



Scenarios for large-scale balancing and energy storage from Norwegian hydropower

Julian F. Sauterleute, Ingeborg Graabak, Ove Wolfgang
SINTEF Energy Research, Trondheim, Norway

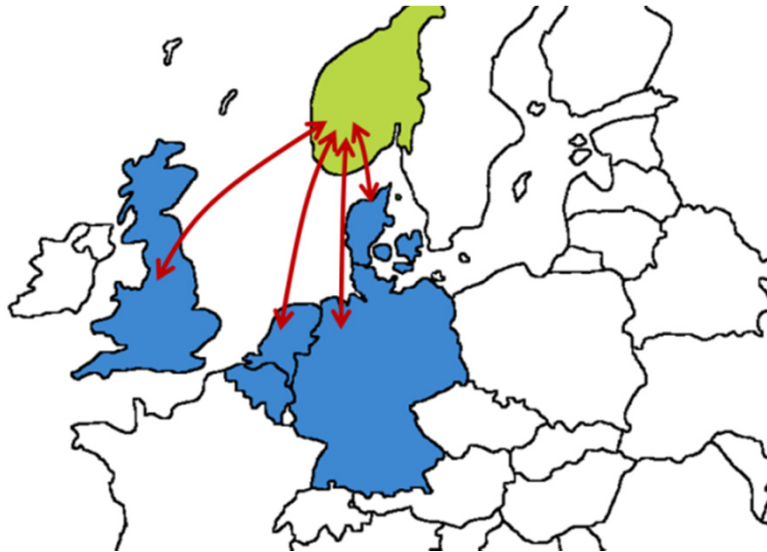
CenSES Årskonferanse, 5 December 2014, Oslo



HydroBalance Project – Environmental, technical, economic and social challenges

Oct 2013 - Oct 2017

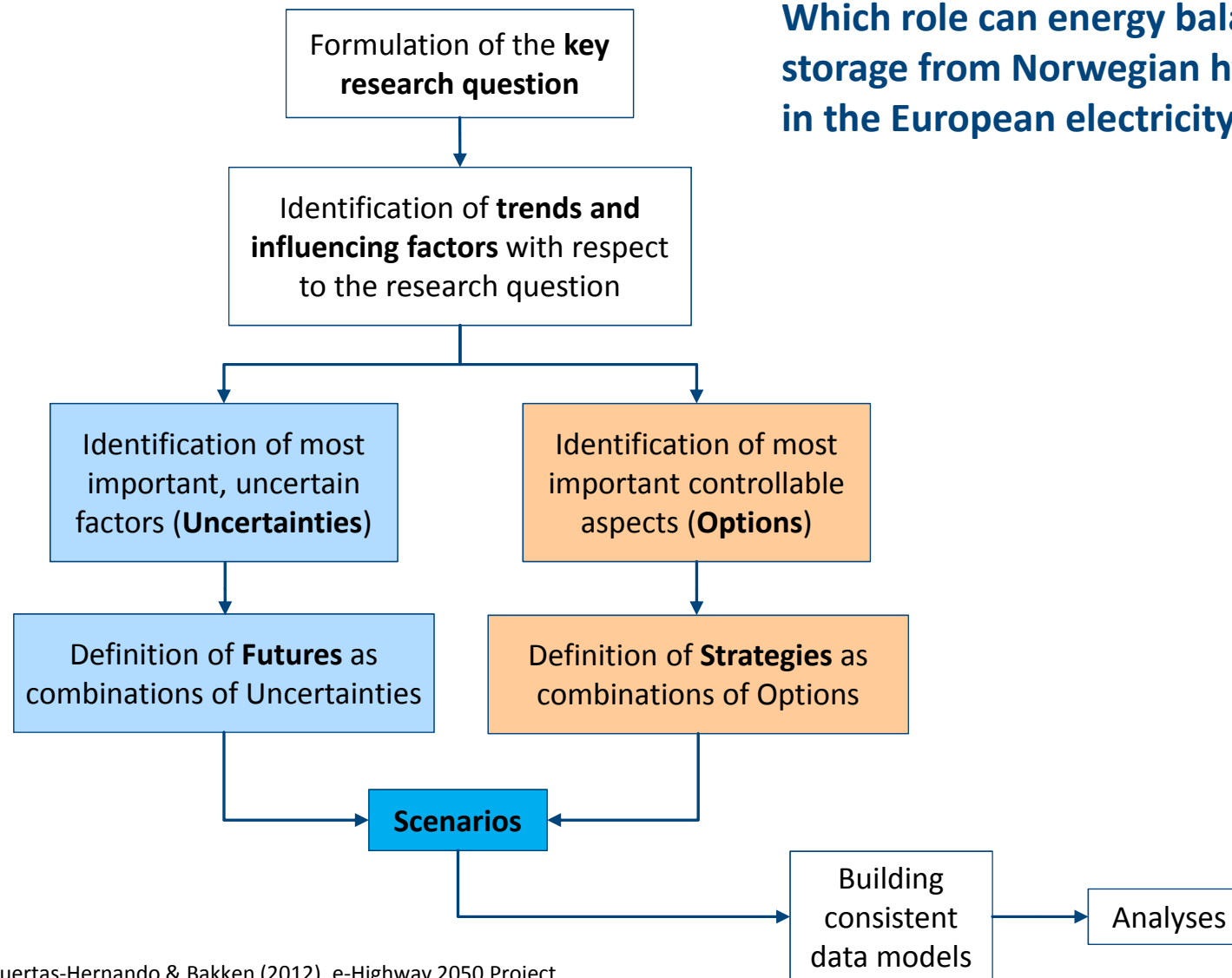
Total budget 25 Mio NOK



- Scenarios for different futures of the Norwegian hydro system in 2050
- Analyses, simulations and case studies of
 - energy system
 - energy market
 - environmental impacts
 - regulatory framework and public acceptance
- Roadmap

Scenario building approach

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



Source: Huertas-Hernando & Bakken (2012), e-Highway 2050 Project

Conclusions from workshop

- All Futures built on the following most important uncertainties:
 - Level of competition between flexible technologies in European market
 - Market framework and business models, market integration
 - Share of variable RES
 - EU and national policy

Structuring of workshop results

- Selection of most important uncertainties to be used
- Selection and modification of *Futures*
 - Relevance for the project's objectives?
 - Lack of differentiation between *Options* and *Uncertainties*?

→ Choice of specific perspective:

Options = Factors which **Norwegian decision makers** can decide on
→ Refer to choices which Norwegian policy controls; EU's and other member states' policies are uncontrollable, i.e. are *Uncertainties*.

Futures

Uncertainty	Possible values	Future 1	Future 2	Future 3	Future 4
		Medium	Niche market	Various flexibility	Critical supply
Technology					
Variable RES share of electricity generation	High/Medium				
Expansion of European transmission grid	Strong/Moderate/Limited				
Deployment of CCS	Yes/No				
Market					
Competition from alternative flexible technologies	High/Low				
EU regulatory framework and market integration	Fully integrated/Day-ahead only				
Policy					
Ambitions of countries to connect to Norway	Strong/Moderate				
Assumptions - constant <i>Uncertainties</i>					
GHG emission reductions in Europe	High				
Electricity demand	Increase				
Maturity of RES technology	Mature				
Maturity of DSM technology	Mature				
Maturity storage technologies at distribution grid level	Mature				

Strategies

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

Option	Possible values	Strategy 1	Strategy 2	Strategy 3	Strategy 4
		Active climate policy	Moderate expansion	Value creation	Nordic only
Expansion of Norwegian transmission grid	Limited/Moderate/Strong				
New PSPP and upgrade of existing HSPP	Limited/Moderate/Strong				
Support of variable RES	Low/Moderate/Strong				
Ambitions of Norway to build interconnectors	Low/Moderate/Strong				

Scenarios

	Strategies	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Futures		Active climate policy	Moderate expansion	Value creation	Nordic only
Future 1	Medium	1	2 = A	3	4
Future 2	Niche market	5	6	7 = C	8
Future 3	Various flexibility	9 = B	10	11	12
Future 4	Critical supply	13	14	15	16 = D

Bold numbers:
Relevant scenarios

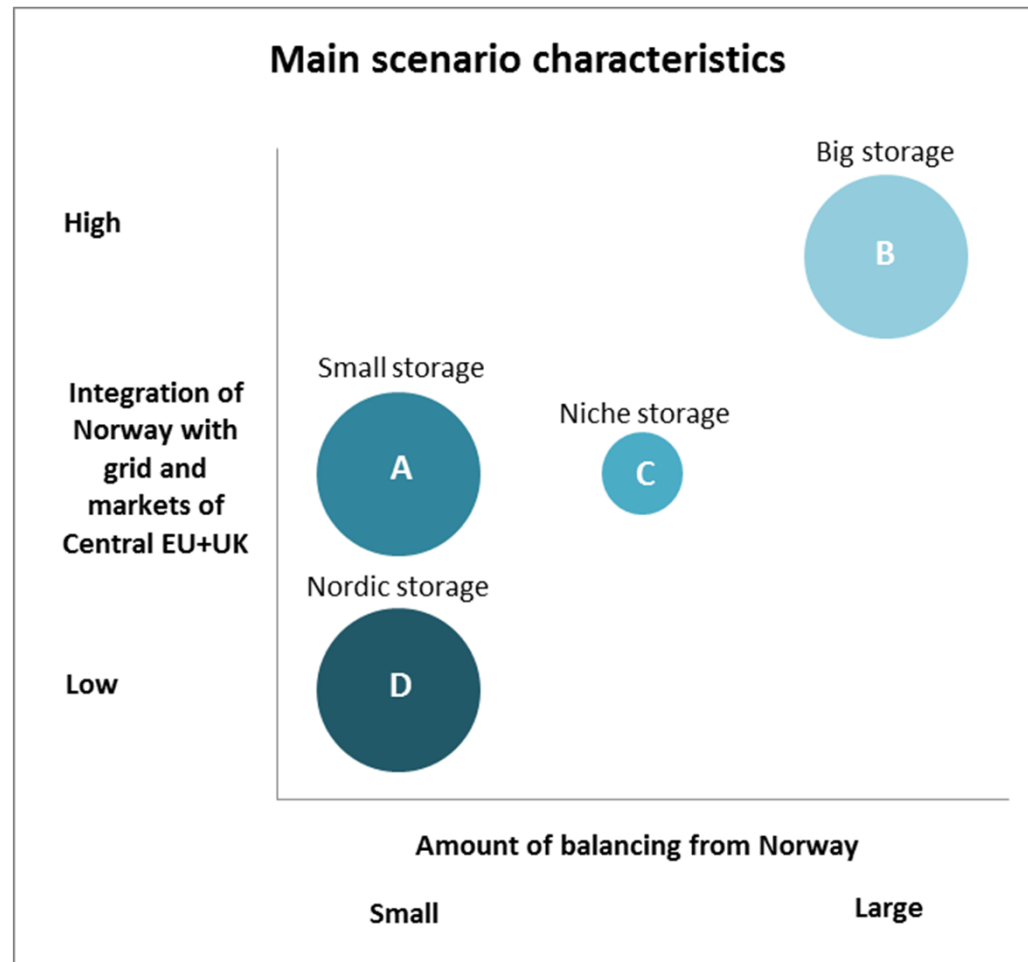
Grey shades:
Scenarios with
similar outcome

Borders: Four
selected scenarios

Selected scenarios:

- A – Small storage
- B – Big storage
- C – Niche storage
- D – Nordic storage

Main characteristics along three dimensions



Bubble size: Balancing on

- all time scales
- long time horizons only

Scenario A – Small storage

- 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 in Strategy 2	Moderate expansion
Expansion of Norwegian transmission grid	Moderate
New PSPP and upgrade of existing HSPP	Moderate
Support of variable RES in Norway	Moderate
Ambitions of Norway to build interconnectors	Moderate

Scenario B – Big storage

- 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 trade on long and short time horizons → good conditions
- Norway supports strongly 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 in Strategy 1	Active climate policy
Expansion of Norwegian transmission grid	Strong
New PSPP and upgrade of existing HSPP	Strong
Support of variable RES in Norway	Strong
Ambitions of Norway to build interconnectors	Strong

Scenario C – Niche storage

- 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 only for trade on long 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

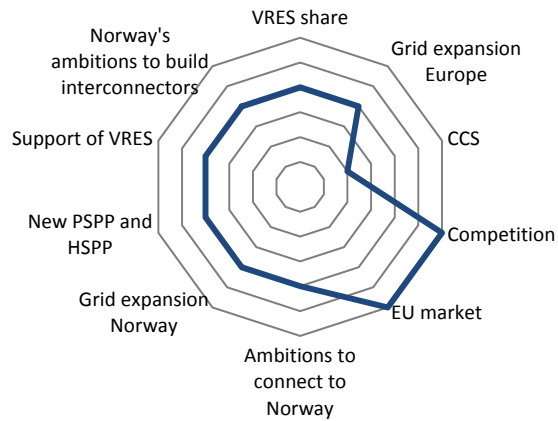
Uncertainties in Future 2	Niche market
Technology	
Variable RES share of electricity generation	High
Expansion of European transmission grid	Moderate
Deployment of CCS	No
Market	
Competition from alternative flexible technologies	High
EU regulatory framework and market integration	Day-ahead only
Policy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

Scenario D – Nordic storage

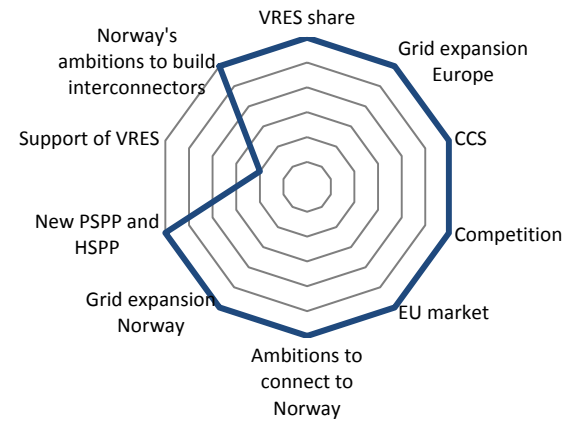
- Ambitions for exploiting Norway's hydro potential strong in EU, low in Norway (focus on Nordic Countries)
- No CCS, high RES share
- Storage technologies at distribution grid level
- Lack of flexibility and storage + low competition to Norwegian hydro
- Limited transmission grid expansion due to low public acceptance
- EU-wide power market only for trade on long 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	Day-ahead only
Policy	
Ambitions of countries to connect to Norway	Strong
Options in Strategy 4	Nordic only
Expansion of Norwegian transmission grid	Strong
New PSPP and upgrade of existing HSPP	Limited
Support of variable RES in Norway	Strong
Ambitions of Norway to build interconnectors	Low

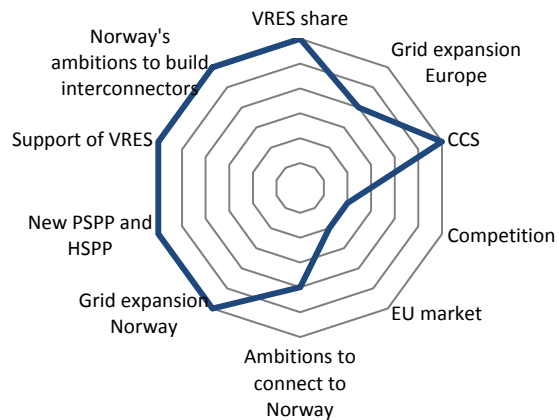
Scenario A - Small storage



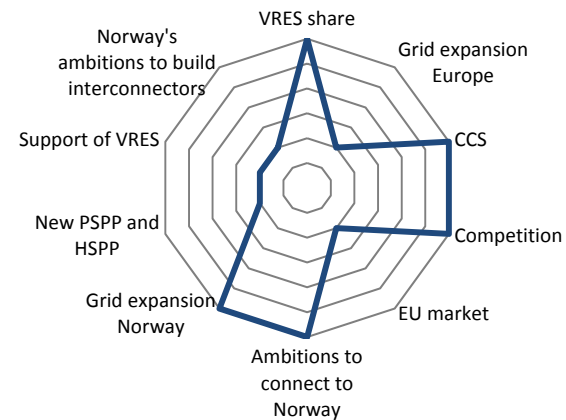
Scenario B - Big storage



Scenario C - Niche storage

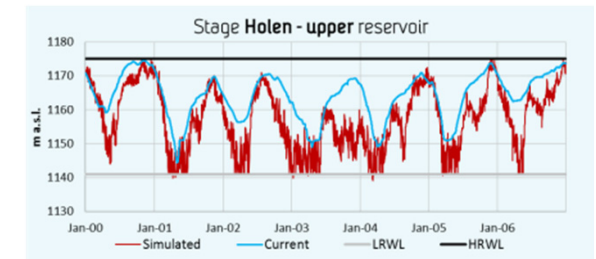
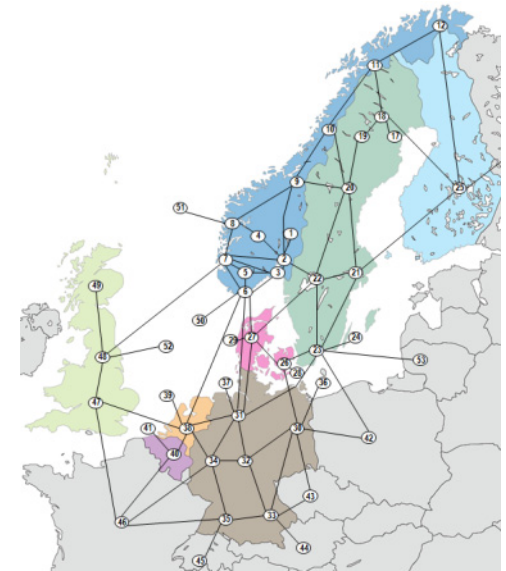


Scenario D - Nordic storage



Use of the scenarios

- Power market model – system perspective
- Power market model, business case – single producer's perspective
- Change in reservoir regulation regimes: impacts of water level fluctuations on fish populations
- Stakeholder interviews: communication of different pictures of the future





Thank you for your attention

Centre for Environmental Design of
Renewable Energy (CEDREN)

julian.sauterleute@sintef.no

www.cedren.no



NATURHISTORISK MUSEUM
UNIVERSITETET I OSLO

