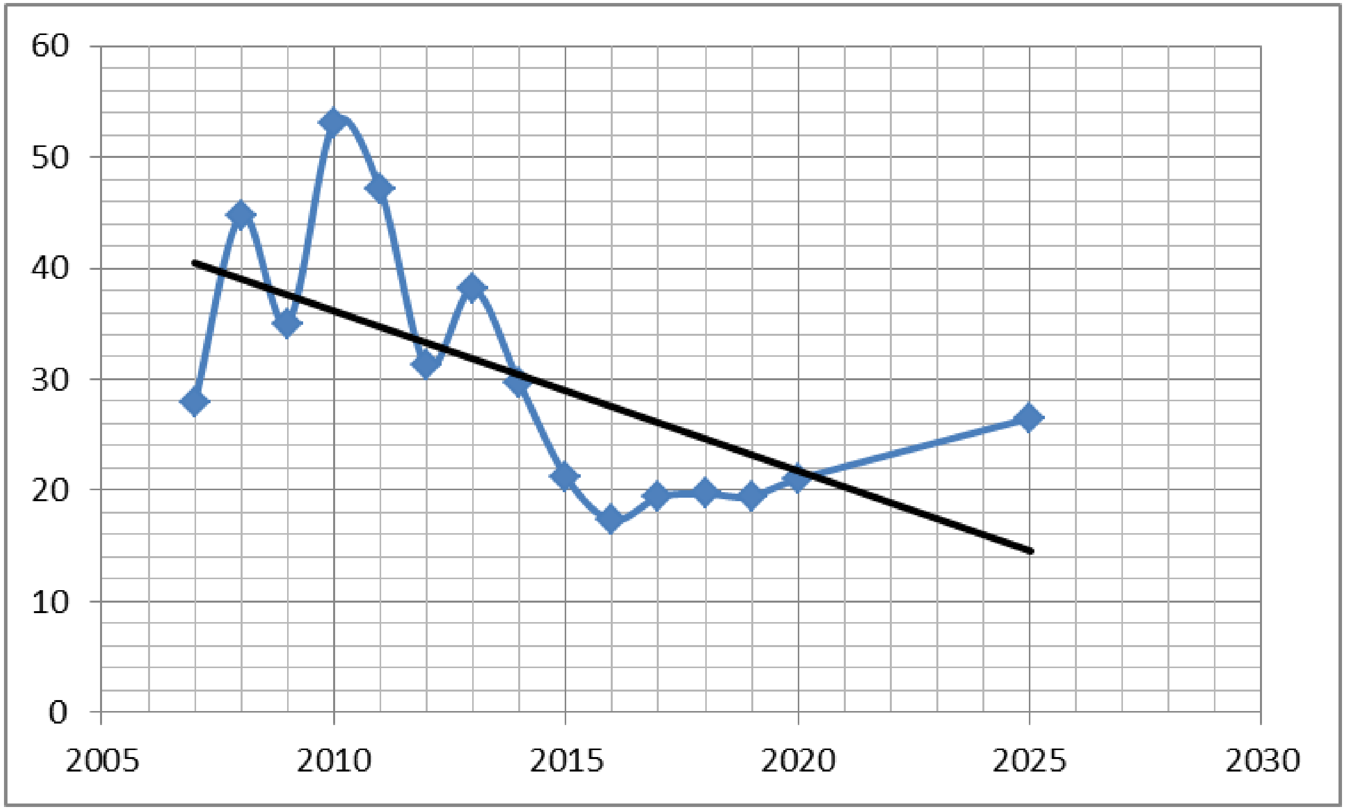
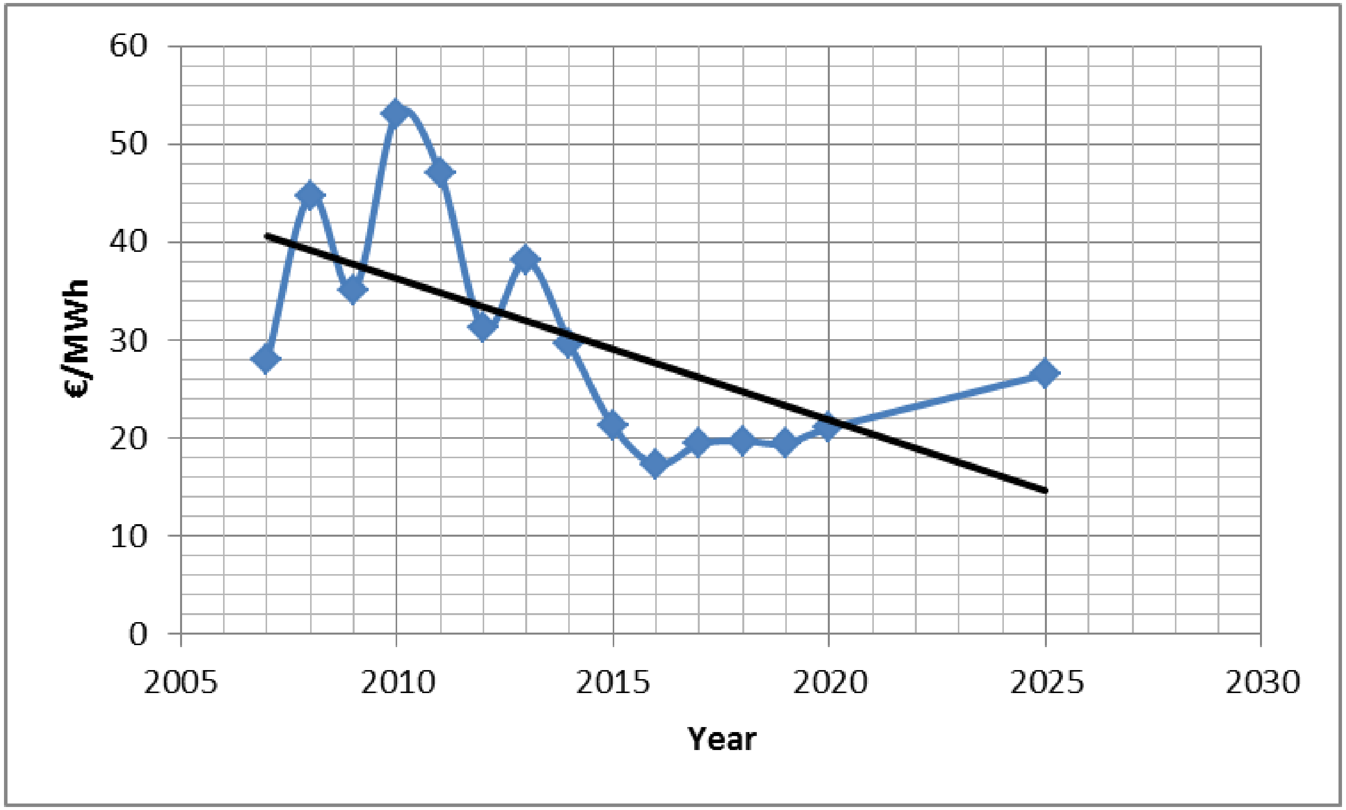
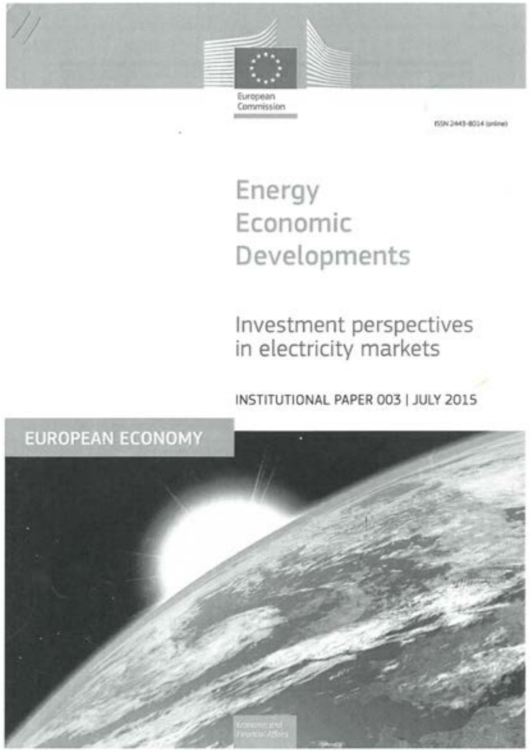
CEDREN HydroBalance



Unweighted average prices at Nordpool



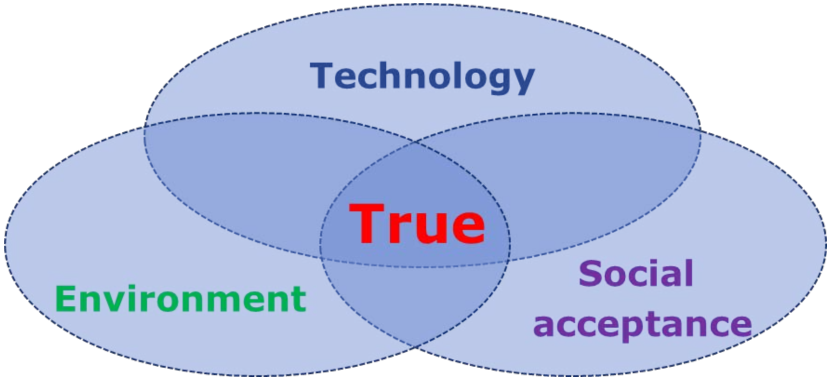
Something will happen and something needs to be done



Cited p.94.The effect on revenues of this almost complete decarbonisation of power systems is an overall decrease in prices, hence revenues compared to stage 2 for most part of the year. **The financial position of all technologies will depend extensively on the frequency and ability of prices to reach high levels.** The feasibility of such price spikes is uncertain.

CEDREN HydroBalance

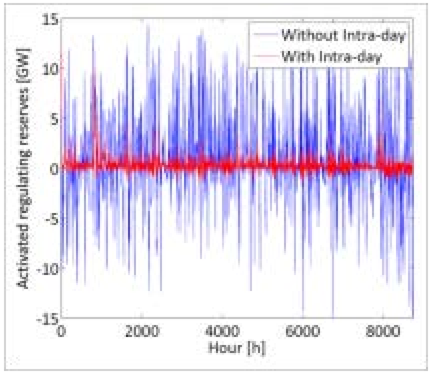
Balancing from hydropower feasibility check



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

CEDREN HydroBalance: Technology

- WP 1:Roadmaps for balancing from Norwegian hydropower (Julie Charmasson)
  - 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
  - Short- long-term storage, interaction between markets
  - PhD: Ingeborg Graabak

- 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 and EON

Challenge…and a whole lotta solutions!

Norwegian hydro
- Fast response
- Large storages
- Big investment desicions
- European collaboration

Efficienct power markets

More flexible
- Coal plants
- Nuclear plants

Balancing load,wind & solar

Strengthen the power grid across borders

Local pumped storage

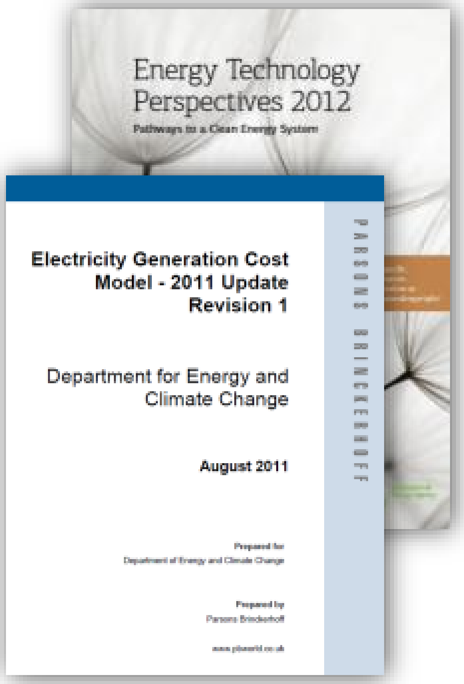
Flexible gas power
- OCGT
- CCGT

- Smarter use of energy
- Interplay with district heating
- Local storage

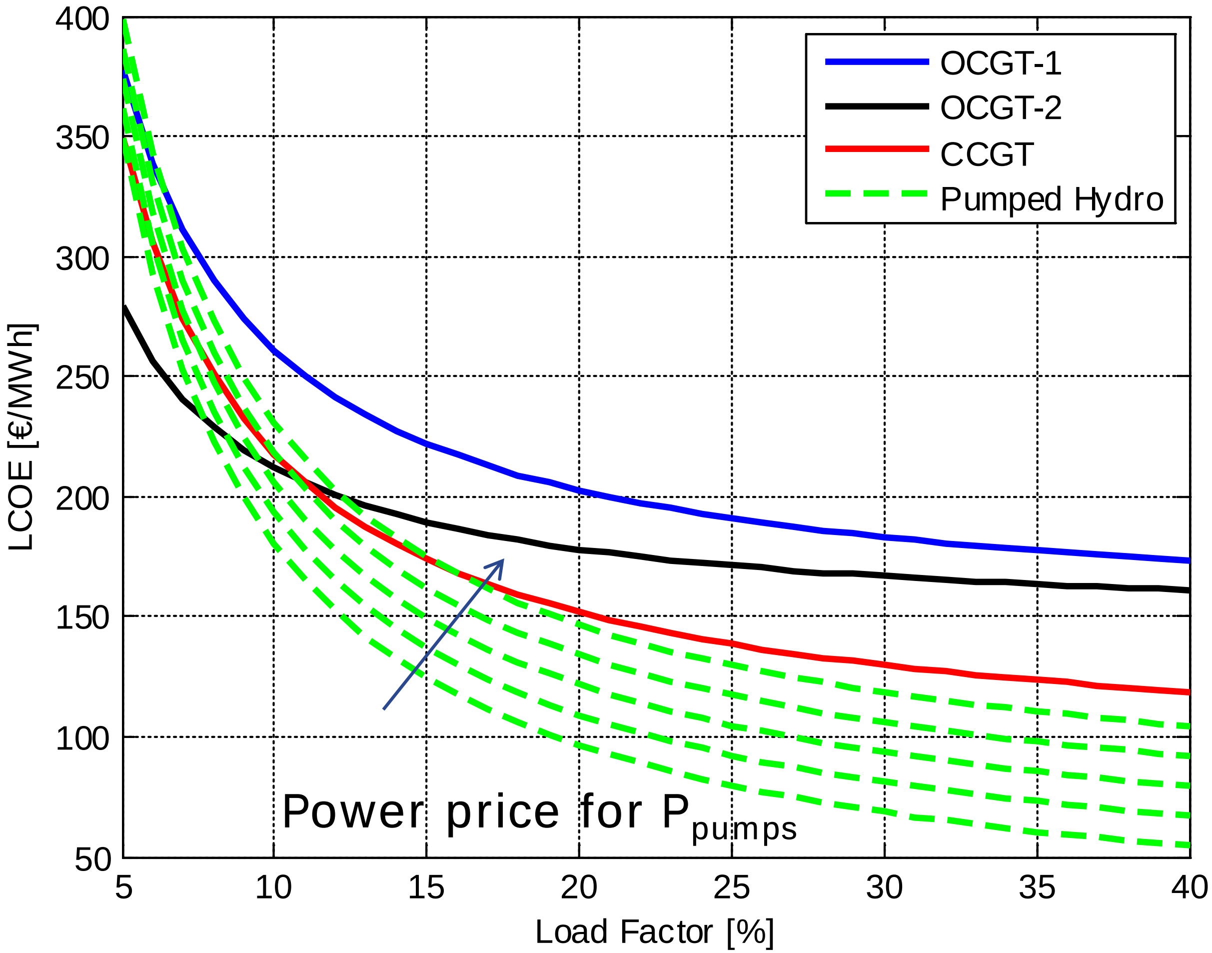
Overview of study

- 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.

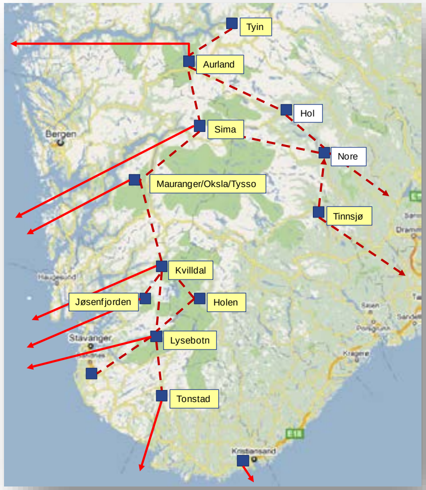


...even when grid and cable costs are included



Conclusion so far..

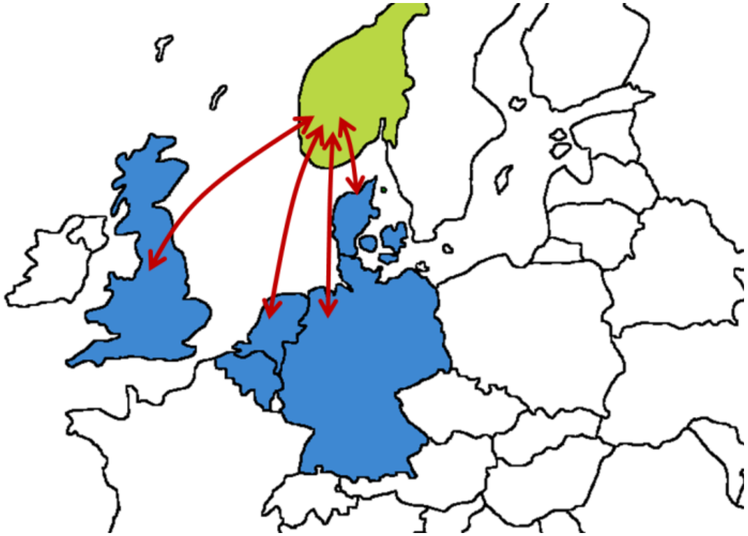
Interconnectors must be given full access to all markets, including capacity markets, for utilization of the most economical viable sources of storage and flexible power in Europe



Scenario building methodology in Hydrobalance

<u>Research question</u>

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



Identify important factors → **Trends**, **Uncertainties**, **Strategies**

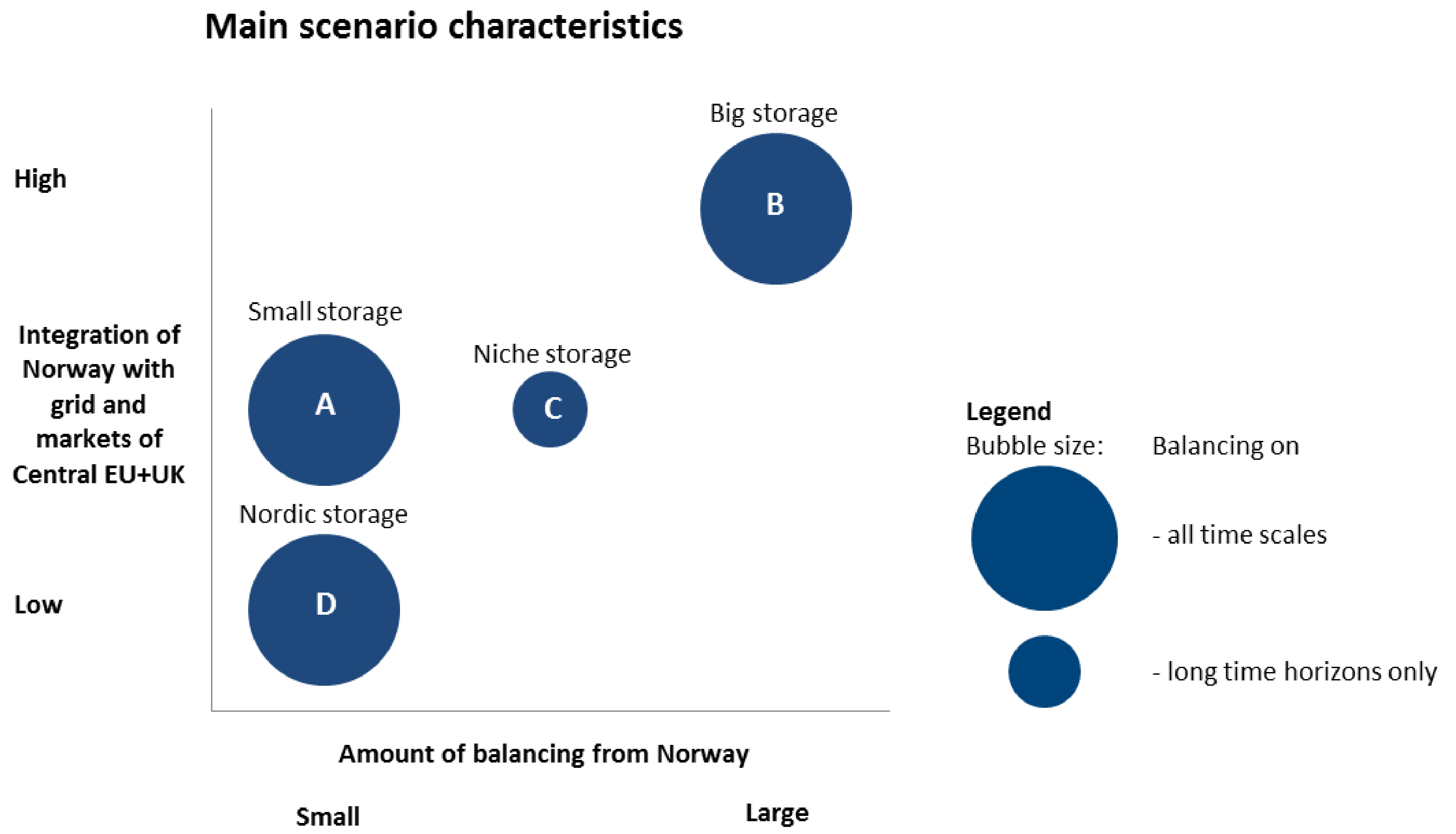
Trends → **Futures**

Uncertainties → **Futures**

Futures → **Scenario**

Strategies → **Scenario**

1. Scenarios selection



Scenario

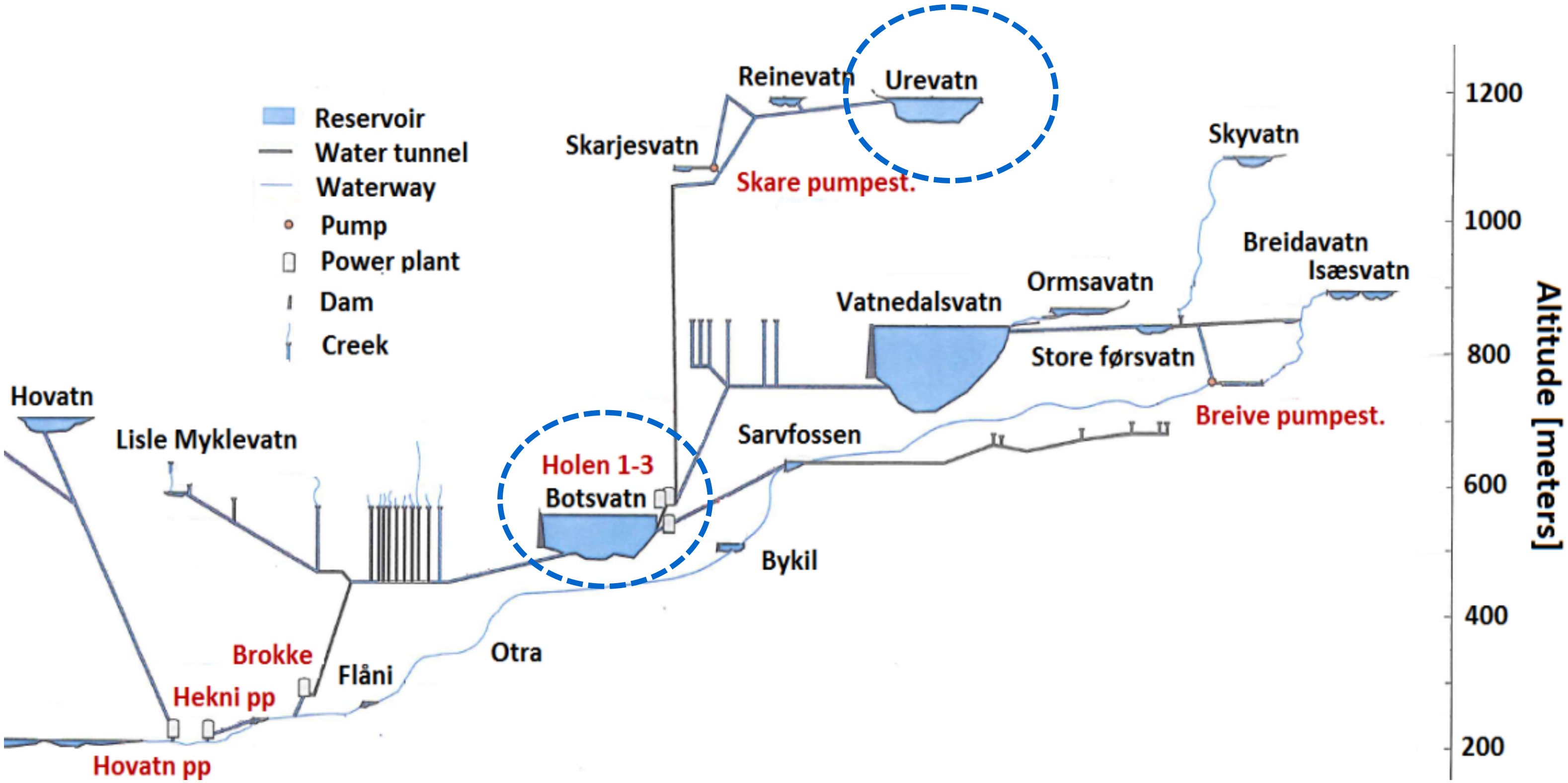
- Statistics
- Big Storage
- Niche Storage

} Supply only for day-ahead market

- Multi-market — day-ahead + RR activation

➢ **All scenarios: With and without investment**

Pumped storage investment



- 1000 MW: extra generation capacity and pump
- Reservoirs: 15 days to empty/fill
- Total efficiency (pump x generation): 72.2 % (conservative, cf. Ibrahim 2007)
- Estimated total costs: 416 M € (Henden, 2014)

Economic results (in M € per year)

	Day-ahead only (Climate years 2007-2011)			German prices (Climate year 2008)	
	Statistics	Niche Storage	Big Storage	DA only	Multi-market
Average yearly income	205	474	517	654	669
Additional operating profits	9	23	30	133	161
Investment cost *)	-24	-24	-24	-24	-24
Investment profits *)	-15	-2	5	109	137
Break even interest rate	-0,5 %	4,5 %	6,6 %	31,1 %	38,8%

*) With 5 % annual interest rate

Summery of results

- Variability in operation
  - Increased with pumped storage (short term and during a year)
  - Highest for multi-market strategy
  - Traditional day/night trend is changed because of solar radiation
- Income
  - Future scenarios gives 2-3 times higher total income
  - Multi-market strategy gives about 2% extra income
- Payback for investment in pumped storage
  - Negative profits for historical prices
  - About break-even for day-ahead strategy at future prices
  - Multi-market strategy: Income from investment increase by 21%

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.
  - Postdoc: Antti Eloranta

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

Resultater

	Drivere	Barrierer
Nasjonalt nivå	Norske magasiner	Miljøkonsekvenser knyttet til endret reguleringsregime
	EUs klimamål og etterspørsel etter balansetjenester	Stor usikkerhet rundt utvikling av energiunionen og etterspørsel etter norsk balansekraft
	Kabler til EU, eksport og importmuligheter	Kabeleierskap, lønnsomhet og kraftpriser
		Kapasitet og fleksibilitet i kraftnettet
Lokalt nivå	Tidlig involvering, informasjon og kartlegge lokale ulemper	Visuelle, miljømessige og økonomiske konsekvenser
	Kompensasjon: Investering i lokal infrastruktur (veier, bredbånd o.l)	Konsekvenser for lokal infrastruktur (usikker is og ferdsel, brygger og båttrafikk)
	Kompensasjon: elektronisk varslingssystem	Sikkerhet knyttet til magasin og is

NIMBY -effekten

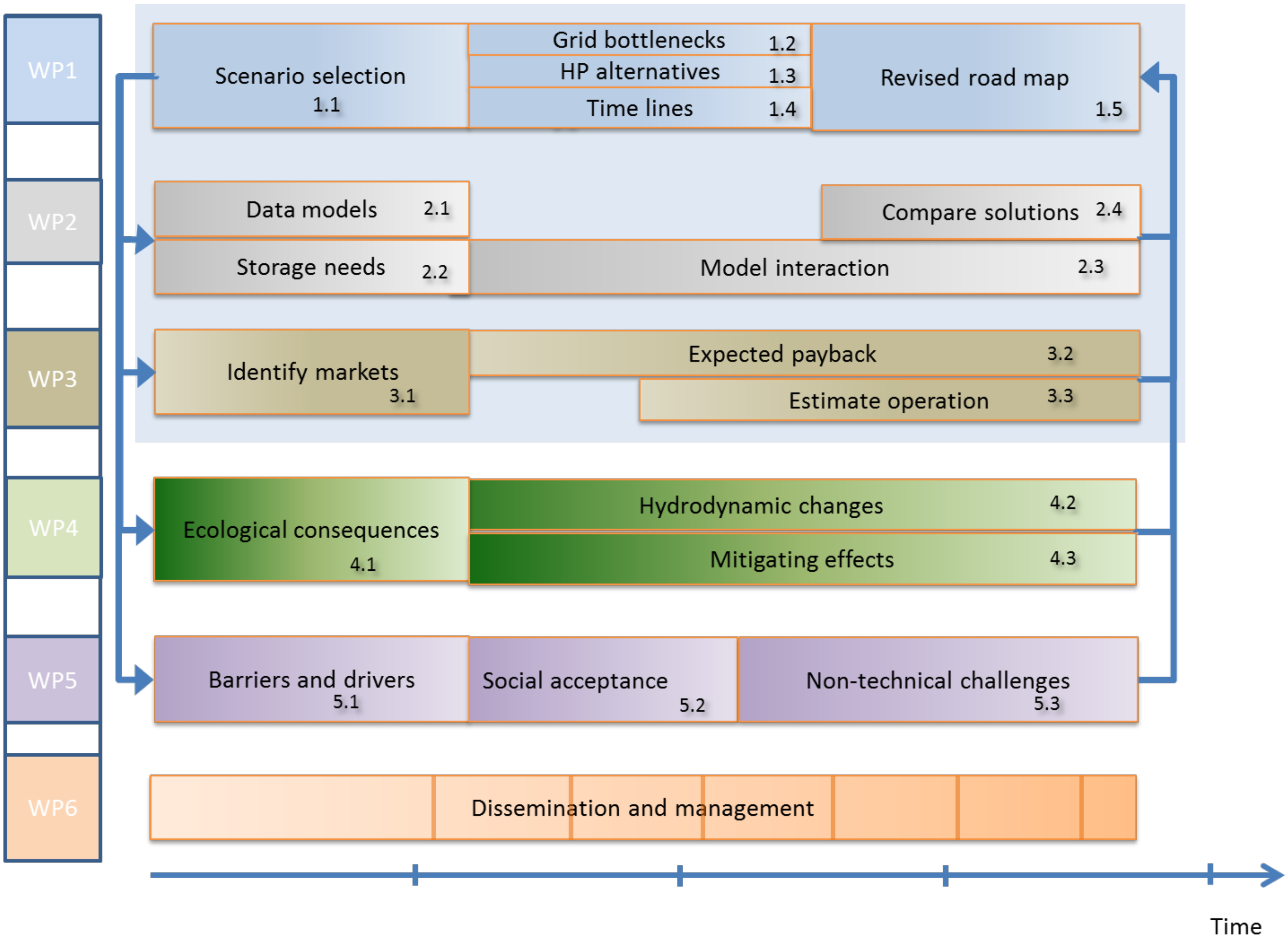
- Folk er positive til «ideen» om balansekraft og at det er positivt i global sammenheng.

- Mer skeptiske dersom de selv blir berørt (balansekraft som prosjekt) og ikke opplever noen fordeler/kompensasjon lokalt, siden «miljøbelastningen» er lokalt forankret.

- Uttalt skepsis til det reelle bidrag fra balansekraft til å dekke Europas behov (regionalt nivå – Oppland FK)

- **Det «problematiske» ligger i overgangen fra det lokale tiltaket til det globale (tenke globalt og handle lokalt). →må kommunisere og/eller tydeliggjøre fordelene man får både lokalt og globalt. Her ligger utfordringen.**

Workflow in CEDREN HydroBalance



Overview of work in WP3

Develop methodology

- Hydropower optimization
- With several markets

Forecast prices

- HydroBalance scenario
- 2050
- Several markets

Case-study

- Real river system
- Relevant pumped-storage project

CEDREN HydroBalance: Facts

- Budget: 24,864 MNOK, (17,692 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, University 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**.