

A composite background image showing a coastal town with a bridge and buildings on the right, and an offshore wind farm with several turbines in the water on the left. The sky is blue with some clouds, and a small airplane is visible in the upper left. The overall scene is a mix of natural and industrial elements.

IS BALANCING FROM HYDROPOWER A FEASIBLE IDEA

RIGA 2017-12-07

Research Manager Michael M. Belsnes



A FEW WORDS ABOUT SINTEF

One of Europe's largest independent research organisations and not-for-profit



NOK 3.1 billion
Revenues

NOK 450 MILL
International sales

Technology for a better society

Strongly linked with NTNU



Background

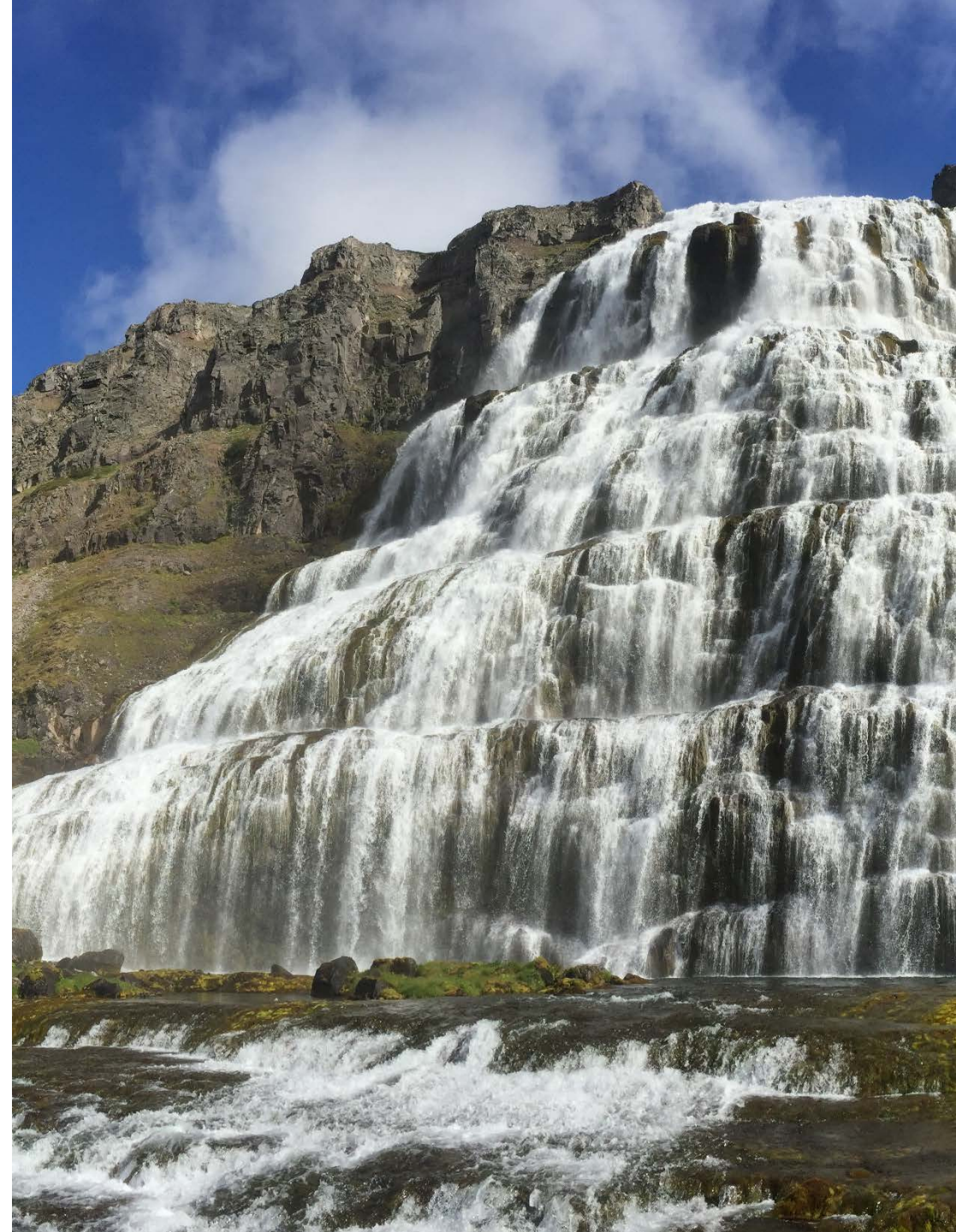


**FME CEDREN
2009-2017**

CEDREN HydroBalance

(2013-2017)

**Research Manager Michael M. Belsnes
Ingeborg Graabak, Ove Wolfgang, Magnus Korpås,
Magnus Askeland, Arild Henden**



UK to run without coal power for a full working day, in historic first since industrial revolution

A decade ago, such a transition would have been 'unimaginable'

Andrew Griffin | @_andrew_griffin | 5 days ago | 42 comments



5

Smoke rises from the cooling towers of Cottam coal-fired power station, owned by EDF beyond a field of rapeseed near Darlton, east England
OLI SCARFF/AFP/Getty Images

From Independent, Friday 21th April

- CO2 price in UK for power industry is +18 £/tCO2
- Shift from coal to gas
- More wind and solar generation

Kriegers Flak project demonstrates rapidly falling costs for offshore wind



© VATTENFALL

Offshore wind bids – no subsidies

- Kriegers flak (Denmark) – 5 €cent/kWh (45 øre/kWh) won by Vattenfall in 2016
 - Size 0,6 GW
- Gode Wind (Germany) - 6 €cent/kWh (54 øre/kWh) won by DONG in 2017
 - Size 0.11 GW

Changing the business: Solar power bids

- Autumn 2017
 - Saudi Arabia at 1,8 cents/kWh
- Spring 2017
 - Dubai solar at 2,99 cents/kWh
- What if multi spectra panels are developed?



Saudi Arabia Gets Cheapest Bids for Solar Power in Auction

By **Anthony Dipaola**

3. oktober 2017 15:19 Updated on 3. oktober 2017 23:00

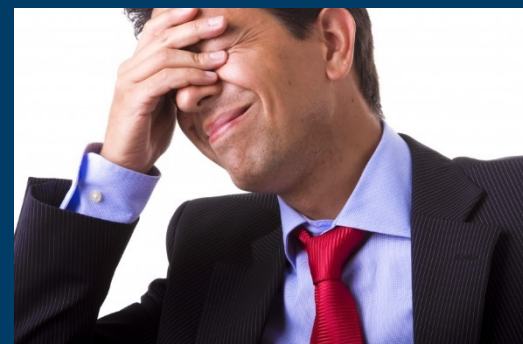
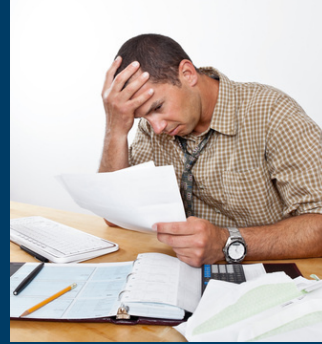
From **Climate Changed**

→ Masdar, EDF offer to supply power for 1.7 cents/Kilowatt hour

→ Plant to be first in \$50 billion plan to expand renewables

Saudi Arabia received offers to supply solar electricity for the cheapest prices ever recorded, marking the start of a \$50 billion program to diversify the oil producer's domestic energy supplies away from fossil fuels.

The energy ministry said Abu Dhabi's Masdar and Electricite de France SA bid to supply power from a 300-megawatt photovoltaic plant for as little as 6.69736 halalas a kilowatt hour, or 1.79 cents, according to a webcast of the bid-opening ceremony on Tuesday in Riyadh. If awarded, that would beat the previous record for a solar project in Abu Dhabi



- What if energy prices become zero?
- Will hydropower have any value at all?
- Is there anything too "balancing from hydropower"?

26 **Debatt** Mandag 30. mai 2016 | Dagens Hæringstidning

I fremtiden kommer det til å komme over av solenergi i det aktuelle halvindustri, og det er nesten bare dårlig vær, dårlig planlegging og dårlig styring fra EU's tryk side som kan bidra til at Norge kommer i en unik eksportsituasjon i fremtiden. Foto: Erlan F. Eldingvåg

Ulønnsomt strømsalg

Strømprisen kan i lange perioder bli lavere i europeiske markeder enn i Norge. IEAs gjettninger tar for lett på teknologitvillingen.

Innlegg Geir Reigstad

Det Internasjonale Energiforbruket (IEA) og Nordisk Energiforskning varsler høyere strøm etter 2020 være for Norge. Proforskjellen mellom norsk vannkraft og tryk solenergi blir meget lav, om noen.

Et scenario basert på dagens etablerte og stadig økende fornybare produksjonskapasitet er at den fremtidige strømprisen i lange perioder kan bli lavere i enkelte europeiske områder enn den er i Norge. Det er viktig å se for seg at prisforskjellen mellom nordisk produksjonskost og tryk produksjonskost for solenergi blir neppeverdig etter.

En stor andel av den totale norske eksport av strøm foregår i sommerhalvåret til Europa. I fremtiden kommer det til å komme over av solenergi i det aktuelle halvindustri, og det er nesten bare dårlig vær, dårlig planlegging og dårlig styring fra EU og tryk side som kan bidra til at Norge kommer i en unik eksportsituasjon i fremtiden men det skal ikke utelukkes.

Når IEA trekker utvillingstipset som strekker seg for de neste årene inn i fremtiden viser at man ser nye teknologier som lagringsmetoder for strøm med ett ord i et toorders oppslag i DN får seg en vakker feilten av spørsmål.

Legg et helt enig med Stein Lier-Hansen når han sier at IEA bedriver en gjetting om strømprisene.

Geir Reigstad, konsulent, tidligere selskapsrådgiver, direktør i NASDAQ OMX Commodities (Nord Post)

Cost competition: gas power vs. pump-storage

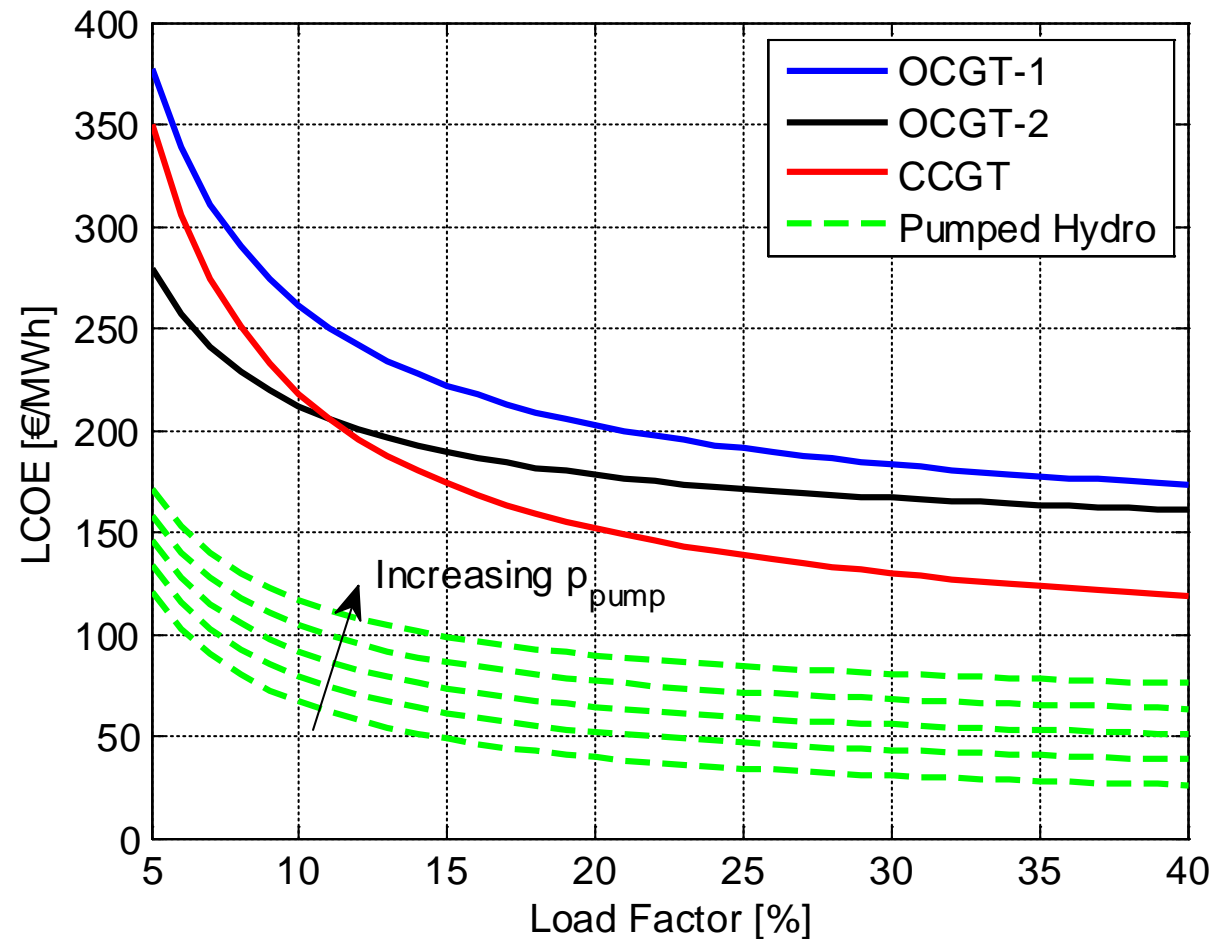
"Levelized Cost Of Energy (LCOE)"

Input data ref: 2040

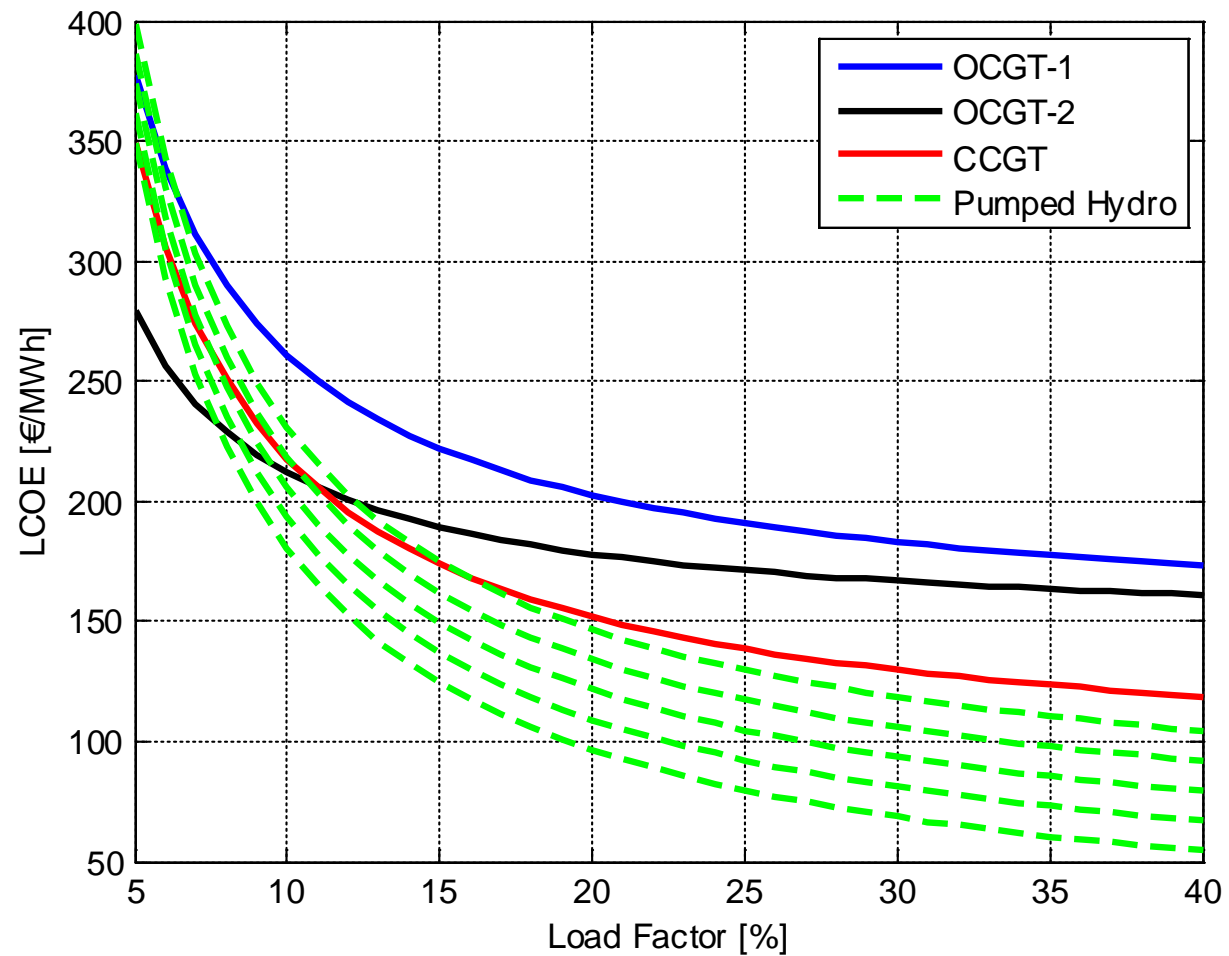
Based on IEA WEO scenarios and figures

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.



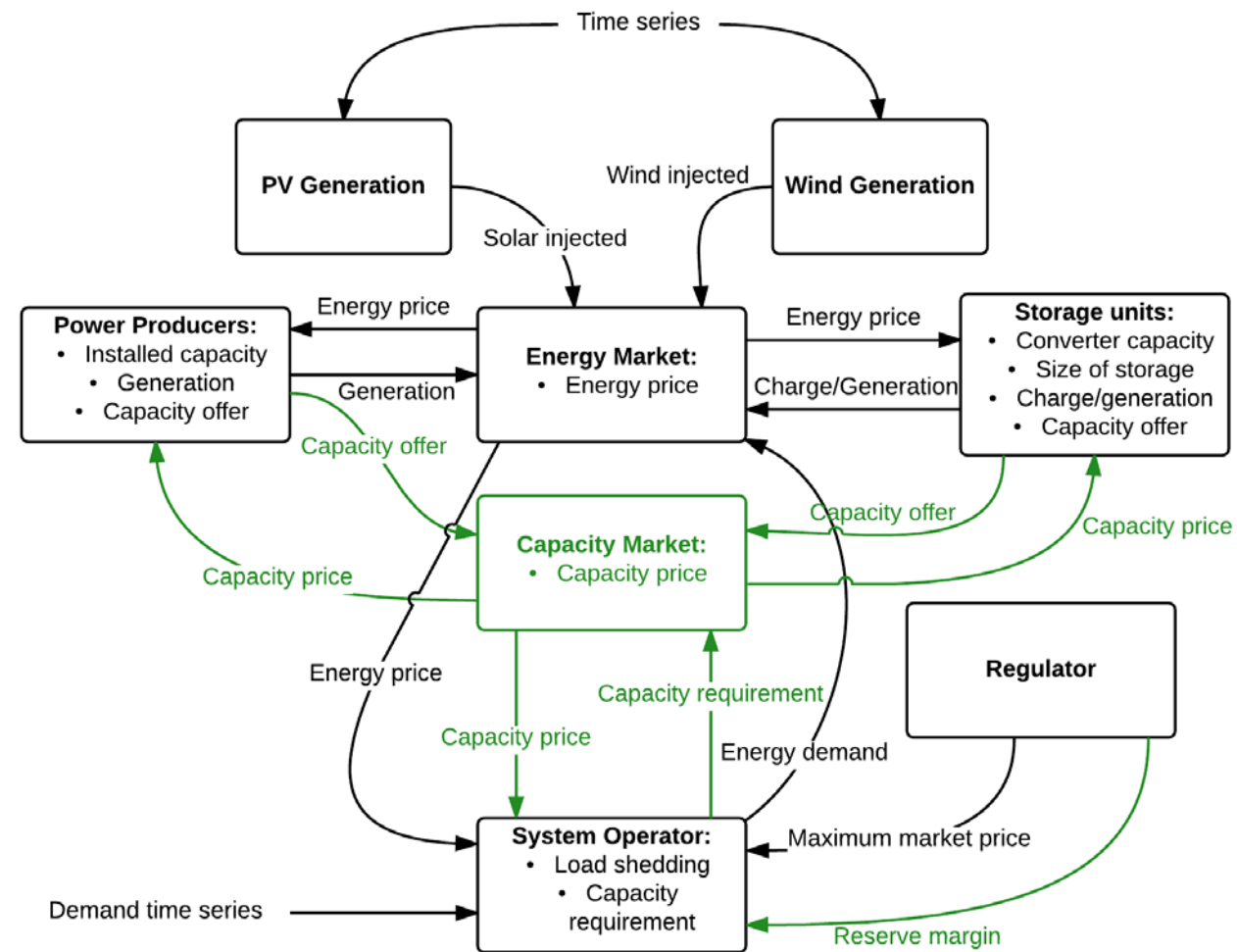
...even when grid and cable costs are included



Optimal power system - starting over

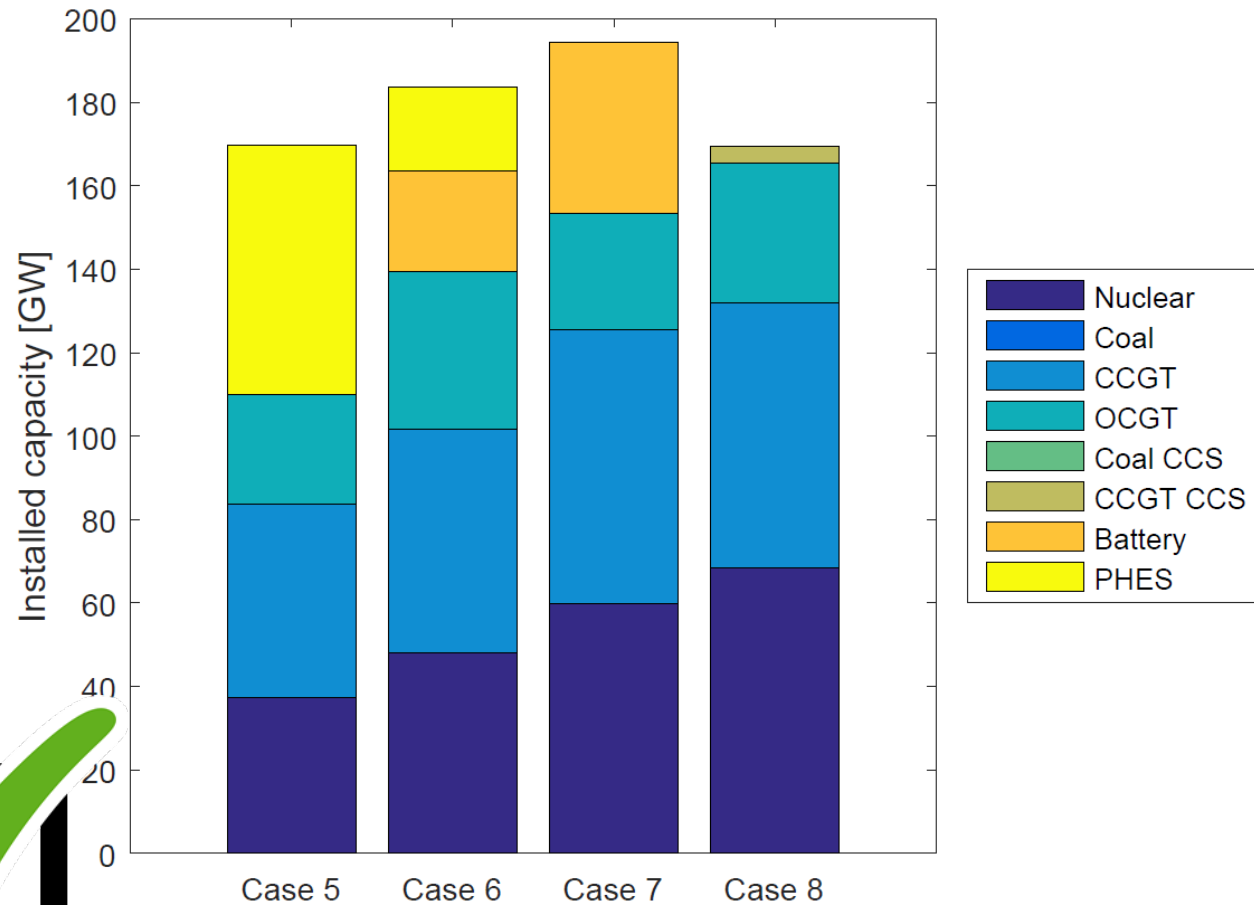
- Calculates the optimal generation mix for one deterministic year with hourly time resolution.
- Includes CO2 market
- Include demand side management DSM, constraints such as thermal ramping.

EQ-Model



Results: CO2 market

- Uses data from ENTSO-E and e-Highway assuming 80% RES in 2050
- Investment cost and variable cost for thermal units included
- Investment cost and cycle cost for energy storage included.
- **With a fixed CO2 quota, what is the consequences with different use of energy storage.**

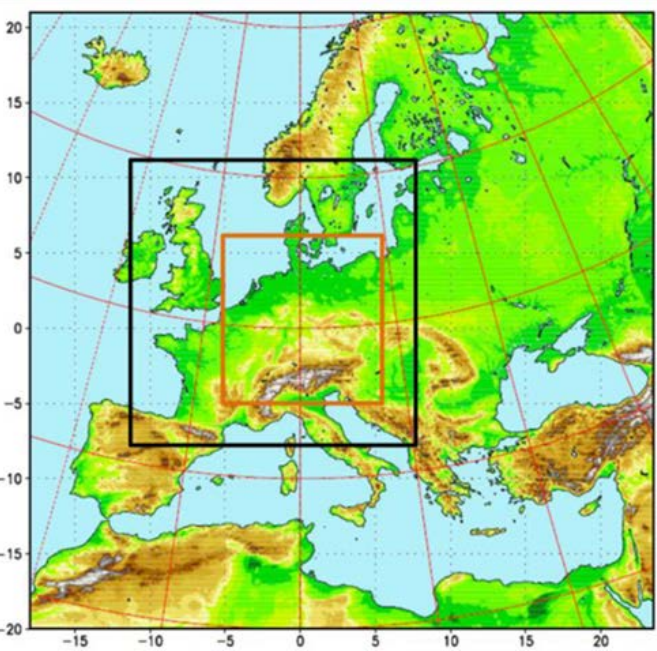


	Case 5 All	Case 6 Limited PHES	Case 7 No PHES	Case 8 No storage
Wind[MW]	372 618	345 922	332 852	372 495
Solar[MW]	146 091	220 570	257 036	146 435
Thermal[MW]	109 953	139 318	153 426	169 546
Battery[MW]	0	24 224	40 964	0
PHES[MW]	59 811	20 000	0	0
RES curt.[GWh]	45 021	84 178	116 394	159 666
Emissions[kton]	32 335	32 335	32 335	32 335
Tax[EUR/ton]	76	92	115	126

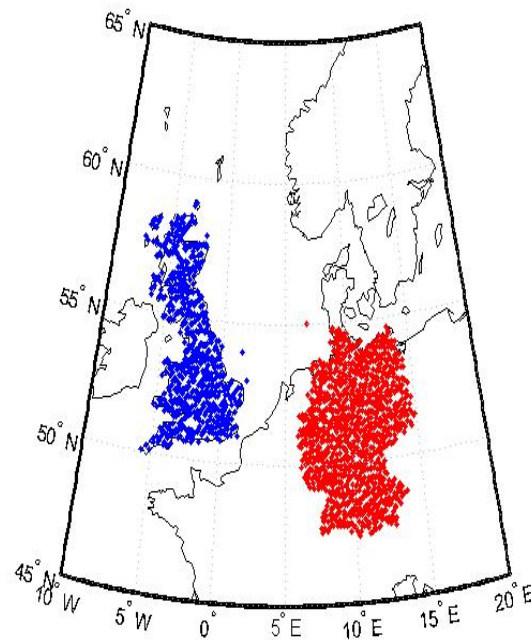
Demand for RES support from other sources

How to calculate output from wind and solar

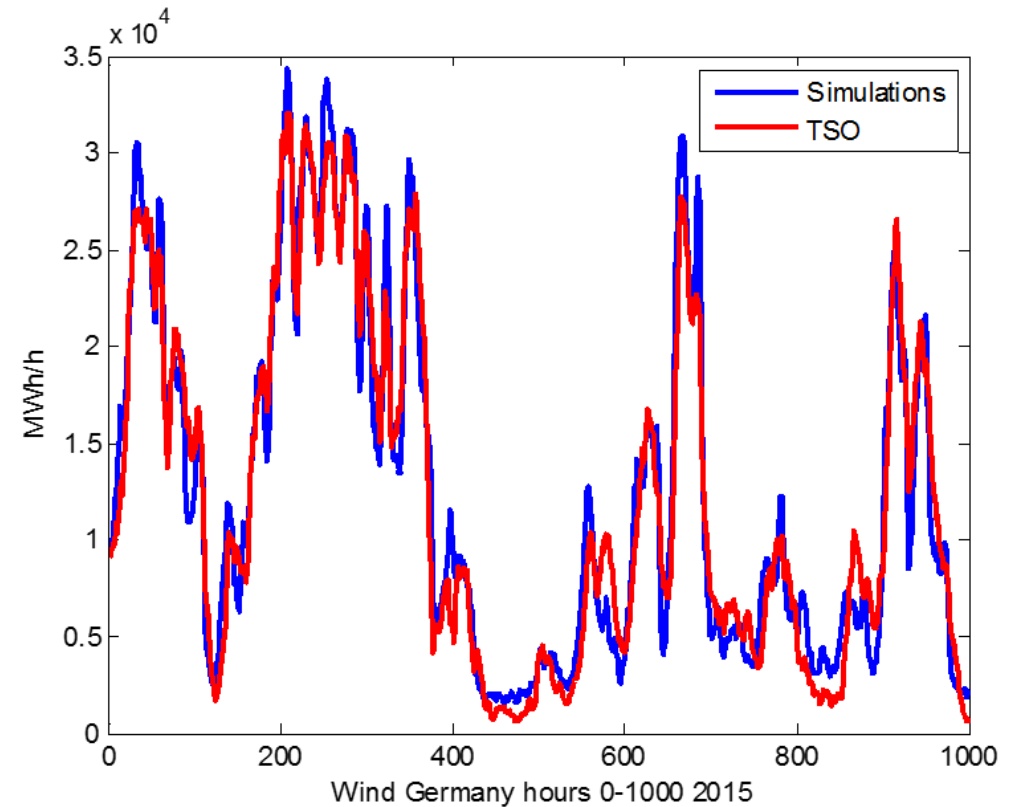
Data from COSMO EU



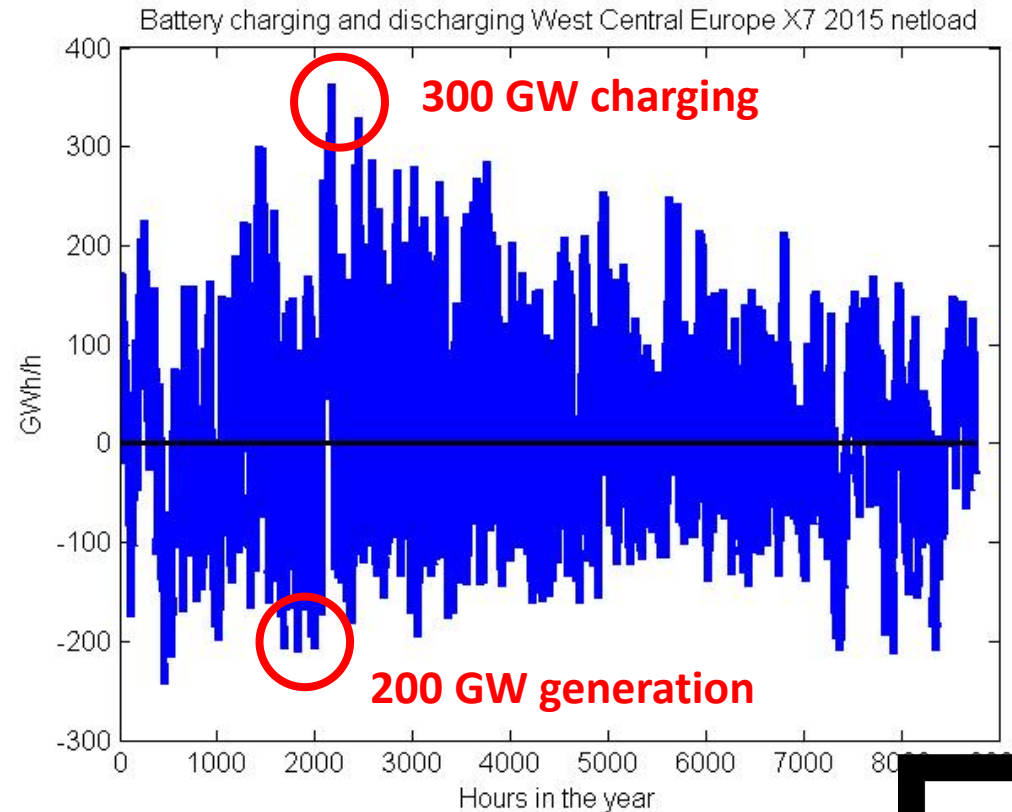
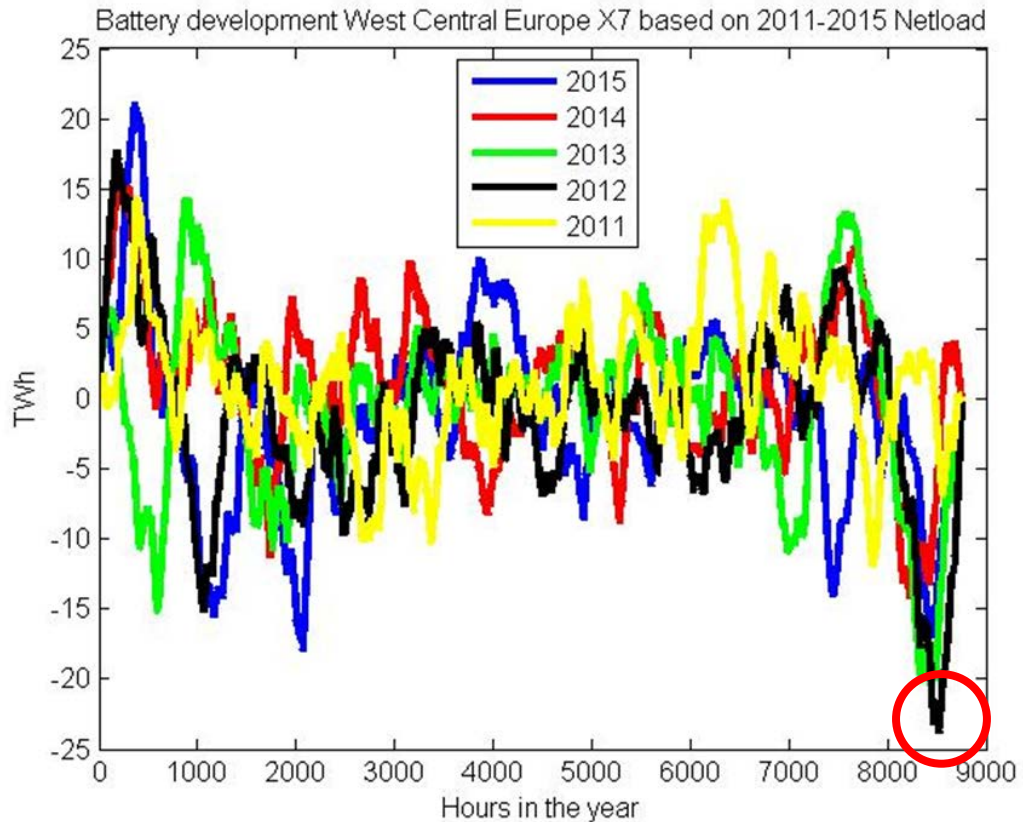
Location of wind and solar



Ability to reproduce real data



Quantifying the 2050 balancing need in West Central Europe

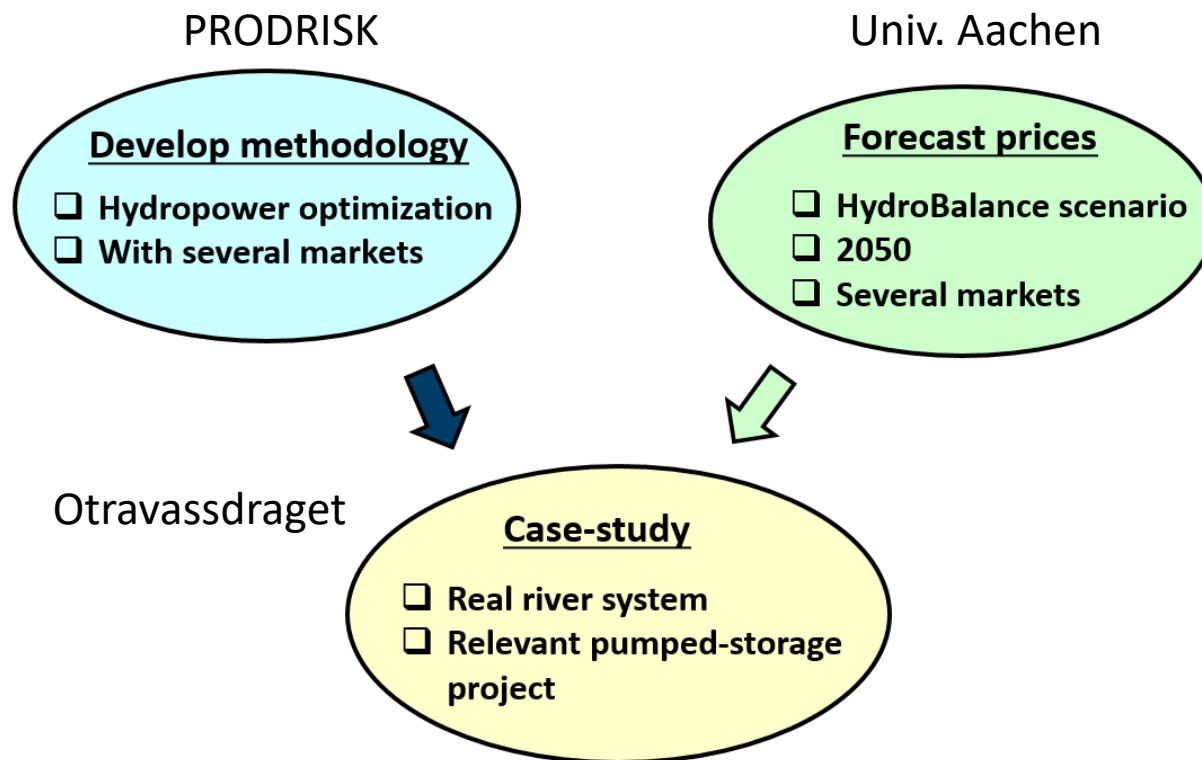


Includes: UK, Ireland, France, Benelux, Germany, West Denmark, Switzerland, Austria, The Check Republic and Slovenia

Assumes no bottlenecks in transmission system in and between countries

eHighway - X7: ~100% res, ~70% from wind and solar,

Can hydro competitiveness and balancing demand be transferred to revenues in a real system?



Price assumptions SINTEF, IEA-WEO and E.ON, adjusted EU trend study by the Commission (2013)

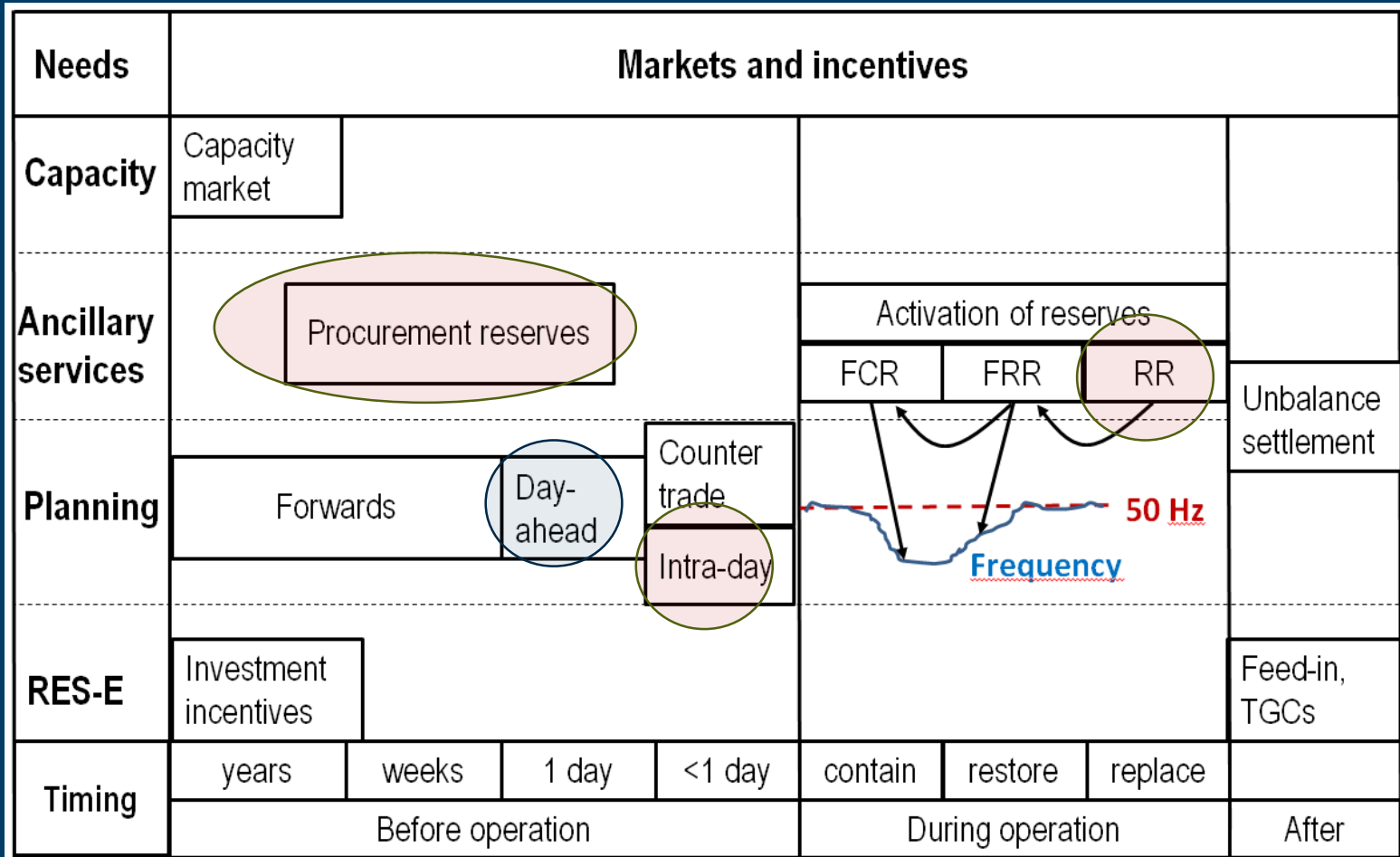
Price simulation (model: Schäfer et al. 2014) Procurement and activation of FCR/FRR/RR), Germany, 2008

OBS: One year of multi-market prices

Prototype model requiring ProdRisk

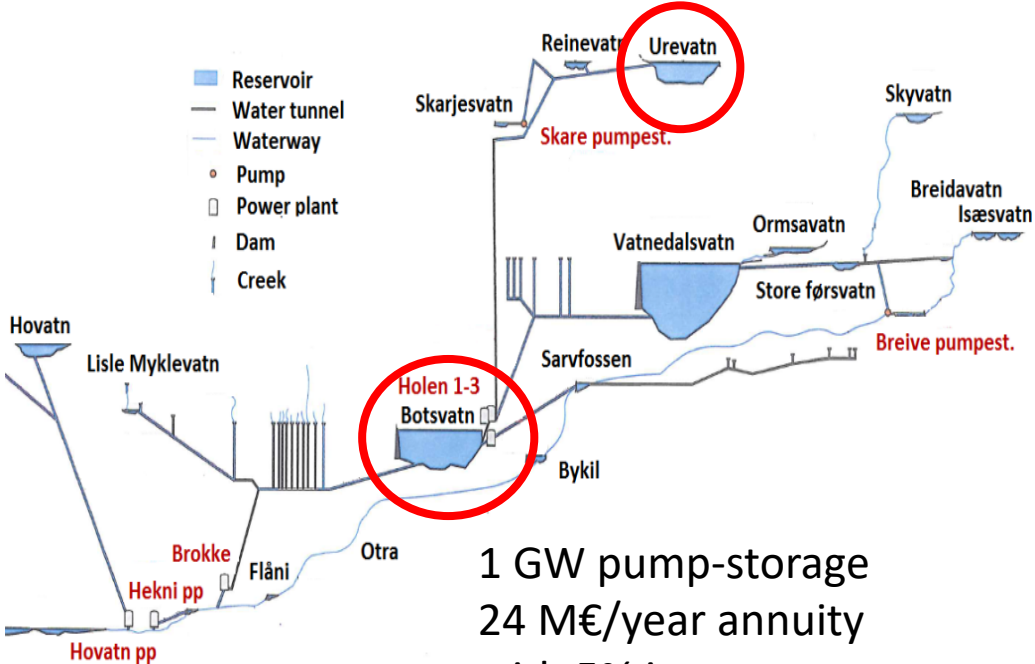
User manual, pay-as-take support

- Bidding in spot as if this is the only market.
- *Response* on new prices in subsequent markets.
- Iterative algorithm for reservation of capacity

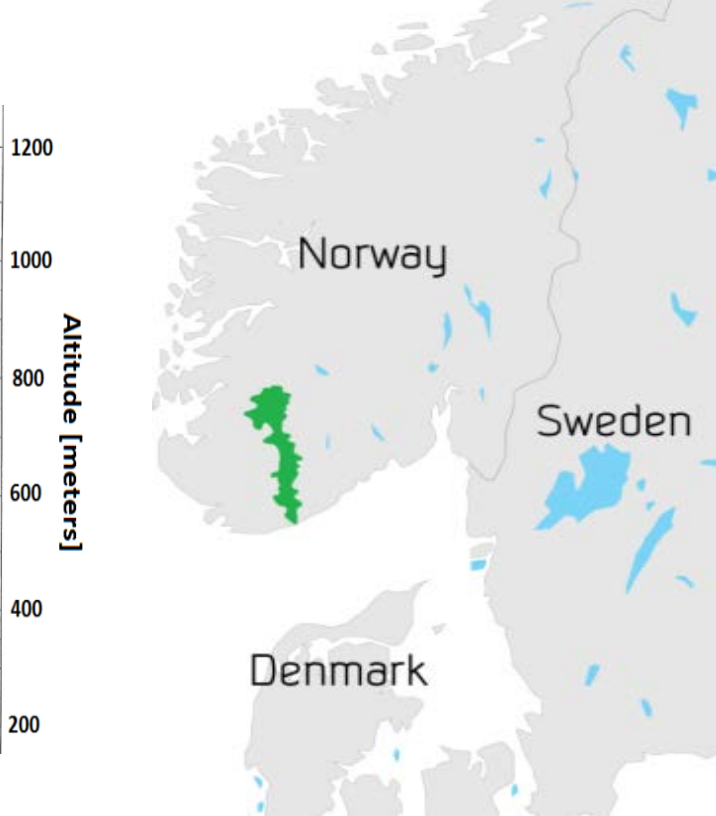


Case study: Pump-storage in the Otra watercourse

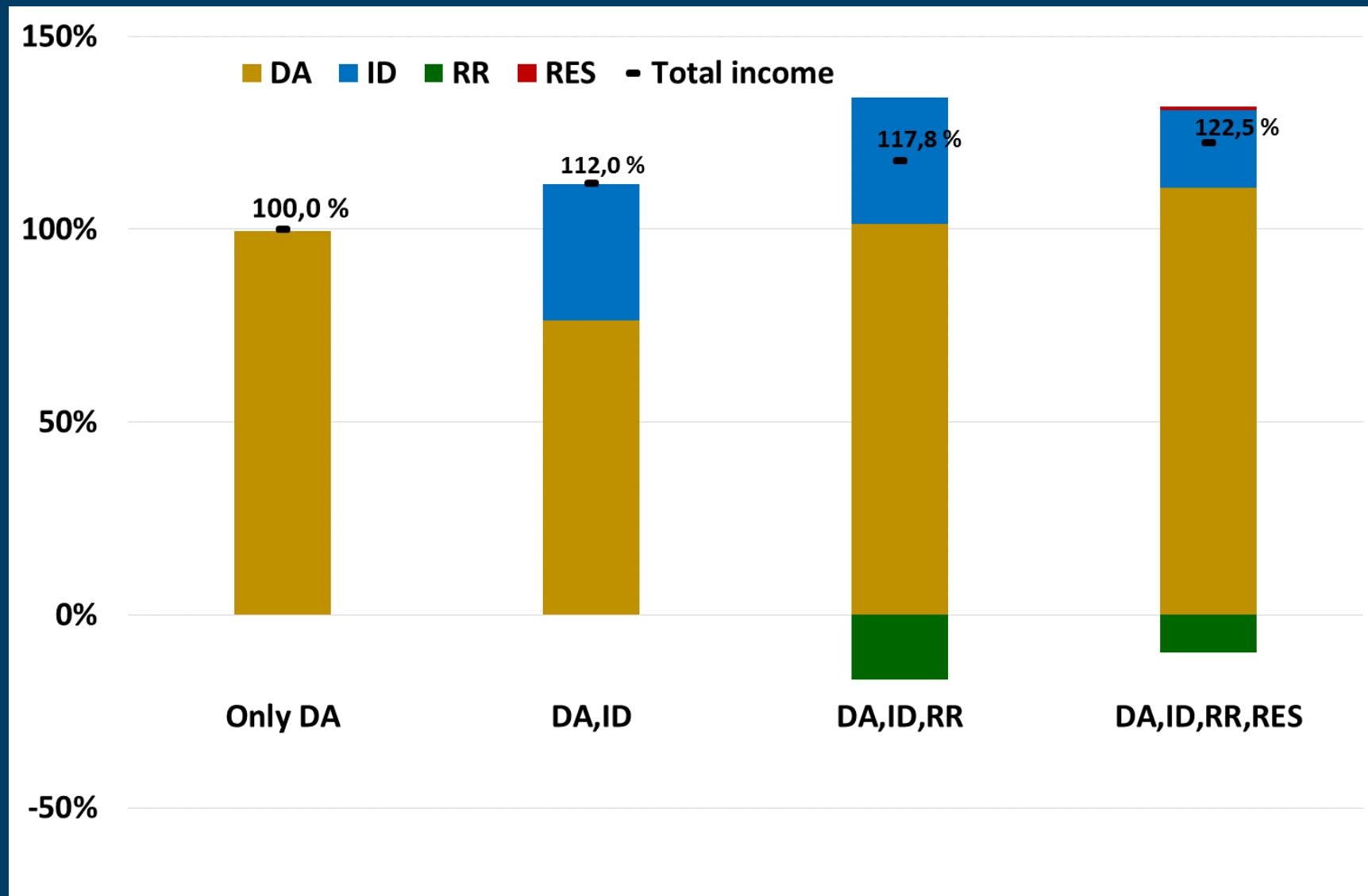
Contact person in Agder Energi: Trygve Døble



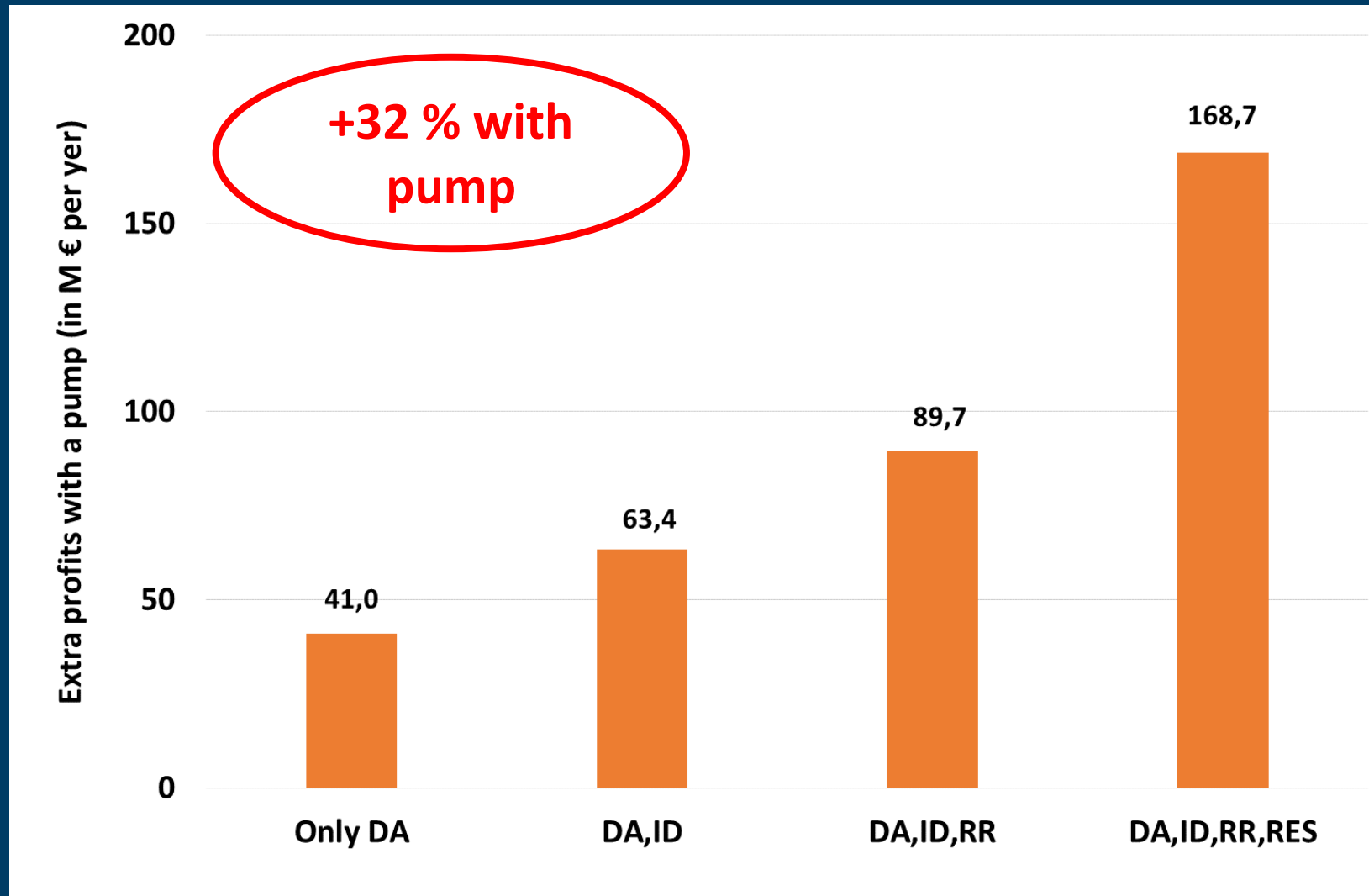
1 GW pump-storage
24 M€/year annuity
with 5% interest



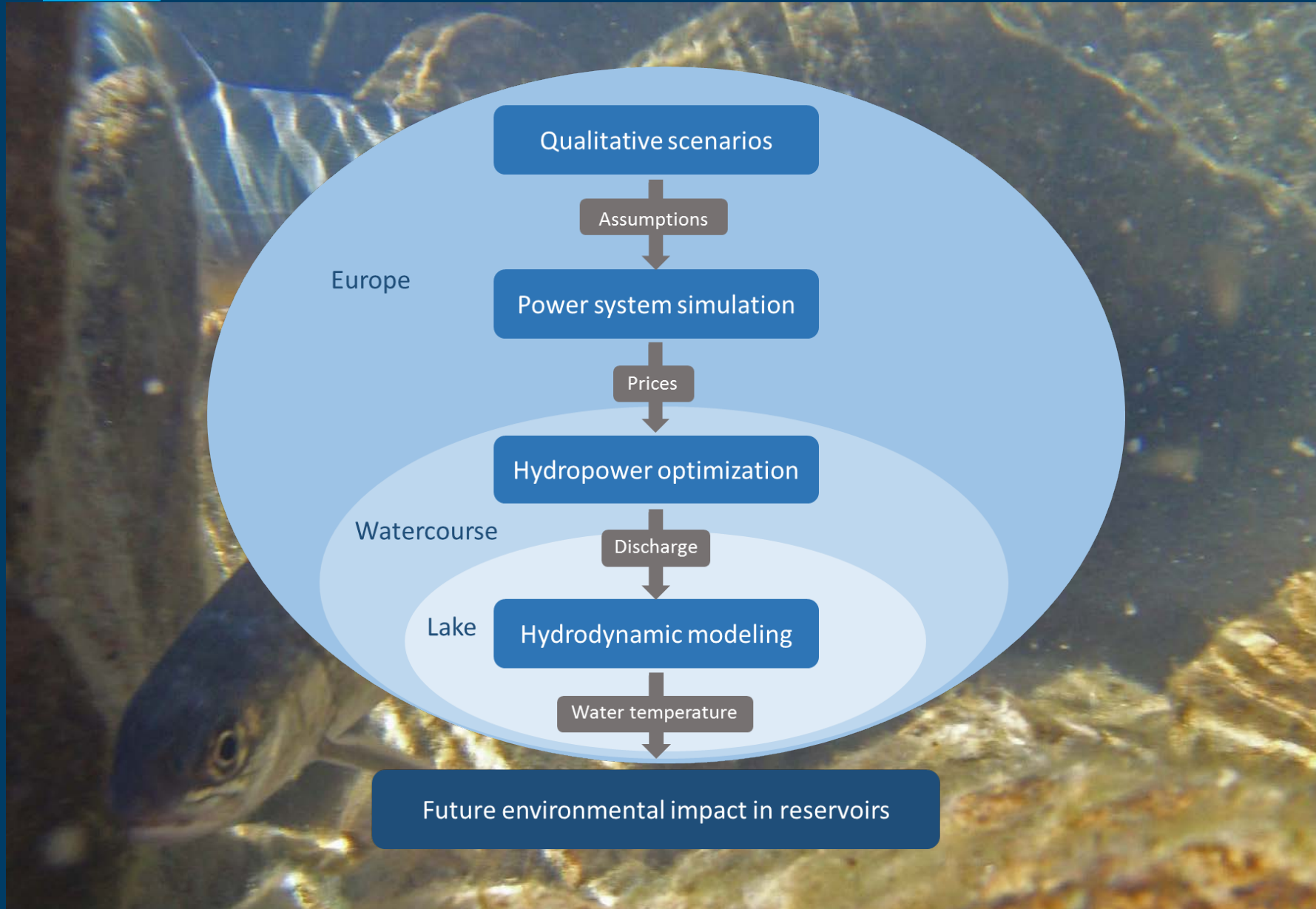
Revenues in different markets in Otra



Revenues from new pump in Otra



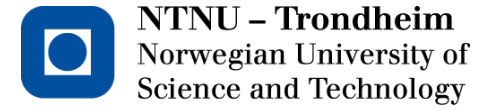
Ex. managing environmental impact



Social acceptance: The «need argument»

- If costs are taken locally while the benefits are nationally or globally → it will be challenging to build (local) community acceptance. Why here? Why us?



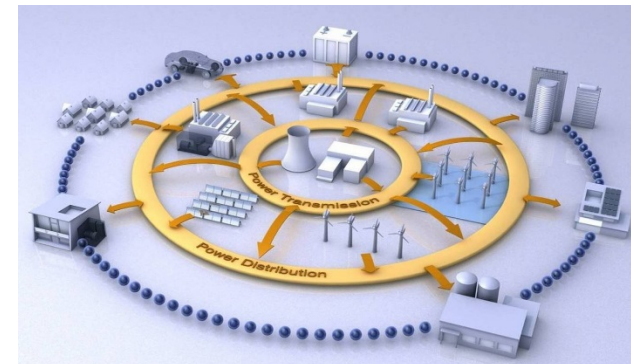


Challenges

- Minimizing operation and reinvestment cost of hydropower
 - Automation of operation and trading, new hydro technology, artificial intelligence.
- New operation patterns: energy to power
 - Extend lifetime, controlling state of equipment, climate change, water framework directive
- Energy transition – when to invest?
 - Policy uncertainty
 - Cost of renewables and cost of storage
 - Demand side flexibility: prosumers, demand , smartgrid, autonomous systems
- Environmental design particular in reservoirs

Germany:
Decom. 26
GW by 2021

Belgium:
Decom. 4 GW
nuclear by
2025





Teknologi for et bedre samfunn