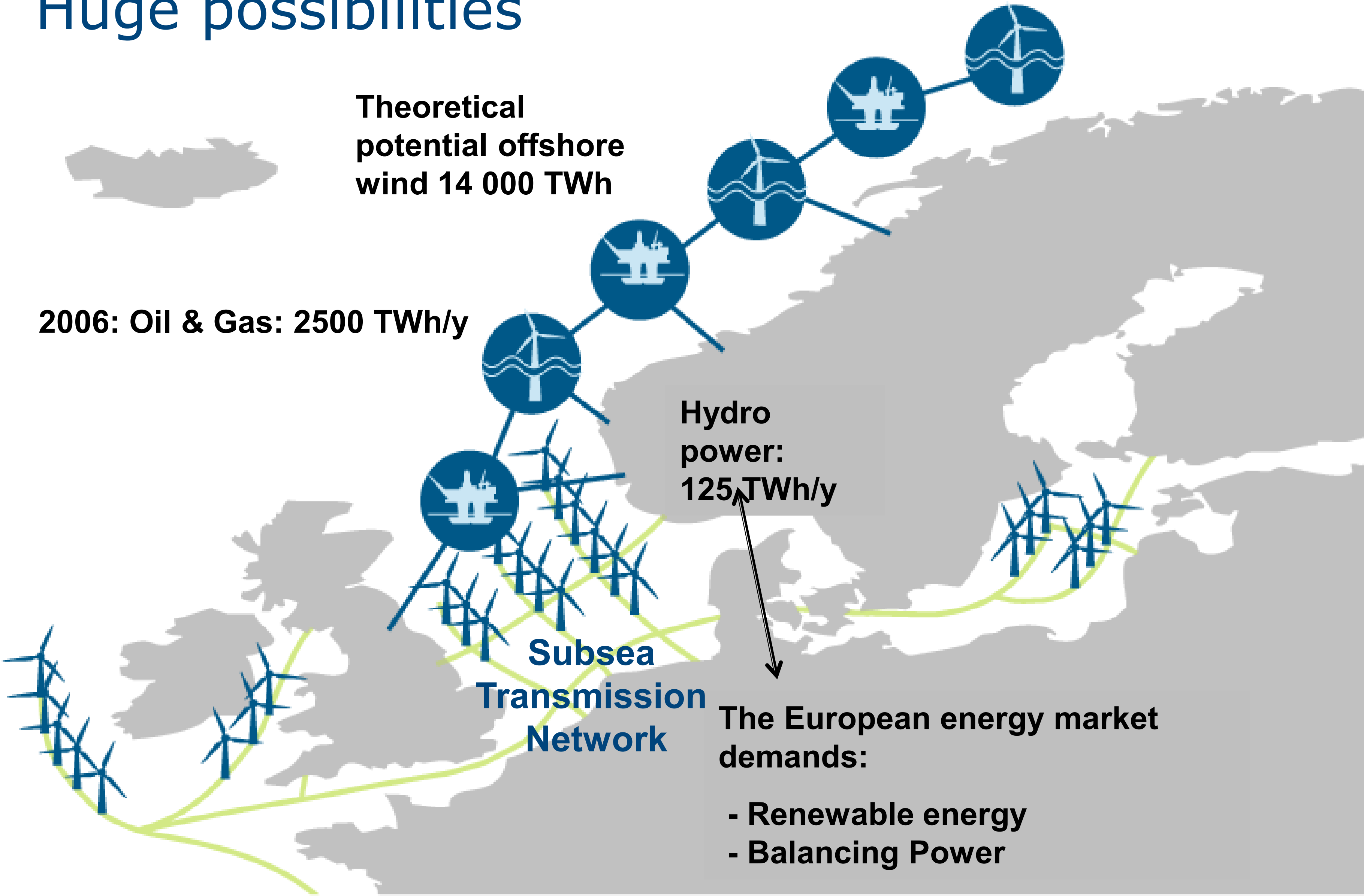
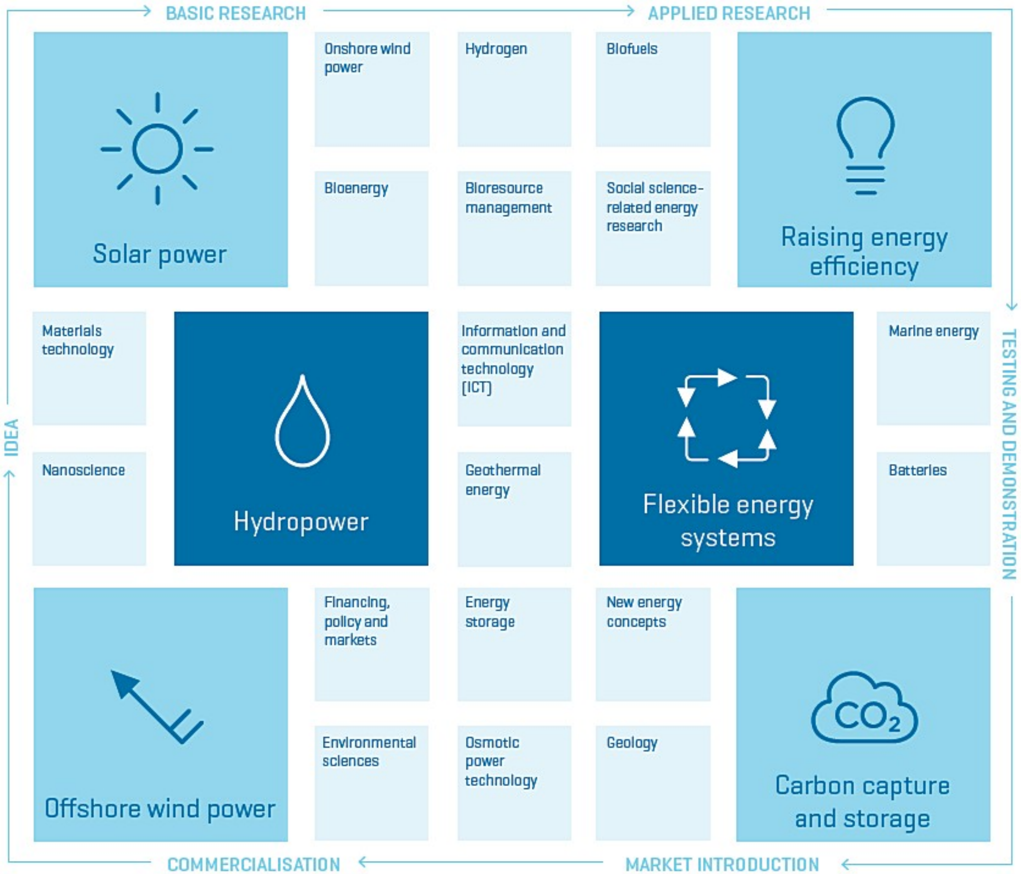
Huge possibilities

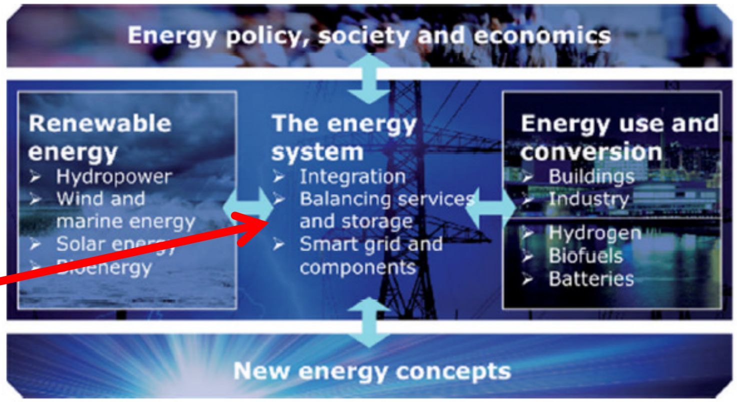




energi21

The Research Council of Norway

Programme: ENERGIX

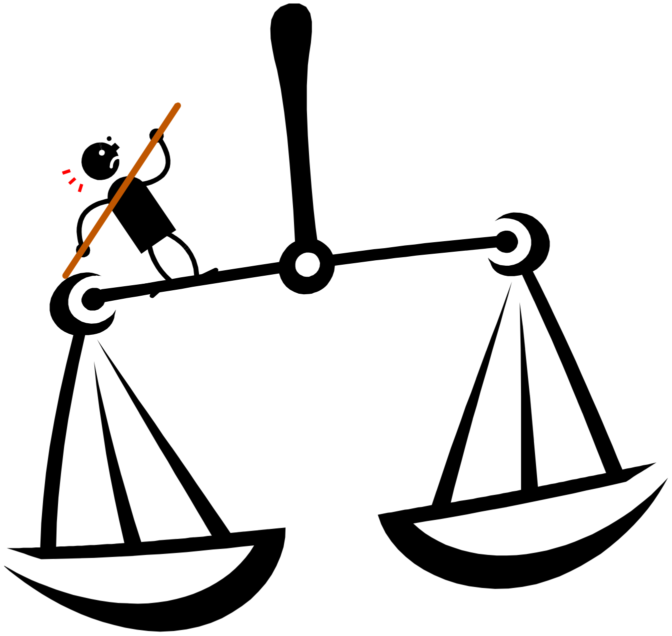


Balancing service and storage

Balancing so much more than just energy

Technology options:
- Large scale expansion
- Small scale expansion

Socialising the cost
- Revenues
- Costs



Security of supply
- Regional
- Cross border

Environment
- Local
- Global

CEDREN HydroBalance

Feasibility check regarding:
Technology
Economy
Social acceptance

By: Research Manager Michael M. Belsnes & WP-leaders

CEDREN HydroBalance: Facts

- Budget: 24863 MNOK, (17692 from NFR)
- Duration: 4 years
- Research partners (11)
  - SINTEF Energy Research, NTNU: Norwegian university of Science and Technology, NINA: Norwegian Institute for Nature Research, UIO: University of Oslo, University of Waterloo, ECN: Energy Research Centre of the Netherlands, University of Exeter, UMB: Norwegian University of Life Science, NIVA: Norwegian Institute for Water Research, Technical University of Madrid, University of architecture, Civil Eng. and Geodesy, Bulgaria, Univercity of Aachen (E.ON)
- Funding (10):
  - EnergiNorge, Agder Energi, BKK, Sira Kvina kraftselskap, Statkraft, Listerrådet, EdF: Electricite de France, E.ON, RCN: Research Council of Norway

CEDREN HydroBalance: Objectives

The project will address key questions regarding use of hydropower flexibility and expansion of such flexibility including pump storage development between reservoirs.

The project will draw a picture of the future for hydropower flexibility towards 2050 and assess needs for flexibility, alternatives to hydropower and required transmission capacity. How can and should the hydropower sector respond to the power system development in Europe? The project will assess and suggest business models in a Norwegian-European perspective.

Use of hydropower flexibility must go hand in hand with environmental concerns and the project will in particular contribute with new knowledge about consequences of reservoir level changes.

CEDREN HydroBalance: Technology

- WP 1:Roadmaps for balancing from Norwegian hydropower (Julian Sauterleute)
  - Assess the possibility space for balancing power from Norway towards Europe
  - Timeline for when, how and where Norwegian hydropower should respond

- WP 2:Demand for energy balancing storage (NTNU: Prof. Magnus Korpås)
  - Establish data models with
  - Time horizon for storage needs, interaction between markets
  - Includes a PhD scholarship

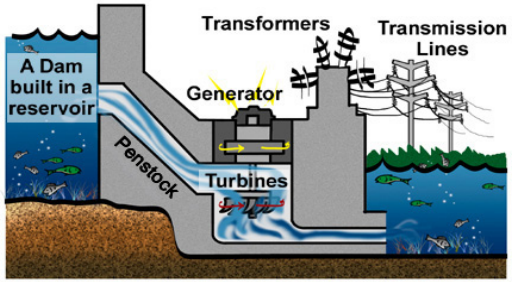
- WP 3: Analyses to develop relevant business models (Ove Wolfgang)
  - Possible business models for operation in different markets for balancing, including cross border possibilities.
  - Analyses of possible capacity projects, profitability and operation
  - Includes a substantial research cooperation with ECN

CEDREN HydroBalance: WP's

- WP4: Environmental impact of operation schemes for balancing (NINA: Ingeborg Helland)
  - Research task regarding environmental impact on reservoirs, size and type
  - Use CEDREN results for broad analyses of environmental impact and mitigation.
  - Includes a Postdoc scholarship.

- WP 5: Social acceptance and regulatory framework (Jørgen Knudsen)
  - Political barriers and success criteria for balancing power
  - Income distribution and socialization of cost, non technical challenges.

CEDREN HydroBalance



Environment

Technology

Society

NINA

NTNU
100 skapende år

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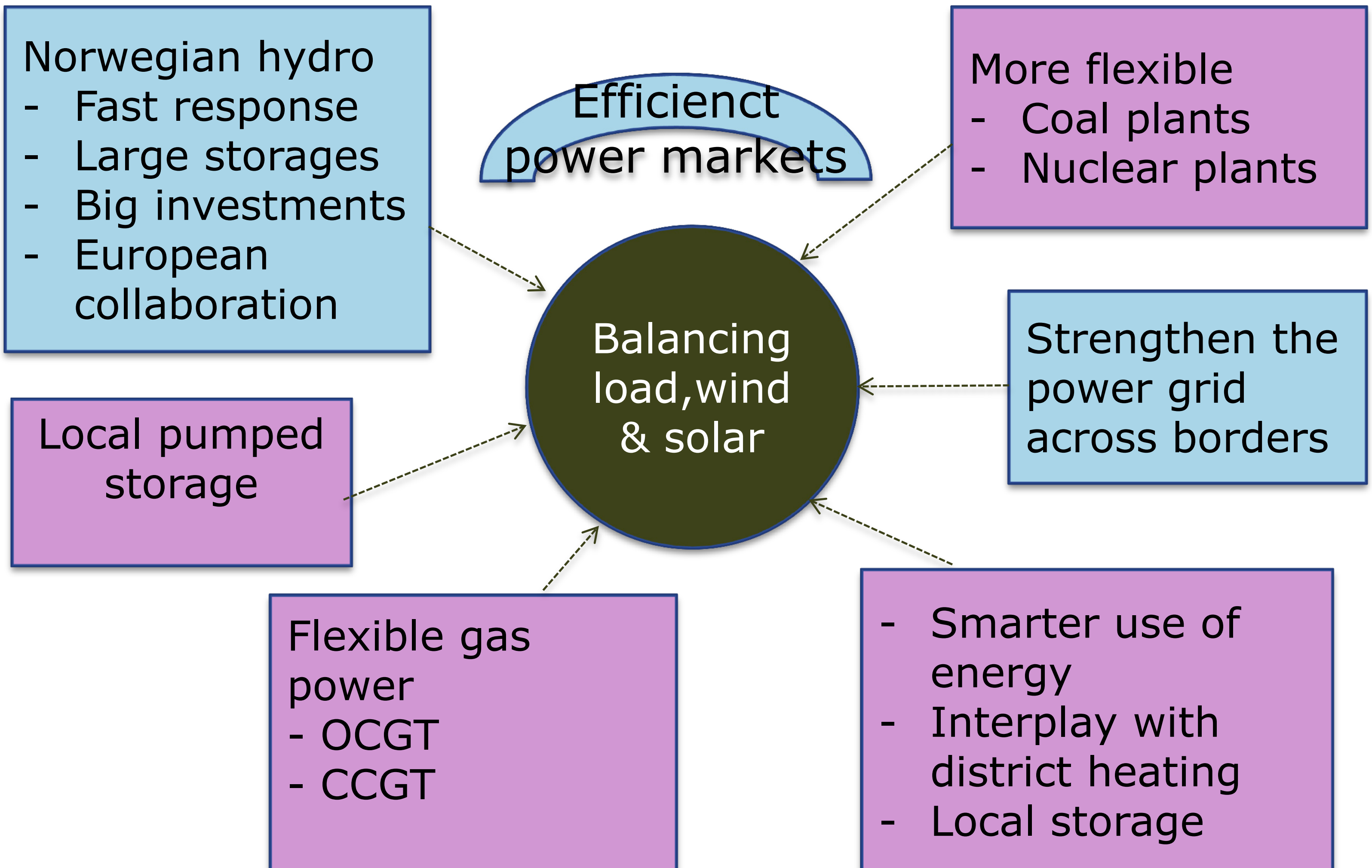
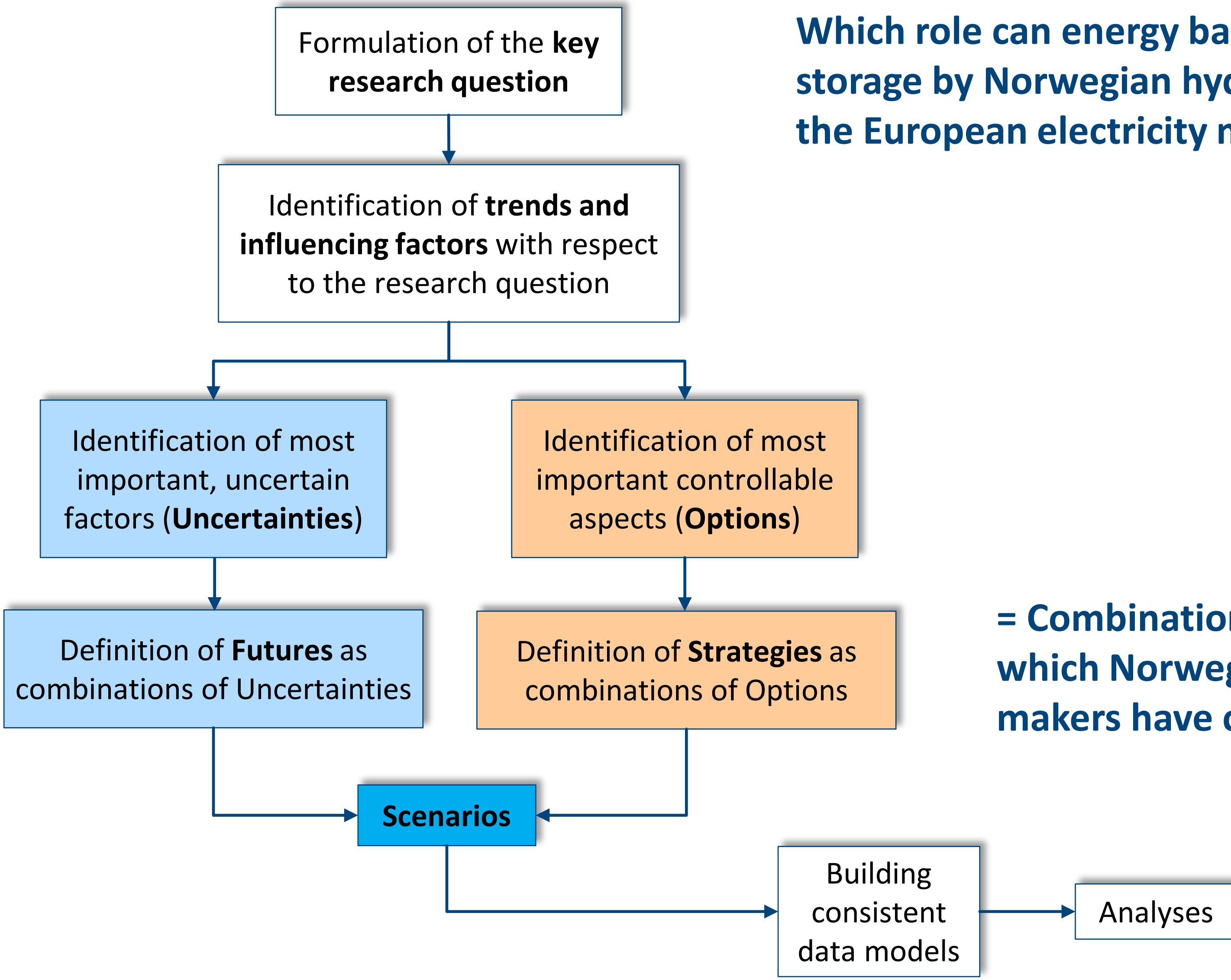
Balancing of renewables in Europe WP 1-3



Scenario building approach

Which role can energy balancing and storage by Norwegian hydropower play in the European electricity market in 2050?



= Combination of *Options* which Norwegian decision makers have control on

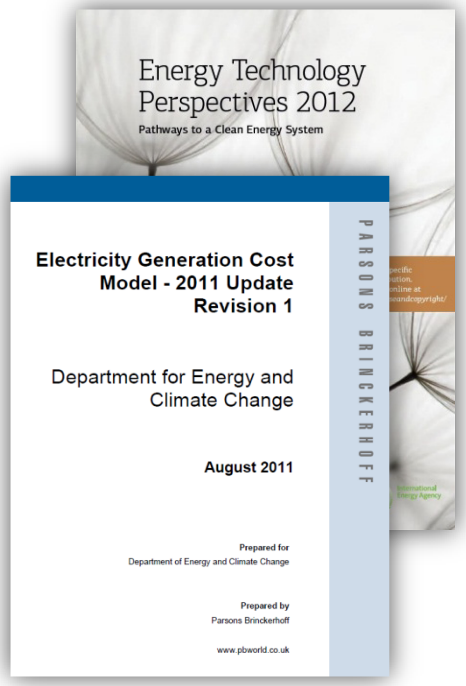
Scenarios

- Small hydro battery
  - Moderate ambitions to exploit Norway's hydro potential
- Big hydro battery
  - "Turning all stones" to provide balancing over all time scales.
- Long-term balancing only
  - Strong competition to hydro power from other technologies
- Nordic balancing only
  - High barriers on all sides also regarding interregional acceptance

Study of power production cost in Europe

- Only cost is considered
  - Market simulation not included
  - Assessment of the most cost-effective solutions in the near term

- In-house study
  - Time period 2025-2050
  - Based on IEA ETP scenarios and figures
  - Gas, Coal and Nuclear cost model according to report for UK Dept. of Energy and Climate Change
  - Pumped hydro storage and grid data based on Norwegian figures; NVE and Statnett

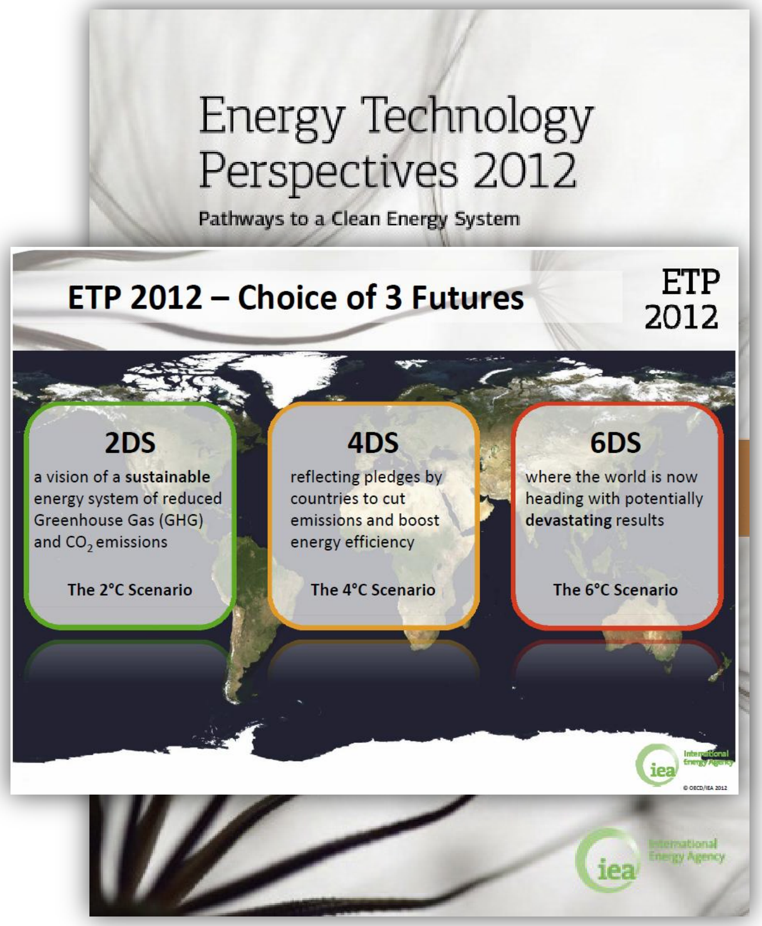


Three scenarios
2025 – 2050 perspective

1. 2DS – IEA 450 Scenario:
   - Gas price 29.5 € /MWh
   - CO_2 price 93.9 €/ton

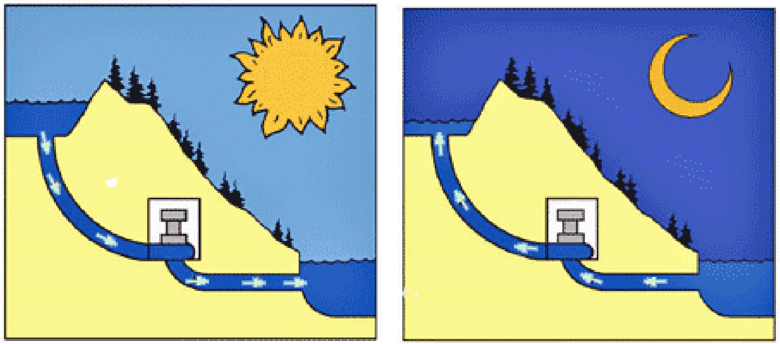
2. 4DS – IEA New Policy Scenario:
   - Gas price 34.8 €/MWh
   - CO_2 price 35.2 €/ton

3. Low Gas price Europe:
   - Gas price 19.7 €/MWh (USA level)
   - CO_2 price 35.2 €/ton (as 4DS)

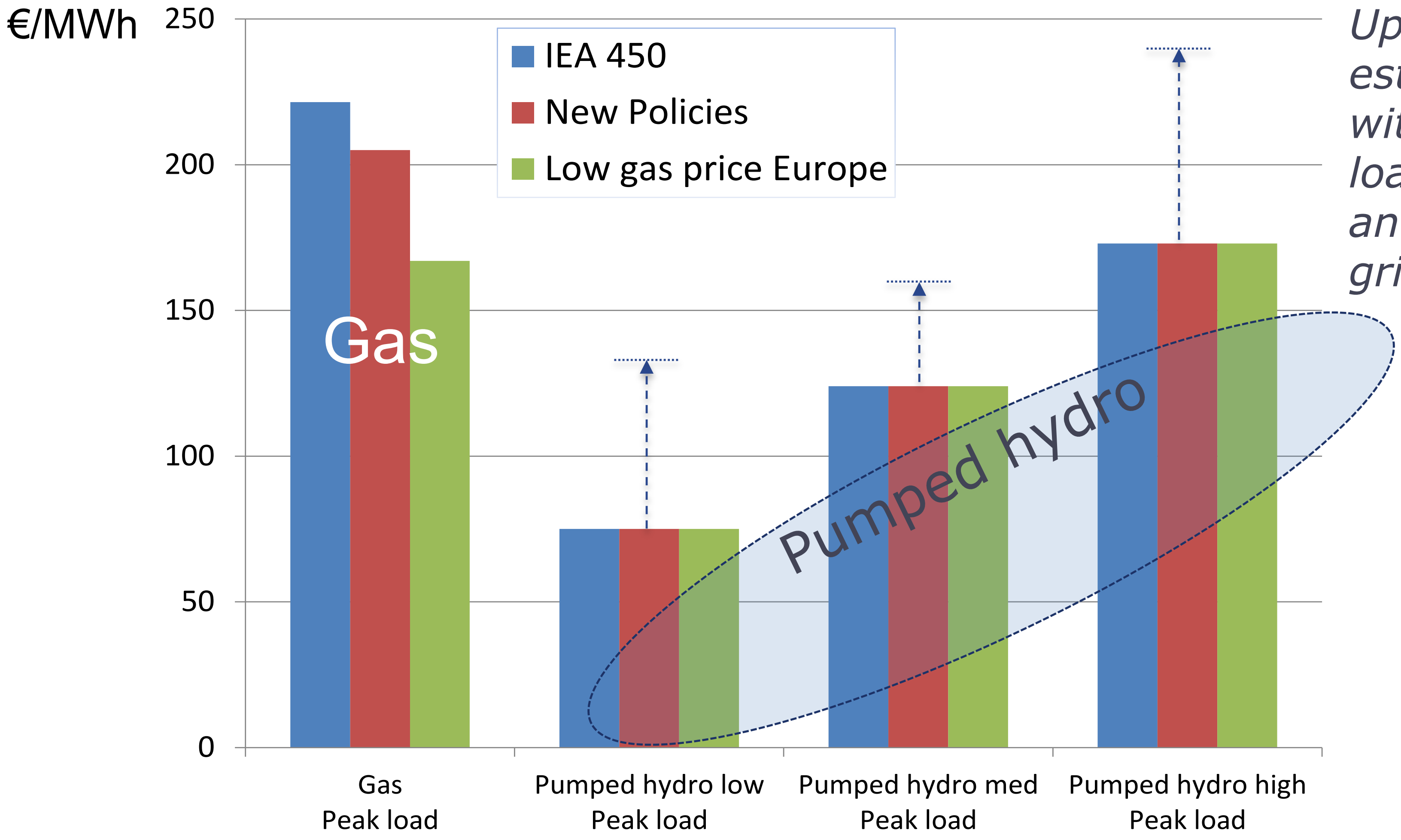


Norwegian hydropower for balancing

- 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



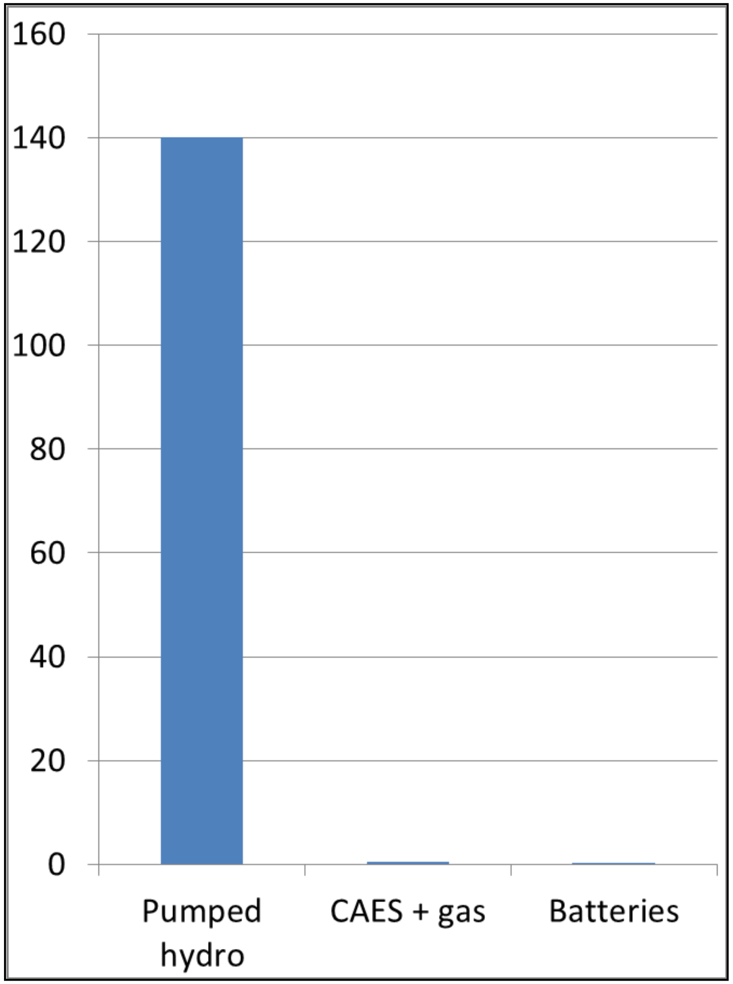
Pumped hydro power is cost-effective for balancing in all scenarios



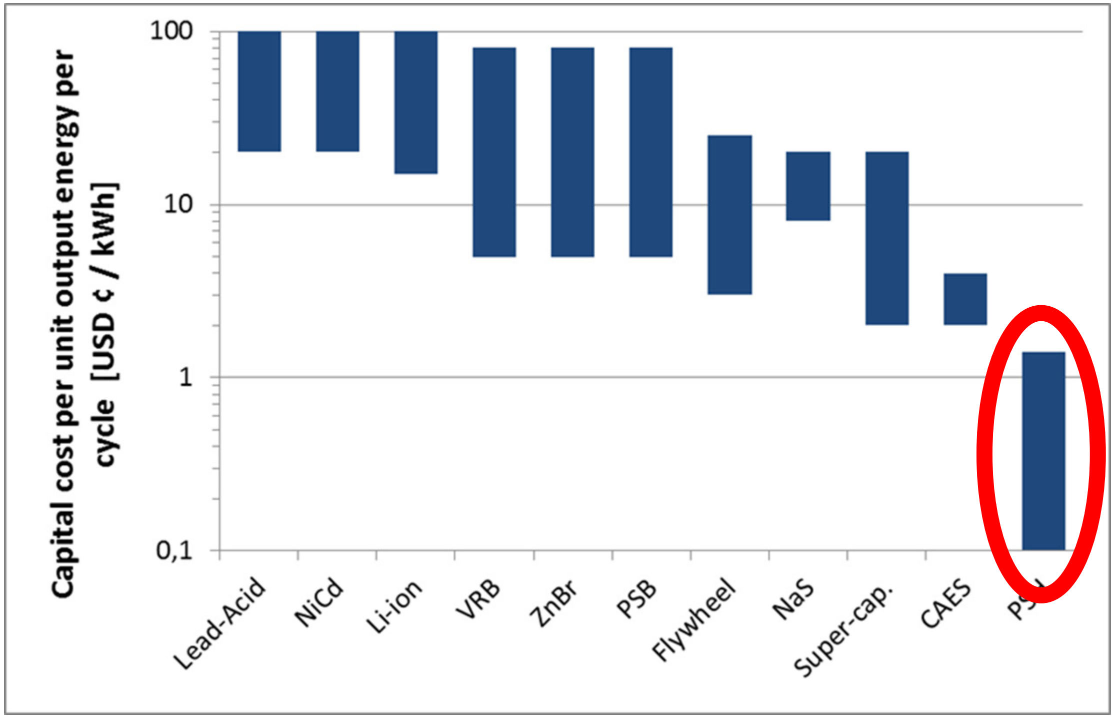
Updated estimates with lower load factor and higher grid costs

Storage capacity and cycle cost

Existing storage capacity in GWH

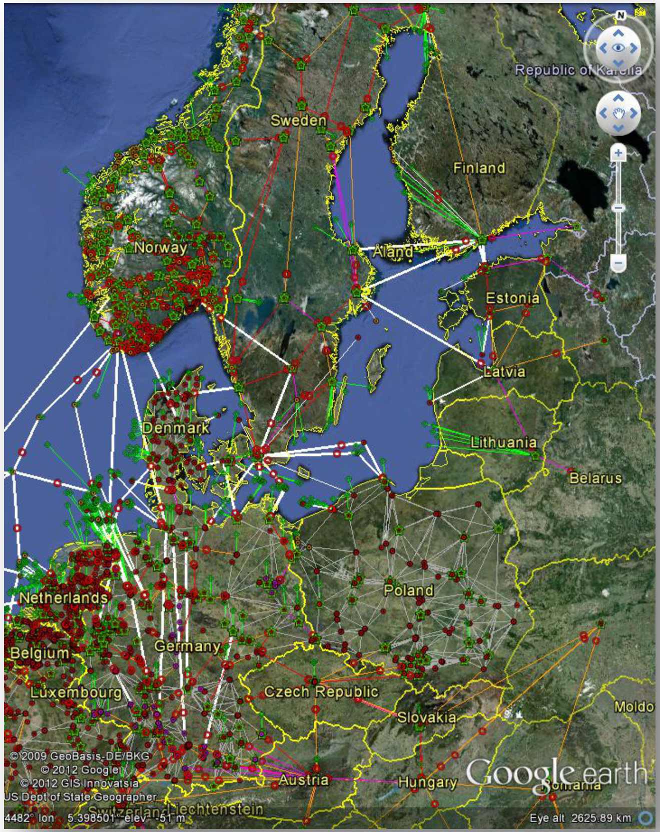


Comparing cycle cost



Integration of balancing markets

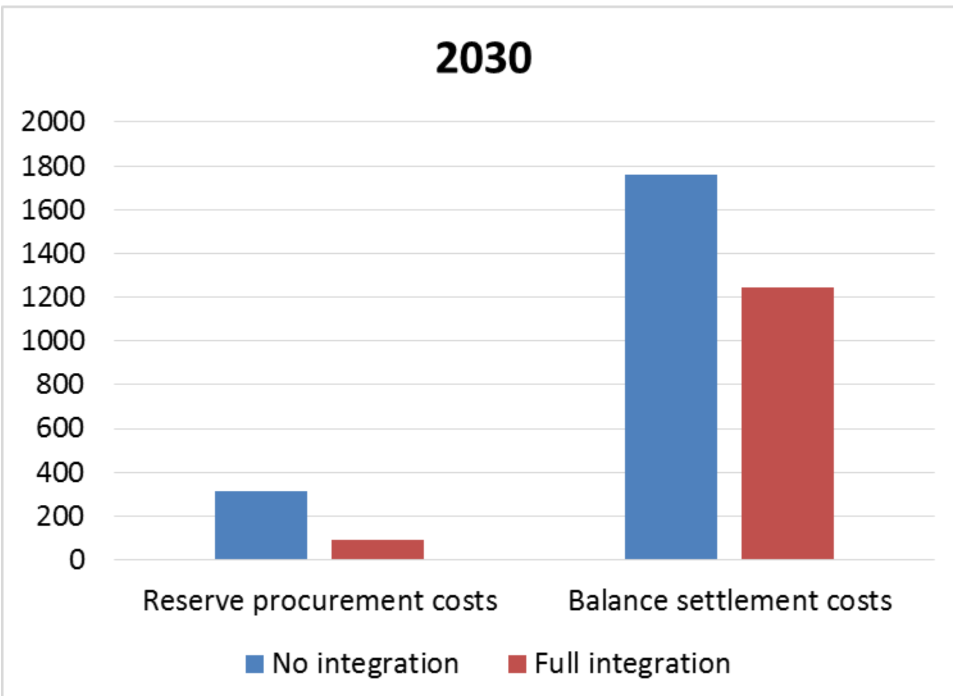
- Detailed European grid model based on DC power flow
- Representation of day-ahead, intra-day and balancing markets
- Co-optimizating day-ahead scheduels and reserve procurements based on forecasts
- Scenarios for load, generation and grid capacity year 2020 and 2030

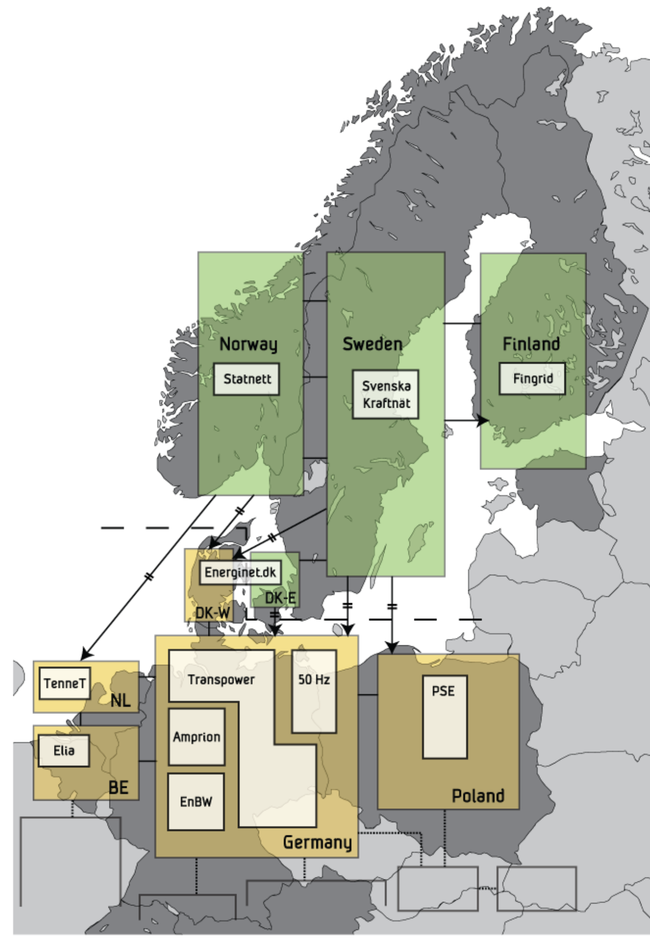


Source: Farahmand (NTNU/SINTEF)

Large benefits of integrating the Northern and continental balancing markets

Total annual balancing cost savings (Mill.EURO)





Source: Farahmand (NTNU/SINTEF)

Research questions in WP3

- For investments in Norwegian hydropower
  - New or upgraded facilities
  - Pumped storage

I. How can profit be made?
  - Market-types
  - Bilateral arrangements

II. How will hydropower be operated?

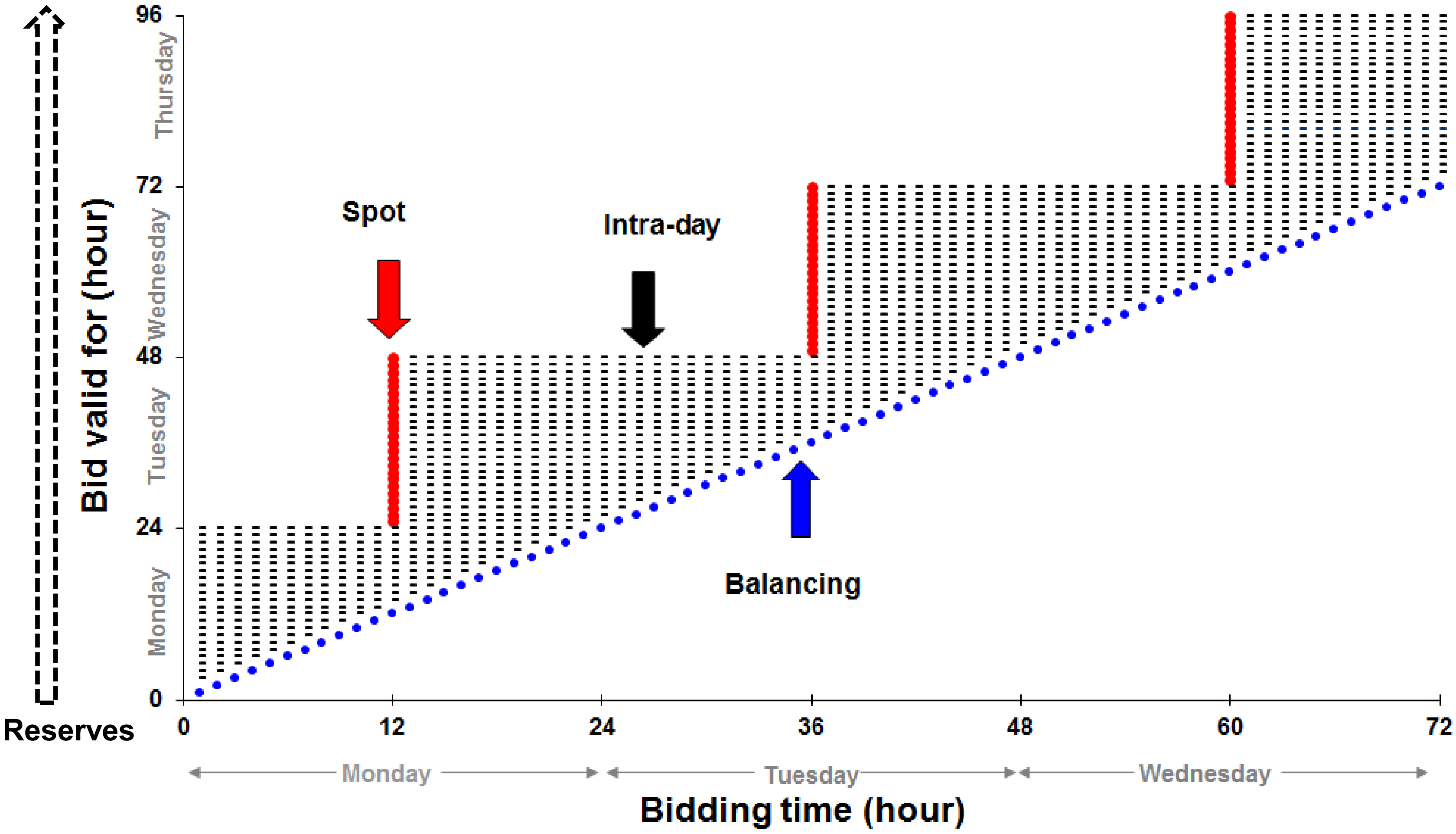
Future electricity prices

- WP3
  - Local producer / investor perspective
  - Detailed models for hydropower
  - Prices are input

- Price estimation in cooperation with
  - E.ON / IAEW
  - ECN

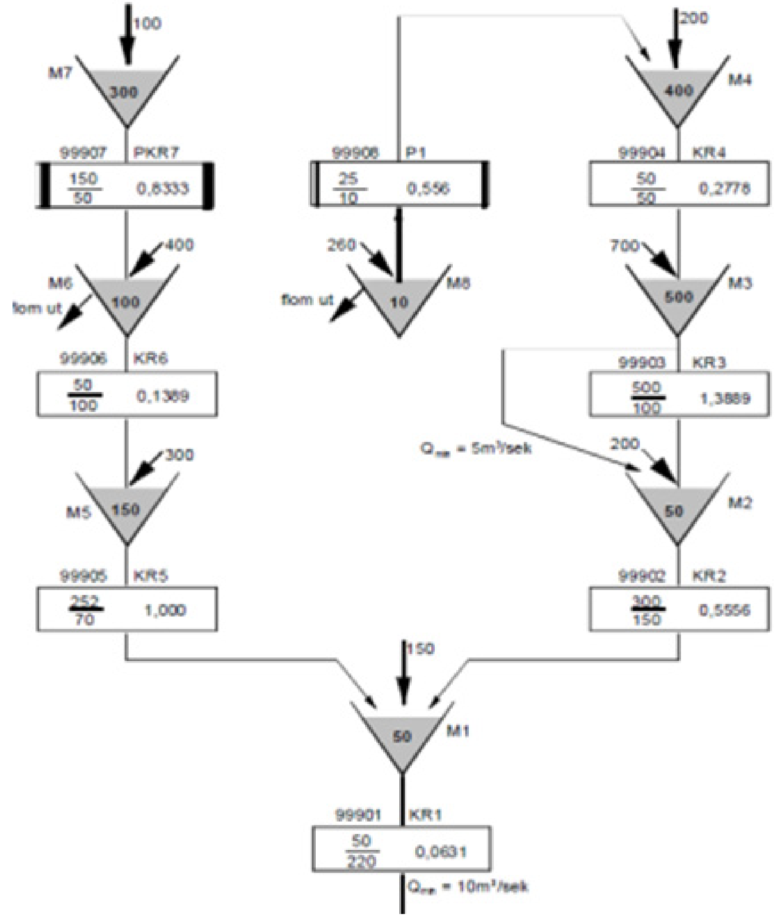
- Long-term (2050) scenario specification in WP1

Trading in multiple markets



SINTEF models

- Details for hydropower
- Short , medium and long-term stochastic storage models applied by most Nordic power producers.
  - EMPS – energy system Europe
  - ProdRisk – SDDP modell generating dependent water values
  - SHOP/SHARM/SIM – short-term scheduling



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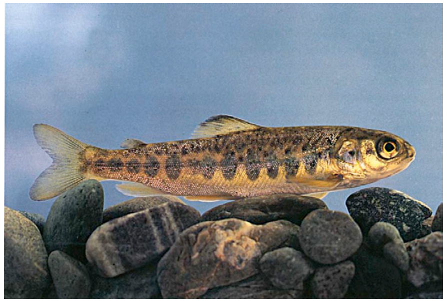
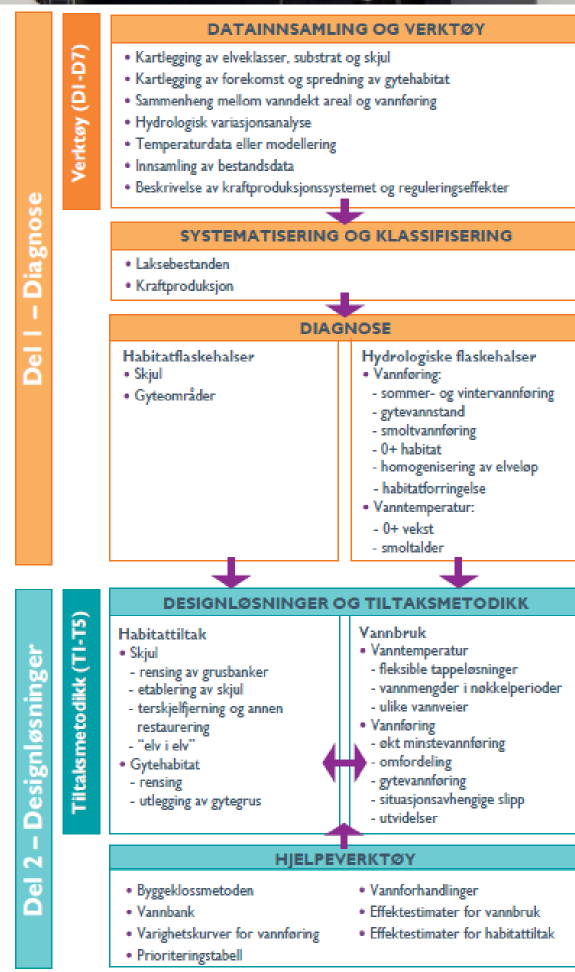
WP 4 Environmental impact



How much water is needed?

Handbook



	Habitatflaskehals	Produktivitet (1-3)
gel	Gyte	1
gel	Gyte	1
gel	Gyte	1
gel	Gyte	2
gel/parr	Begge	1
gel/parr	Begge	1
r	Skjul	2
r	Skjul	2
r	Skjul	2
en	Ingen	3
en	Ingen	3
gel	Gyte	2
gel	Gyte	1
gel	Gyte	2

WP4: Disentangle effects from natural variation and hydropower

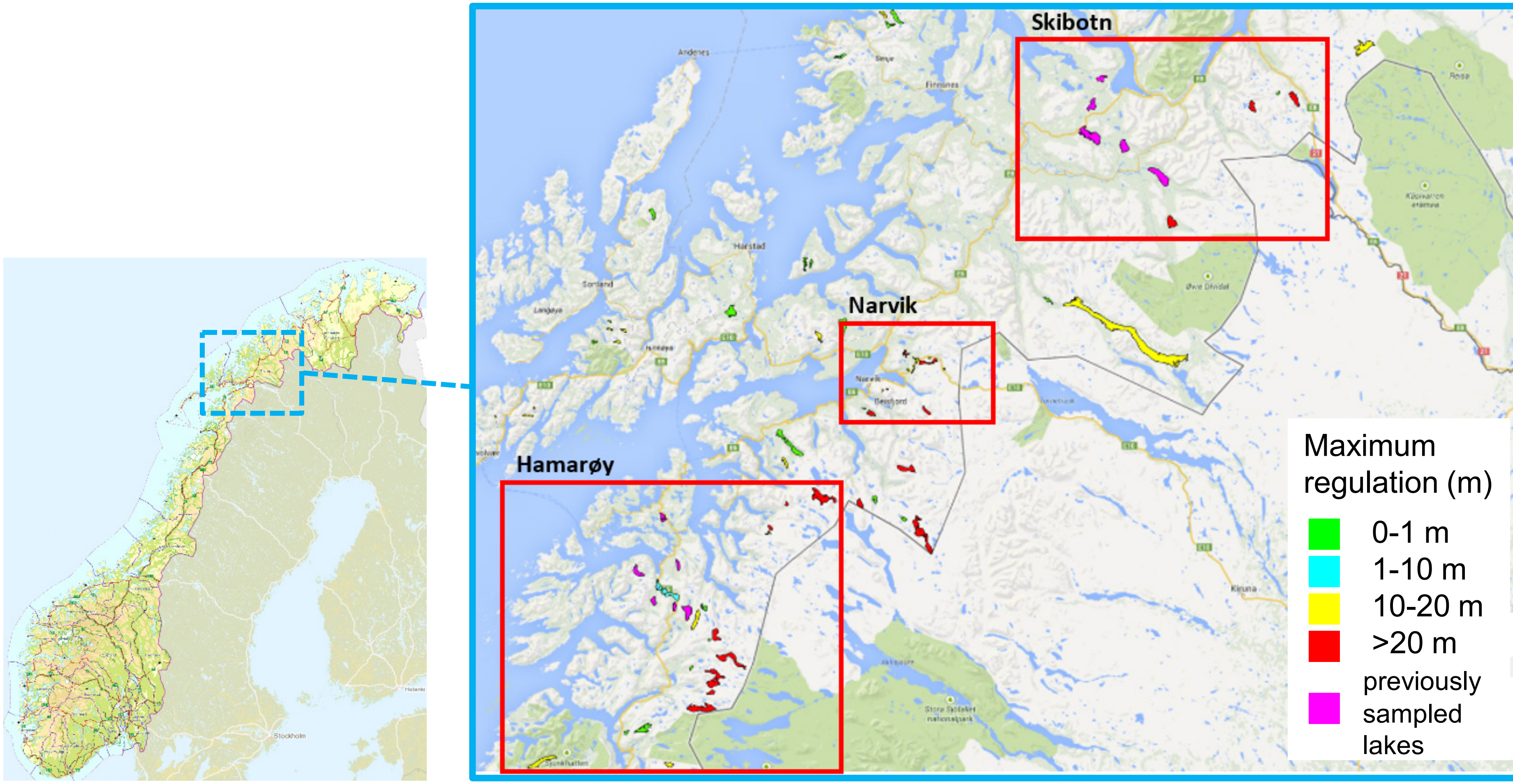
- Combine data on:
  - **Fish populations**: biomass, species composition, diet, growth
  - **Hydropower**: waterlevel fluctuations
  - **Lake morphometrics**: area, shape, depth
  - **Climate**: ice break-up, air temperature, altitude
  - **Catchment characteristics**: vegetation, water colour, runoff

WP4: Study approaches

- Compare reservoirs with varying hydropower impact based on data from:

1) **Space-for-time**
   - Modelling existing datasets (>600 lakes)
   - **Question**: how environmental gradients (climate, lake characteristcs) and hydropower affect fish production?
2) **Field studies**
   - Studying diet, growth and habitat use of fishes in ~20 lakes with varying waterlevel regulation
   - **Question**: does hydropower affect littoral and pelagic food webs and fish growth in Norwegian reservoirs?

WP4: Field study approach



WP 4: Connecting environmental impact and economy

Discharges and reservoir levels

ECO tools

ECO consequence

ECO mitigation

Recalculate: Discharges and reservoir levels

WP5 Feasibility regarding social acceptance

Societal acceptance (1)

- A major challenge for increased balancing from Norway is related to the need for upgrading the national grid.
- Conflict reduction by increased focus on the involvement of stakeholders in grid projects during recent years, in order to prevent conflicts and thereby ensure more effective processes in terms of time and resources.

- An initial study for the HydroBalance project has indicated that:
- Stakeholders (public agencies, decision-makers, NGO's, energy companies) generally support the idea that Norway could play a role in **reducing climate change** by offering hydrobalancing
- At the same time there is widespread doubt that this is realistic due to
  - Lack of political support for needed changes in the legal framework
  - Political uncertainty as to how to share costs and benefits

Societal acceptance (2)

- There is general agreement that **host communities must get their share of benefits** from production of balancing services, and that the current legislation must be changed to take this into account
- Better **involvement** of stakeholders (NGOs, industry etc.) and local communities is seen as crucial in further planning of balancing services, but there are different views on how and who should be responsible for improved involvement

➢ ***Follow-up interviews with stakeholders to be conducted during winter 2014/15.***

Hydrobalancing from Norway: Possible measures given the political and societal framework

- **No overall strategy with long-term objectives for hydrobalancing is expected from the Government shortly.**
- Based on the experiences with the UK and Germany interconnector projects, one can assume that projects with broad political anchoring and regional backing can represent realistic options – as compared to a 'large-scale scheme'.
- **A clear political commitment from European countries and the prospect of a long-term, standardized market framework will increase Norwegian political decision-makers' confidence and long-term interest.**
- Involvement of national and local stakeholders, as well as compensation measures at the local level seem to be key measures in order to prevent conflicts and ensure less time-consuming processes.

Summing up

- Balancing needs with potential
- Balancing potential with impact
- Balancing impact with acceptance

Thanks for your attention!

Thanks to the CEDREN team and the project team

Centre for environmental design of renewable energy - CEDREN

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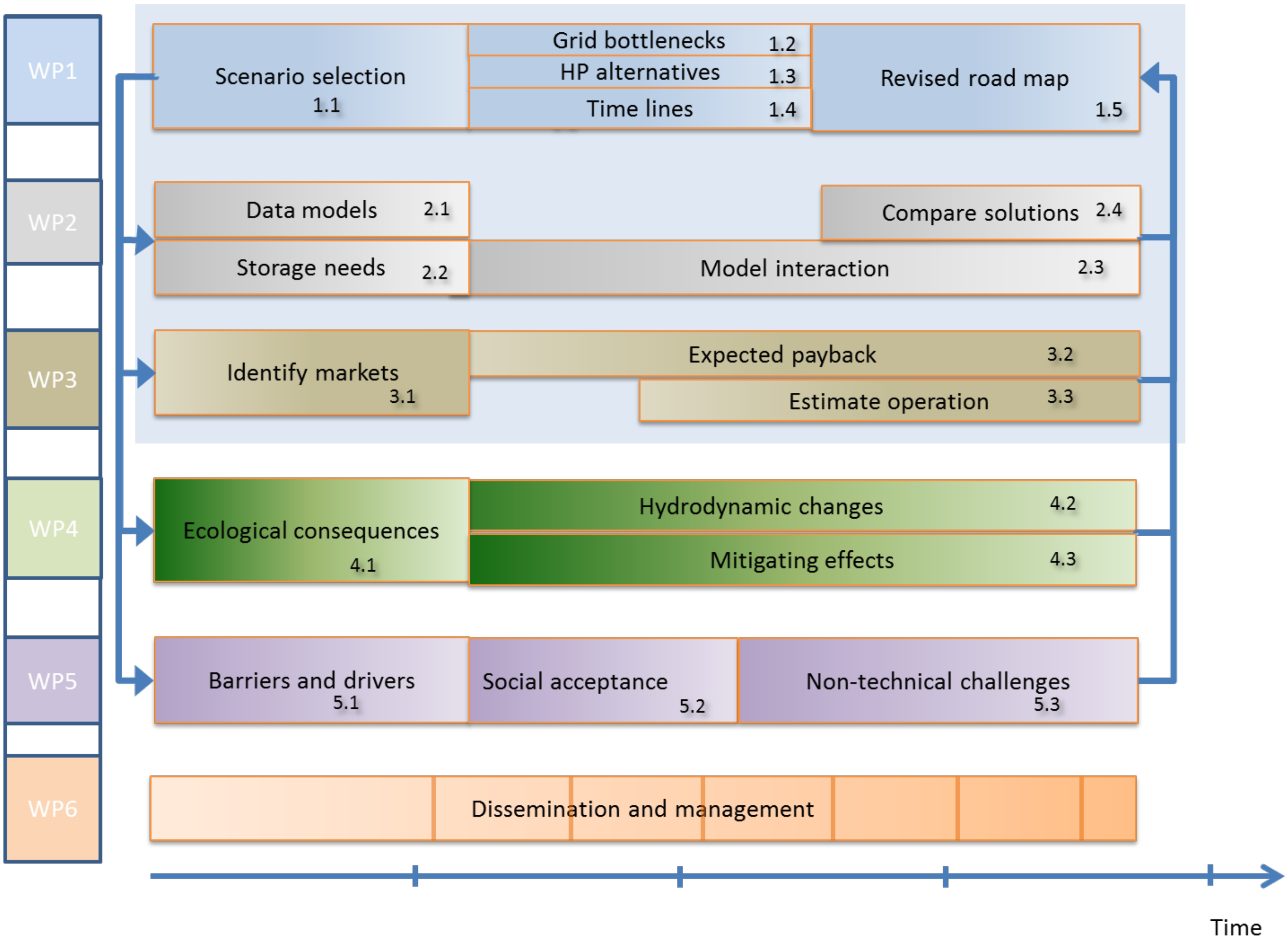
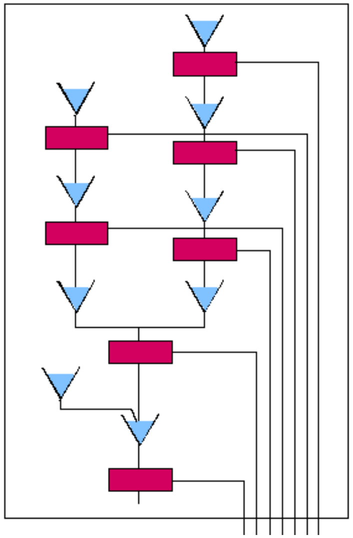
EXTRAS

Workflow in CEDREN HydroBalance

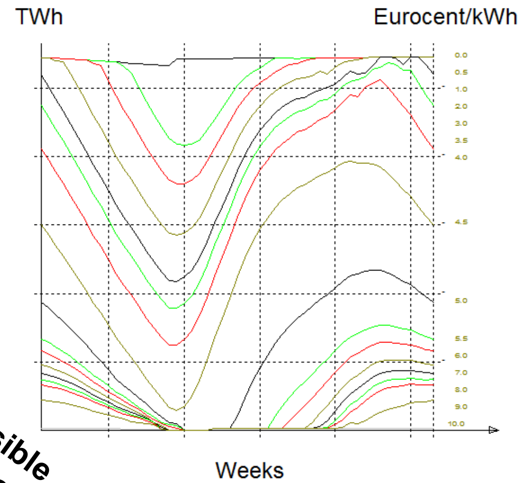


WP 3 & WP 2: Profitability in a larger perspective

Storage possibilities

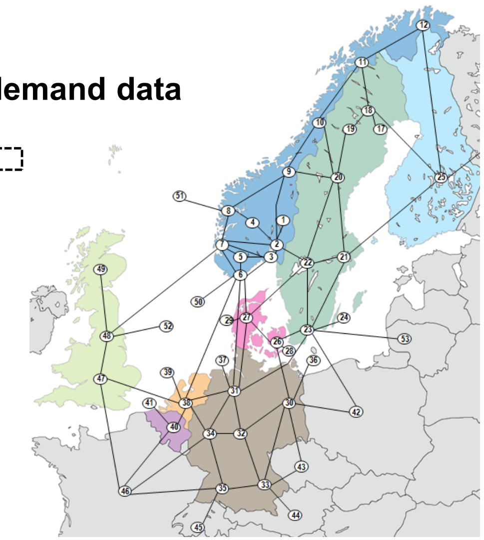


Strategy by (SDP/SDDP)



Markets and prices

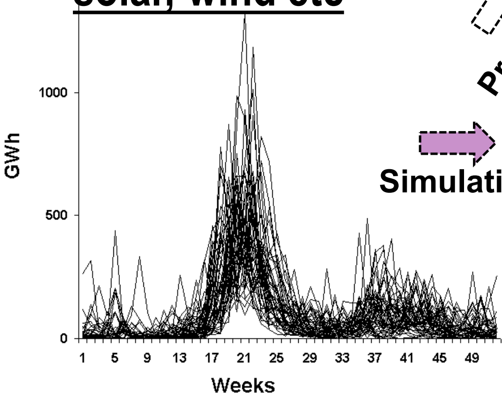
Supply/demand data



Feasible solution

Vannverdi

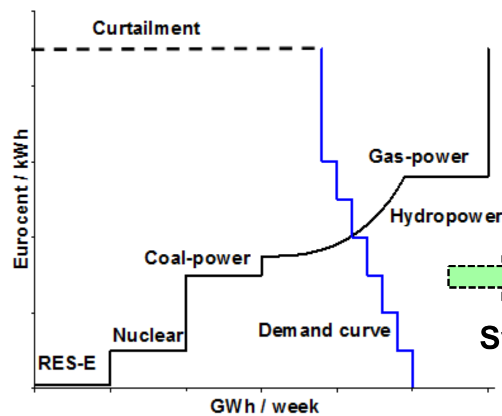
Stochastic, inflow solar, wind etc



Probability

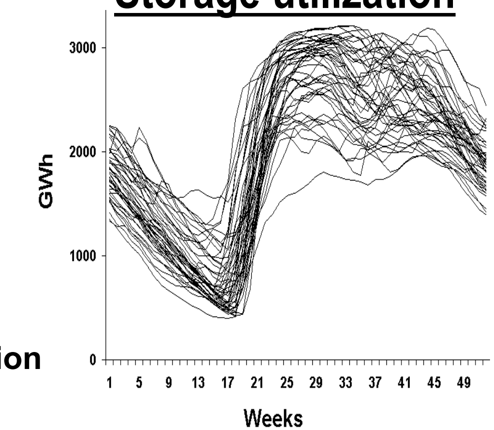
Simulation

Simulating markets (LP)



System operation

Storage utilization



Scenario A – Small hydro battery

- Both Norway and EU have moderate ambitions to exploit Norway's hydro potential
- Medium RES share due to CCS
- Less RES development, moderate transmission grid expansion
- Storage technologies at distribution grid level
- Lack of flexibility and storage + low competition to Norwegian hydro
- EU-wide power market for trade on long and short time horizons
- Norway: moderate expansion of transmission grid, hydro system and RES
- Support of some grid connections abroad (EU plan or bilateral)
- Medium amounts of balancing over all time scales

Uncertainties in Future 1	**Medium**
Technology	
Variable RES share of electricity generation	Medium
Expansion of European transmission grid	Moderate
Deployment of CCS	Yes
Market	
Competition from alternative flexible technologies	Low
EU regulatory framework and market integration	Fully integrated
Policy	
Ambitions of countries to connect to Norway	Moderate
Options for Strategy 2	**Moderate expansion**
Expansion of Norwegian transmission grid	Moderate
New PSPP and upgrade of existing HSPP	Moderate
Support of variable RES	Moderate
Ambitions of Norway to build interconnectors	Moderate

Scenario B – Big hydro battery

- Both Norway and EU have strong ambitions to exploit Norway's hydro potential
- No CCS, high RES share
- Storage technologies at distribution grid level
- Strong lack of flexibility and storage + low competition to Norwegian hydro
- Strong transmission grid expansion + EU-wide power market for for trade on long and short time horizons → good conditions
- Norway supports stronly development of transmission grid, hydro system and RES
- Active policy promoting environmentally sound projects
- Large amounts of balancing over all time scales

Uncertainties in Future 3	**Various flexibility**
Technology	
Variable RES share of electricity generation	High
Expansion of European transmission grid	Strong
Deployment of CCS	No
Market	
Competition from alternative flexible technologies	Low
EU regulatory framework and market integration	Fully integrated
Policy	
Ambitions of countries to connect to Norway	Strong
Options for Strategy 1	**Active climate policy**
Expansion of Norwegian transmission grid	Strong
New PSPP and upgrade of existing HSPP	Strong
Support of variable RES	Strong
Ambitions of Norway to build interconnectors	Strong

Scenario C – Long-term balancing only

- Ambitions for exploiting Norway's hydro potential moderate in EU, strong in Norway
- No CCS, high RES share
- Storage technologies at both distribution and transmission grid level → high competition to Norwegian hydro
- Demand for balancing on long time horizons
- Moderate transmission grid expansion
- EU-wide power market for trade on long and short time horizons
- Norway focuses on providing balancing on long time horizons
- Strong grid and hydro system expansion
- Large amounts of balancing, but only for long time horizons

Uncertainties in Future 2	**Niche market**
Technology	
Variable RES share of electricity generation	High
Expansion of European transmission grid	Moderate
Deployment of CCS	No
Market	
Competition from alternative flexible technologies	High
EU regulatory framework and market integration	Long-term only
Policy	
Ambitions of countries to connect to Norway	Moderate
Options for Strategy 3	**Value creation**
Expansion of Norwegian transmission grid	Strong
New PSPP and upgrade of existing HSPP	Strong
Support of variable RES	Low
Ambitions of Norway to build interconnectors	Strong

Scenario D – Nordic balancing only

- Ambitions for exploiting Norway's hydro potential strong in EU, low in Norway (focus on Nordic Countries)
- No CCS, high RES share
- Storage technologies at distribution grid level
- Lack of flexibility and storage + low competition to Norwegian hydro
- Limited transmission grid expansion due to low public acceptance
- EU-wide power market for trade on long and short time horizons
- Norway: strong transmission grid expansion, but existing hydro system used to balance domestic and Nordic RES
- Support of grid connections to Nordic Countries
- High RES + too small transmission capacities + lack of flexibility/storage → Situations of critical security of supply in Central Europe

Uncertainties in Future 4	**Critical supply**
Technology	
Variable RES share of electricity generation	High
Expansion of European transmission grid	Limited
Deployment of CCS	No
Market	
Competition from alternative flexible technologies	Low
EU regulatory framework and market integration	Long-term only
Policy	
Ambitions of countries to connect to Norway	Strong
Options for Strategy 4	**Nordic only**
Expansion of Norwegian transmission grid	Strong
New PSPP and upgrade of existing HSPP	Limited
Support of variable RES	Strong
Ambitions of Norway to build interconnectors	Low