cost of Peak Generation (LCPG)

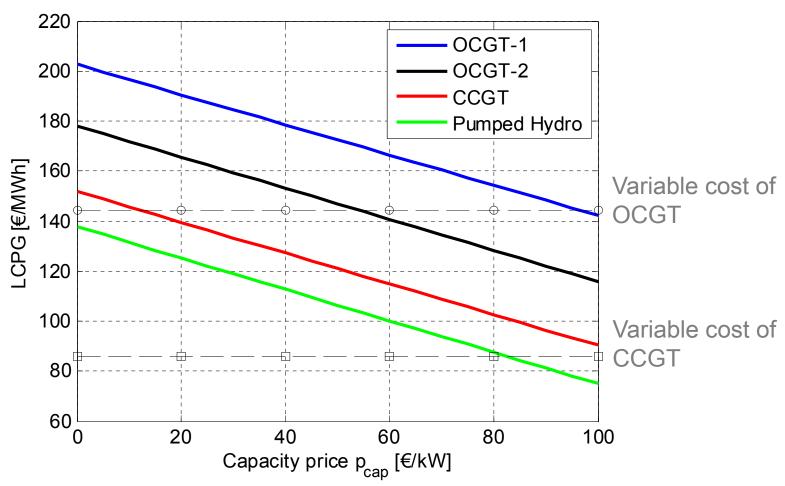
- A proposed new metric for the cost of providing electricity when fluctuating renewables and inflexible thermal generation cannot meet the (fixed) demand
 - Peak generation must cover the residual load
- In this paper, we use fixed scenarios for capacity prices, and calculate the needed payment for delivered energy.
 - Flexible demand not considered in the specific case study, but can be treated equally

Natural gas:
$$LCPG_{ng} = \frac{i_{ng} \cdot (\delta_{n_{ng},r} + OM_{ng}) - p_{cap}}{\alpha_{ng} \cdot T_{ng}} + \frac{\left(p_{ng} + p_{CO_2} \cdot e_{ng}\right)}{\eta_{ng}}$$



LCPG for 20 % load factor

Sensitivity on capacity price





Summary of study

- A method for calculation of the Levelized Cost of Peak Generation (LCPG)
 - Peak periods are defined as the time of the year when nonflexible resources cannot cover all the demand
 - The method account for possible capacity payments and additional revenue during off-peak periods
- A case study of a future European power system with high penetration of wind and solar power
 - Building new reversible pumping stations between existing reservoirs in the Norwegian hydro system can be economical advantageous over new CCGT and OCGT plants
 - Additional costs of subsea cables across the North Sea and corresponding reinforcements of the mainland grid is included





Conclusion so far...

Interconnectors must be given full access to all markets, including capacity markets, for utilization of the most economical viable sources of storage and flexible power in **Europe**





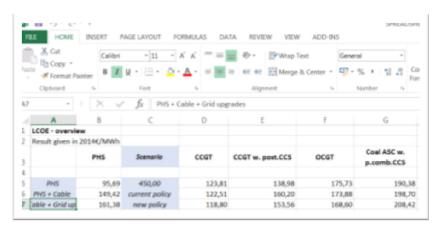




WP 2 MSc thesis







Spreadsheet cost model available for Hydrobalance partners

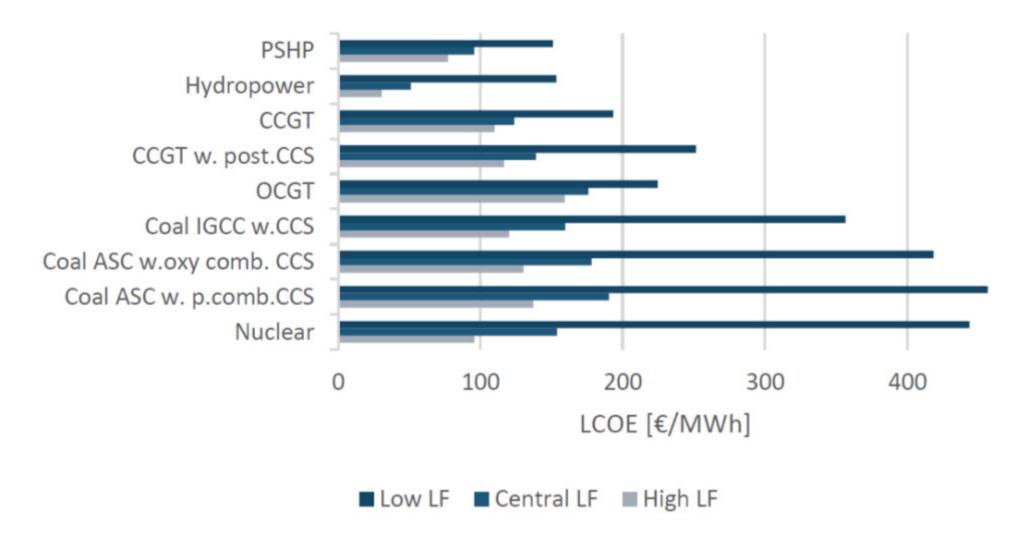


MSc thesis: Cost of flexibility

- Technologies: PHS, conv. hydro, several types of thermal with and without CCS
- Main sources: IEA, DECC, EIA, NVE
- Sensitivity analysis on assumptions
 - Discount rate
 - Load factor for all technologies
 - Investment cost of pumped hydro
 - Average pumping price
 - Fuel and carbon prices
 - Costs for cables and grid upgrades

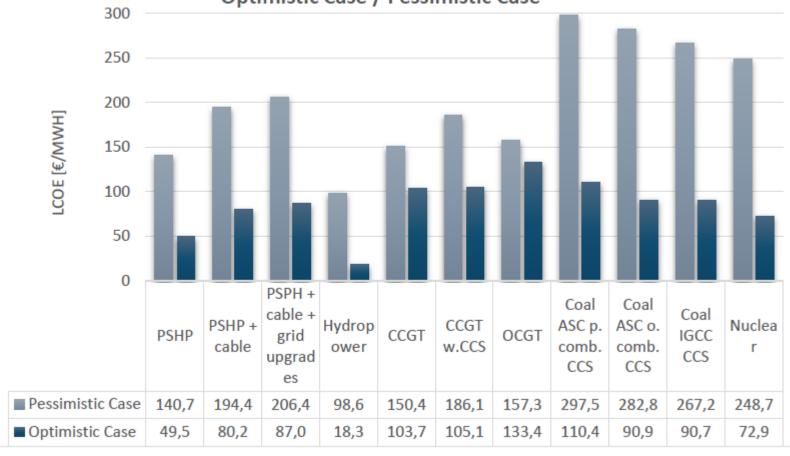


Base Case Result





LCOE
Optimistic Case / Pessimistic Case



	Investment	Capacity	Load factor	Price for pumping	Fuel price	Carbon tax
Optimistic Low values	Low values	Central	0.6	Low	450	450
	Low values	values	(0.35 for PSHP)	[20 €/MWh]	Scenario	Scenario
Pessimistic	High values	Central	0.2	High	450	450
		values	0.2	[40 €/MWh]	Scenario	Scenario

PhD project: Demand for energy balance and storage



PhD Fellow: Ingeborg Graabak

Nationality Norwegian

Magnus Korpås and Olav Fosso

Department: Dept. of Electric Power

Engineering,NTNU

Start: September 2014 Finished: September 2017

CEDREN project: HydroBalance



Develop methodology and models for assessing the value of Norwegian hydro for balancing wind and solar variations/uncertanty

- Categorization of variability of wind and solar for different time horizons
- Develop data model with high spatial and temporal resolution for different scenarios of wind and solar production in Northern Europe
- Establish a possibility for analyses of several markets (day-ahead, intraday, balancing)
- Assess the value of applying Norwegian (pumped) hydro for balancing of large shares of wind and solar production in future Northern Europe

Balancing of variable wind and solar production in Continental Europe with Nordic hydropower – A review of simulation studies

Topics studies

- 1) The need for balancing and storage
- 2) Possible further development of the Nordic power system
- 3) Consequences of different market solutions
- 4) Changes in operation patterns of the Nordic system

Selection

Twelve scientific papers are reviewed.

Main findings

None of the studies have modelled the future variability in both wind and solar power sufficiently realistic.

Further research should start with establishing such a model.



Title / Year of publishing/ Reference	Main research question	Need for balancing and storage	Develop- ment of Nordic power system	Consequences of market solution	Changes in hydro operatio n pattern
Balancing of Wind Power Variations using Norwegian Hydro Power/[4]	The role of the Norwegian hydropower system to provide balancing power to a future European system, e.g. how such a role will affect the Norwegian hydropower system.	X	(X)		Х
The effect of Large- Scale Wind Power on System Balancing in Northern Europe/[5]	i) Simulation of actual and forecasted WPP for 5 scenarios in 2010 and 2020. ii) Analyses of procurement of reserves capacities and their activation. iii) Analyses of the potential of integrating Northern European regulating power markets	X		X	
Nordic hydropower flexibility and transmission expansion to support integration of North European wind power/[6]	Assess the challenges related to WPP variability, especially offshore in the North and Baltic Seas and the transmission grids needed to enable the optimal use of hydropower flexibility in a long term cost-benefit analysis.	X	X		X

Title / Year of publishing/ Reference	Time perspective /Geographic al resolution	Main input data	Model(s)	Main findings
Balancing of Wind Power Variations using Norwegian Hydro Power/ 2013/ [4]	2030/ NO *), DK, NL, BE, UK. In the EMPS analyses also SE, FI FR, PL and AU	EMPS analyses: "Europe": wind power generation: 323-474 TWh/y, no increase in Norwegian hydropower capacity, exchange capacity NO – "Europe": 2,3 GW and 5,8 GW, Wind speed data from the Reanalysis global weather model for the years 2000-2006	2 analyses: one with a simplified model and one with the EMPS model	The generation constraints and the exchange capacity, and not the aggregated reservoir size, are the most important physical limiting factors of the amount of balancing that can be provided.
The effect of Large- Scale Wind Power on System Balancing in Northern Europe/ 2012/[5]	5 scenarios covering 2010 and 2020, NO, SE, FI, DK, GE, NL, BE	Exchange capacity NO – other countries: 3.7 GW (2010) and 6.8 GW (2020), 6 GW increased capacity in Norwegian hydro power WPP based on a mixed input data set including measurements of wind speed and values from the COSMO EU tool, Installed WPP capacity 2010: 34 GW, 2020: 96 GW	EMPS and IRIE (Integrated Regulating power market in Europe)	Integrated market: 2020 procurement costs reduced by 30% compared to non-integrated markets, balancing costs reduced by 50%, gross reserve activation in the Nordic area nearly doubled in 2020 with integrated regulating market
Nordic hydropower flexibility and transmission expansion to support integration of North European wind power/ 2014/[6]	2030, Europe including the North-Sea	Installed wind capacity in NO, SE, DK, FI, NL, BE, GE and UK are onshore: 98 GW and offshore: 97 GW, solar production: 30 GW based on reanalysis data. Increased capacity of 18.2 GW in the NO hydropower system. The grid is an extrapolation of	EMPS and PPST (Power System Simulation Tool)	Long term strategies for the expansion of the transmission grids must be defined in a coordinated way to ensure optimal developments. The analysis shows high correlation between pumping patterns in southern part of NO and WPP in Northern GE

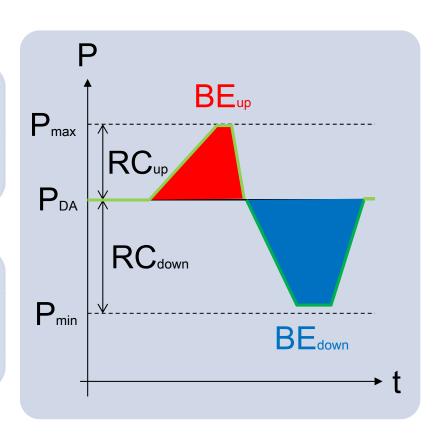
Balancing Reserve Capacity vs Energy

Reserve procurement

- Reserve capacity (RC) [EUR/MW]
- TSOs ensure sufficient reserves in the system during operation

System balancing

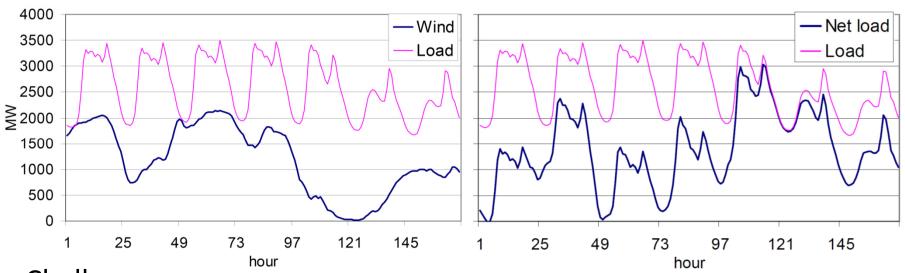
- Balancing energy (BE) [EUR/MWh]
- TSOs activate reserves to counteract system imbalances





It is the Net Load that matters

- The system will see the aggregated net imbalance
 - Unforeseen variations in load, wind and solar
 - Net load = Load Wind Solar



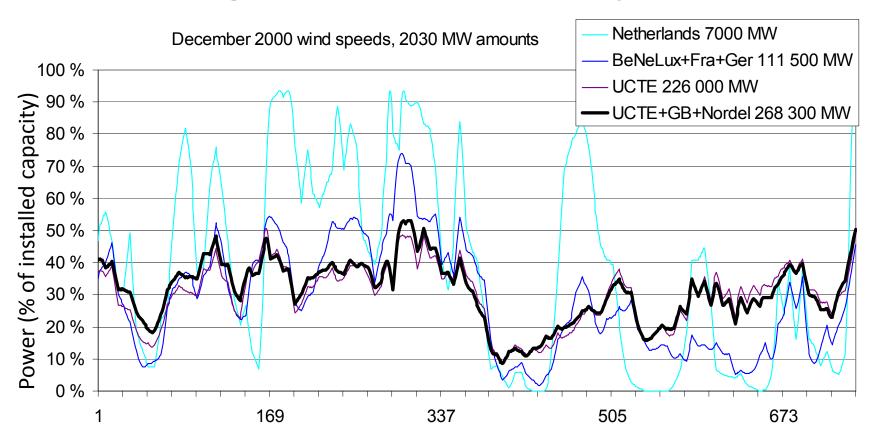
Challenges:

- Flexibility of thermal power plants (ramp rates, start/ stop operation)
- With very high RE share, thermal plants can be pushed out of the market security of supply has to be fulfilled





Smoothing effect of variability

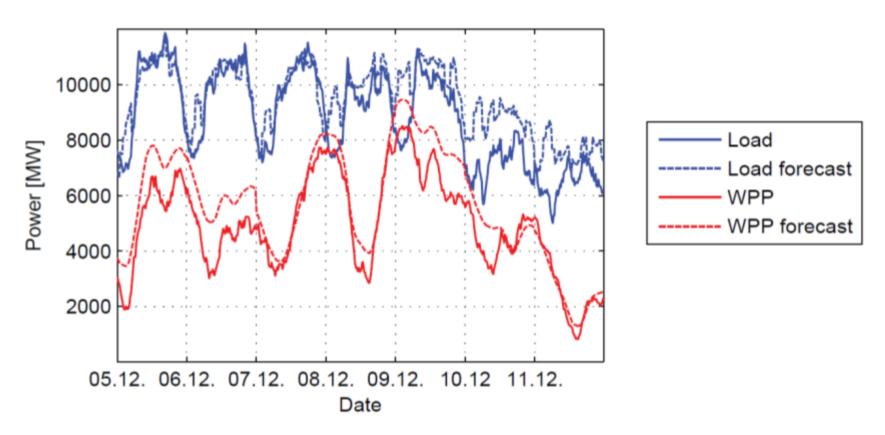


Pan-European balancing can reduce storage needs of wind+PV by a factor of 11 compared with regional storage



Source: Fraunhofer IWE\$

Wind forecasts are not that bad...

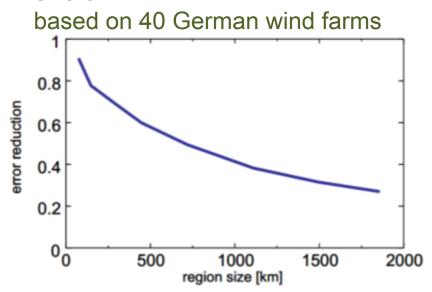


 Actual and predicted load and wind power forecasts in the 50Hertz area in Dec. 2011



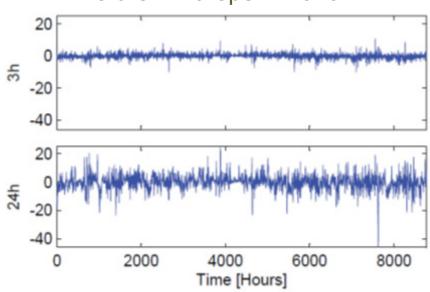
..but forecast horizon and geograpichal spread are essential

Geographical smoothing of forecast errors



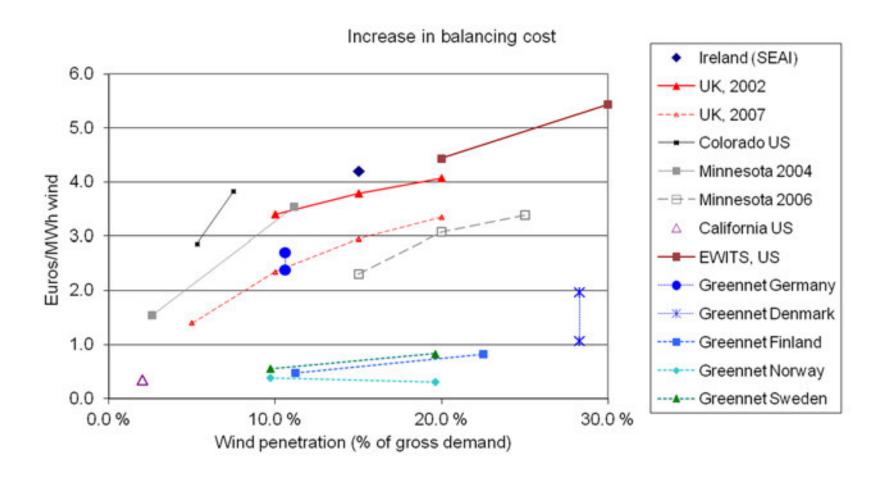
Source: energy & meteo systems, IEA Wind

Simulated forecast error [GW] in Northern Europe in 2020



Source: Jaehnert (NTNU)

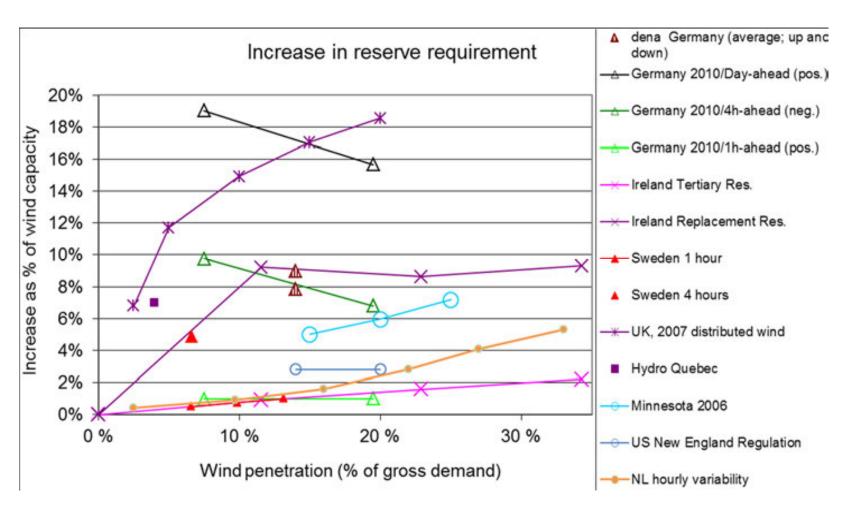
Increase in balancing costs due to wind







Increase in reserve requirement due to wind





Study model 1 – Integration of balancing markets

Fundamental model

Detailed water course description About 300 thermal power plants Transmission corridors (NTC)

Northern Europe

Denmark, Finland, Norway, Sweden Germany, Netherlands, Belgium

System scenarios

2010 – current state of the system 2020 – a future state of the system

Several climatic years

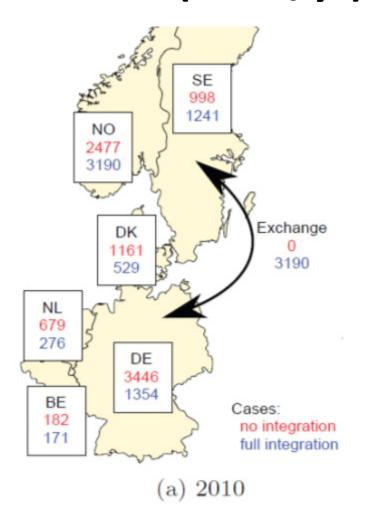
Hydrology (Inflow) Temperature Wind speed

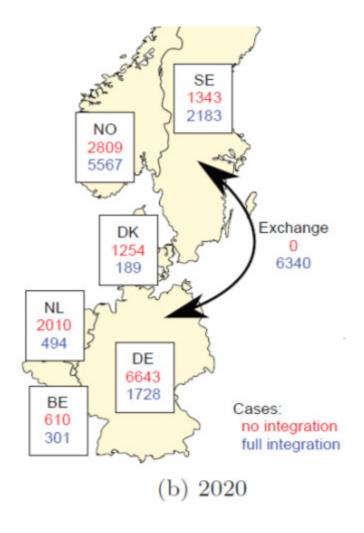




Source: Doorman (NTNU)

Country wise annual balancing reserve allocation (GWh/yr)

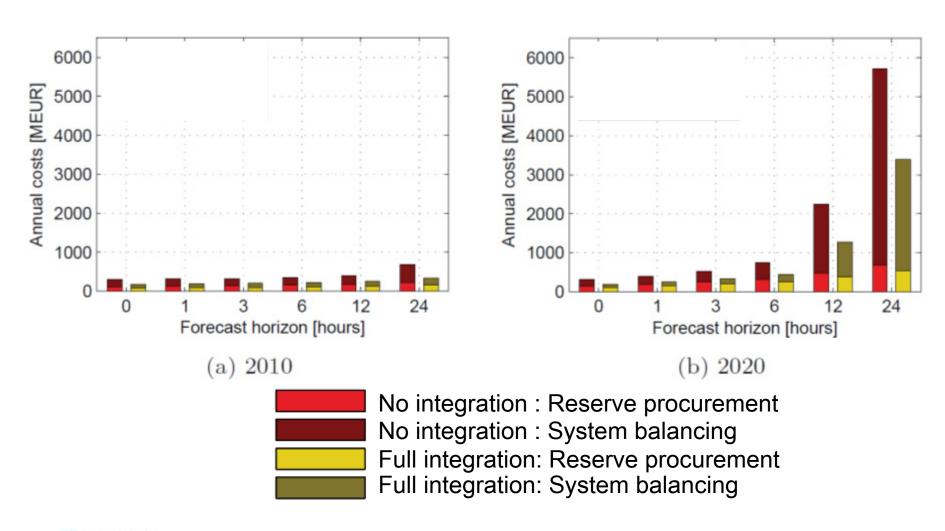






Source: Jaehnert (NTN4)

Total balancing market costs for different wind forecast horizons





Study model 2 – Integration of balancing markets

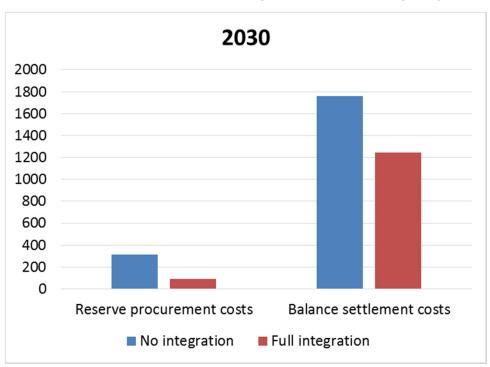
- Detailed European grid model based on DC power flow
- Representation of day-ahead, intraday and balancing markets
- Co-optimizating day-ahead scheduels and reserve procurements based on forecasts
- Scenarios for load, generation and grid capacity year 2020 and 2030

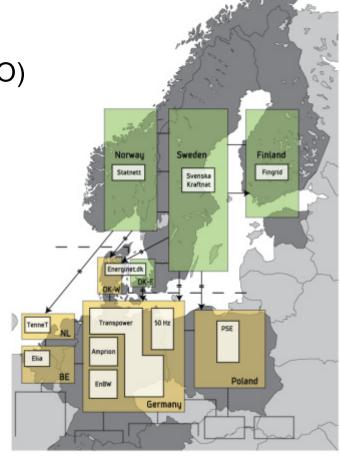




Large benefits of integrating the Northern and continental balancing markets

Total annual balancing cost savings (Mill.EURO)

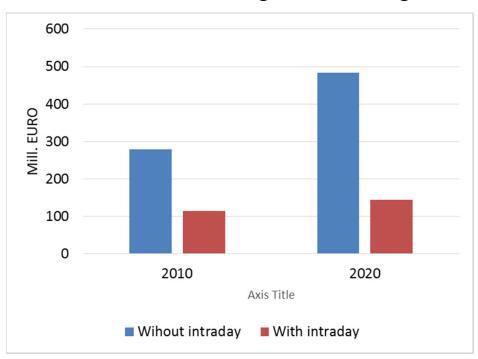




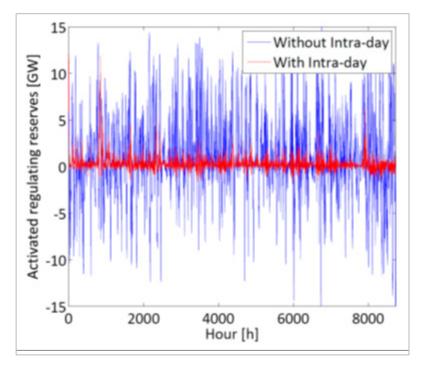


Significant additional savings are achieved with intra-day markets

Total annual balancing cost savings



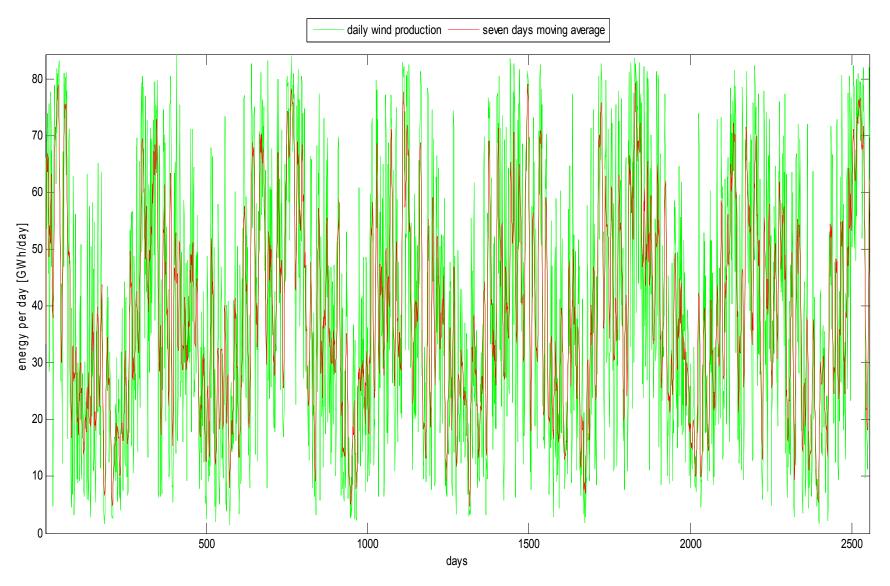
Activated reserves





Source: Aigner (NTNU)

Smoothing of offshore wind power variations with Norwegian pumped hydro: A case study



Approach

() SINTEF

- Builds on previous work and case study at SINTEF Energi
- New optimization model is developed
- Adress the trade-off between
 - Fulfilling the balancing request
 - Not deviating from planned reservoir level target
- Different time-steps and planning horizons are investigated

Report

Norwegian hydropower for large-scale electricity balancing needs

Plot study of technical, environmental and social challens

Authors

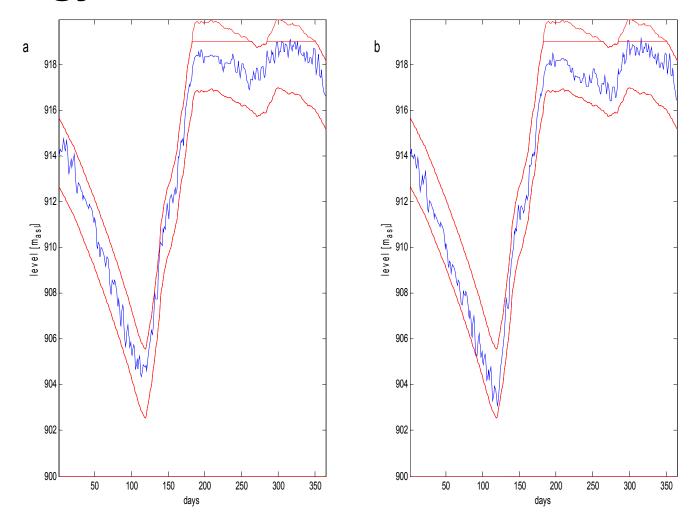
hend Sahang (tead author), Julie Charmisson, Julian Sasterfeste, Atle Harly, Anund Bingheit, Helene Egeland, October Andersen, Audion Book, McCarle, Atle



SINTEF Energy Research Energy Systems



Perfect forecast vs «rolling horizon» strategy



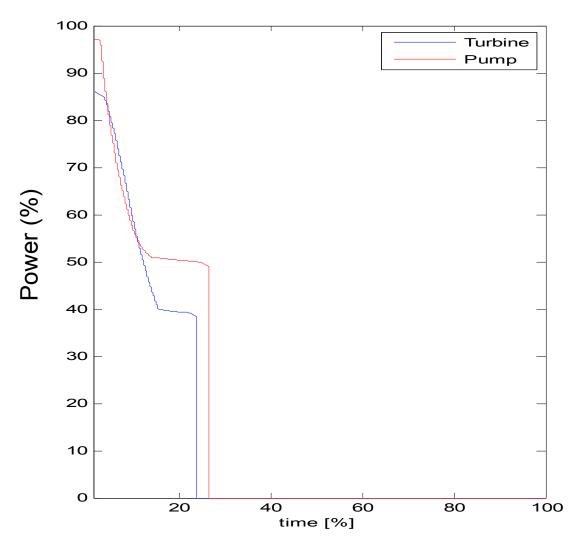


Sensitivity of operation strategy parameters

Hydrop ower plant	Bands on the levels	$oldsymbol{eta}_{usag}$	Balanci ng request = E _{br}	Balanced energy = E _{be}		Unbalanced energy = E _{uel} + E _{uee}		Lack of production = E _{uel}		Excess of production = E _{uee}	
	(m)		(GWh)	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)
Holen	± 0.5	0.98	33230	23188	70	10042	30	6687	67	3356	33
Holen	± 1.5	0.98	33230	23257	70	9973	30	6588	66	3386	34
Holen	± 3.0	0.98	33230	23271	70	9959	30	6561	66	3398	34
Rjukan	± 0.5	0.95	36717	14273	39	22444	61	16851	75	5593	25
Rjukan	± 1.5	0.95	36717	14280	39	22437	61	16724	75	5713	25
Rjukan	± 3.0	0.95	36717	14257	39	22460	61	16650	74	5811	26
Tonstad	± 0.5	0.98	32870	23112	70	9758	30	6180	63	3578	37
Tonstad	± 1.5	0.98	32870	23037	70	9833	30	6298	64	3534	36
Tonstad	± 3.0	0.98	32870	22897	70	9972	30	6279	63	3693	37



Usage of pump-generation pair





Media contributions

Nyheter

Vil doble vannkra

Norsk vannkraft er billigst og kan dekke store deler av kraftbehovet i Tyskland på en vindstille kveld, itølge NTNU og Sintef.

Ida Grieg Riisnæs

n innebarer at utalig

osent, og sto tilter for en fænde

Men fortuatt er det kull som produserer det meste av strømmen t Europa, og skal EU ob indlene for 2030, må svært mye kullkraft fases ut til fordel for store mengder tw nn energt.

- Tyskland vil tronge en backup

som raskt kan kobles ten når det tikke er sol eller sted. I de aller fleste scenarior vi har regret på, vil det være klart billigere å bygge ut vannkraft i Norge som overfæres til Tyskland, enn å begge lokale gasskraftverk i Tyskland som kan skrus tuskt av og på, ster NTNU-professor Magnus Korpås.

Rillie à doble

Forklaringen ligger i at gassturbt-ner er billige å liygge, nien dyre t drift, mens med varnkraft er det motorie. Med on how and of forms bur kraft i Tyskland, vil gasskraft-verk bit stående mye at Be, noe som vil gi en svært høy marginal-

Samenen med forskere ved Sta-tef har NTNU professoren bereg-netat Norge kandelske vanskraft-kapastieten ved å bygge nye tun-noler, generatorer og pumpekraft-verk, samt testallere mer nett og mer ttillegg til de regjeringen sylig kar vedtatt.

Dette vtl kreve tovesperinger Korpia amilir til mellom 100 og de vil ua noett være snakk om 200 militæder kroner, men han inneser det vil bit mer læmsom til de en dolsting av kapanistens daumerfornyhar energi som hans

Vannkraft | Europa

 Halvparton av Fursy varefraftikassestet er I Norge or dot at stort autnyttet potensial ved pumper venn opp igjen i gumpaliralit. Svenge har mer agan i nord, men dette lagger langre unna Furopa og vil hit dynere enn fra Sør-Norge. Tyrkse

Studien

Et samarbeid mellom forskere ved NTNU, Sintef og

sconarior hazart nã framskri norning are solding spans on CO'sprison.

Berognut på 12 kraftserk i
Ser-Norgo, hvor det forutsettes
at det bygges nye kraftserk og
tanneter, og at det rivstatteres.

pumpokraftverk ved oyv av dem.

Det or forutsatt at oksport av Dat är fonstaat at öksport.
 kraft filke skal gå på bekontne av levening av leraft innenland
 Konkluderer med at Norge kan ekoportere belensekraft til Europe i flere uler av gangen uten at vannstanden synker under regularingsbestammel

branspen er vant til store tall, og

inn. Det er ogentlig fikkernye. Sepå hva vi tiener på vannkraften hvert overskudd des, som igten kan bru-

FORSKNINGSNYTT FRA NTNU OG SINTER

Teknologi Energi og miljø Naturvitenskap Fisk og hav



I framtida kan norske vannkraftmagasin bli viktige når det ikke blåse blåser igjen, kan billig overskuddskraft brukes til å pumpe vann tilba

Norge er Europas billigste l

Norsk vannkraft er den rimeligste energikilden Tysklan solceller og vindkraft, viser ferske beregninger.

må ha tilgang til strømkilder som kan kobles raskt inn når s Magnus Korpås. Han er vitenskapelig rådgiver ved SINTEI

Sammen med kolleger fra SINTEF har han det siste året re koste å dekke Tysklands back-up-behov. Forskerne har be

Mbredfesbifes Onedag 3. juni 2015

FNs klimapanel

195 land er medlem av FNsklämapanel (Intergrevernmental Panelor Climate Change, IFCL3. Merenn 800 eksperter fra 85 lander panelets inglige ryggrad og forfatter rapportene. Medlemslandene og andre kan nominere forfattere til panelet. Forfatterne velges av panelets byrå, som hestår av 31 eksperter og forskere. Klimapanelet driver ådse med egen forskning, men gjennomgår faglitteraturen innen klimaforskning og systematiserer og oppsummerer status for kunnskapen

Kronikk Knonådoer kom være

inntil 9500 tegn inidusive Legg ved et bilde av god teknisk kvalitet avkronikk forfatteren og send til leronlek@adressesvises.no «Det overveldende flertall av det norske folk anser religion for å være et personlig anliggende uten mellomfolkelig konsekvens.»

Ordet fritt, neste side >

FNs klimapanel lanserte sin femte hovedrapport før jul. Der stadfester panelet at det er ekstremt sannsynlig at menneske skapte klimagas sutslipp har forårsaket over halvparten av den observerte temperaturøkningen de siste seksti år.

Viktig rolle i et fornybart Europa



m chak for hill ned undippene, oker phvirkninger på miljø og EU leder an i sassingen på

fornybar energi. I rapporten legger paneles soor veks på hva som må til for å unngå de verste konsekvensene. Dette vil si hvordan vi skal klare å holde den globale umperatur-okningen på under 2 °C frem mos år 2100. I flervalles av disse somariene må andelen av 30 prosent til over 80 prosent

ress spor. For & oppnå EUs måll om et lækarbonsam/unn innen 2050, kreves en forrebarandel krafiproduksjonen på mellom 65 prosens og 96 prosens. Deue avhenger av hvilkes av kommisjonens seenarier som legges al grunn. Elektrisises som energibærer kommer til 4 spille en stadig større rolle og bide innen oppvarming, kjøling

og sranspors. Tilserekkelig fleksibel kraft blir en unfordring. Når store deler av krañforsyningen i Europa skal bli dekkes av vindog solkraft, blir deres varterende produksjon en utfordring våre saropeiske wenner må hanskes med. Dever ikke últsrekkelig å home energien når vinden. også ha kapasiser silgjengelig

for å dekke sie krafibehov på

løsninger som kan bidra ell å masche forbruk og produksjon i et krafusystem dominert av solog vindkraft. Noen av disse skala allerede i dag, mens andre fremsidige konsenser. Oks. autynelse av dernorske førsse kasegorien. Ved å øke effeksen på vannkrafsverkene kan vi ciffer mer kraft pår overskudd av vind og sol så kan vi holde ig jen vannes, og på den måsen lagre energien på en effeksiv måse. Ysserligen fleksibiliser oppnår vi ved å bygge us punipékraliverk

mellom eksisserende pumpois afth aparitet or mulig og nødvendig. Les forprosjekt rjennomárn i lere mulige effeks- og See Norge blin identifisers, som samles vil gi en MW. For alle krafwerkene, inkluden numnekrafeverkene. er des snakk om å umyste eksisserende magasiner, men å

gjøre andre større

begynner uansen å dra på

-Elektrisitet som en ergibaer navarinngrep. Den samlede vannkrafskapasisesen i Norge i dag er i overkans av 30 000 MW. til å spille en stadig

ikke lenge. Da er des viksig as kraftserkene samsidig tilpasses en framsidig bruk med mer behov for kapasises og pumpekrafs, som nasurlig nok er forskjellig fra des de ble bygger for. De forestline nye usbyggingene vil ikke føre al øks kraji produkcion samles seupåvirke av as des bygges nye runneler og kruftseasjoner. Det de derimot bidrar til, er å gjøre

mer krañ eilgjengelig når des er men behov for den. Samudig som vi sar vare på overskuddskraften. Og denne ekstra fleksibiliseren vil bli salgbar vare i es fornybars Europa.

europeere, må krainessene nies senere sammen. Saunen fikk nylig konsesjon for 10 nye usenlandskabler på 1400 MW hver, en til Tyskland og en til Storbriummia, Deue er et viktig skrimpå veien. Selv om det i dag er overkapasion på krafiproduksjon i EU, forvenser des insernasionale energibyrdes (IEA) at rundt 250-000 MW sermisk kraft (gass-, kull og kjernekraft) vil bli faset ut inn 2035 pk grunn av levealder srengs 100 000 MW ny sermisk kraft i EU for å sikre ullstrekkelig rilgjengelig kapasises for å dekke forbrukes når des er

iden nodbøren neppe lar seg

mangel på vind og sol. Norsk vannkran blir aseraksiv vare i Europa. Len ny sendie som på den europeiske

mengder vind ogsol påkontinentet, må det betydelige investeringer til i kabler nett og kraftsta sjoner, skriver kronikkforfatterne. krafenarkedskonferansen EEM

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2015 (www.eemi5.com), har viregner på kosenadene for å bygge ut ny ficksibel kraft i et fremodig Europa dominers av vind og sol. For as norsk vannkrań skal kunne bulansere» store mengder vind og sol på kontinenter, mi Tross disse ekstra kostradene commer fleksibili nonk vanakrań gunosig us sammenligner med kosenaden for fleksibel gasskraft på konsinenses, Desse skyldes i ovedsak lave driftskosmader lang leverid, god reguleringsgrad og høy virkningsgrad.

Sale omvisor at de tiye urvidebene kan ware til det besse for samfunnes, så er vi klar over as averanden kan være nor derira til sange inveseringsbedunings Rammebeningelsene for urbyggerne må være forungbure og norsk vannkraft må sikres full ulgang til de europeiske kraftmarkedene. De to viktigste forusseningene er as polisikerne endelig sar klimapaneless advarsker på alvor, og as EU står fass på sine 2050. Gián de des kun Nonre spille en besydelig rolle i å realisere et europeisk lavkarbonsamítann, og samúd tjene penger på des. Hvis vi vil

Av Svein Tønseth

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- Tyskland har fått mye sol- og vindkraft inn i energisystem

for to konkurrerende løsninger:

WP 2 in brief so far

- Balancing cost comparison PHS vs Gas
 - EEM 2015 paper by Korpås, Wolfgang, Aam
 - MSc Thesis Hanne Ommedal
- Cost comparison of energy storage options in progress
 - PHS, Batteries, Power2Gas, Flywheels, Compressed Air
- PhD-candidate Ingeborg Graabak started sep 2014
 - 2 papers submitted
 - "Variability Characteristics of wind and solar power resources a review with focus on Europe"
 - "Balancing of variable wind and solar production in Continental Europe with Nordic hydropower A review of simulation studies"
- Simulation study of PHS wind power smoothing
 - Guest researcher Nicola Destro, Univ. of Padova
- Several media contributions and public presentations on the role of Norwegian (pumped) hydro in the future European energy system

