Scenarios for large-scale balancing and storage of variable electricity sources from Norwegian hydropower

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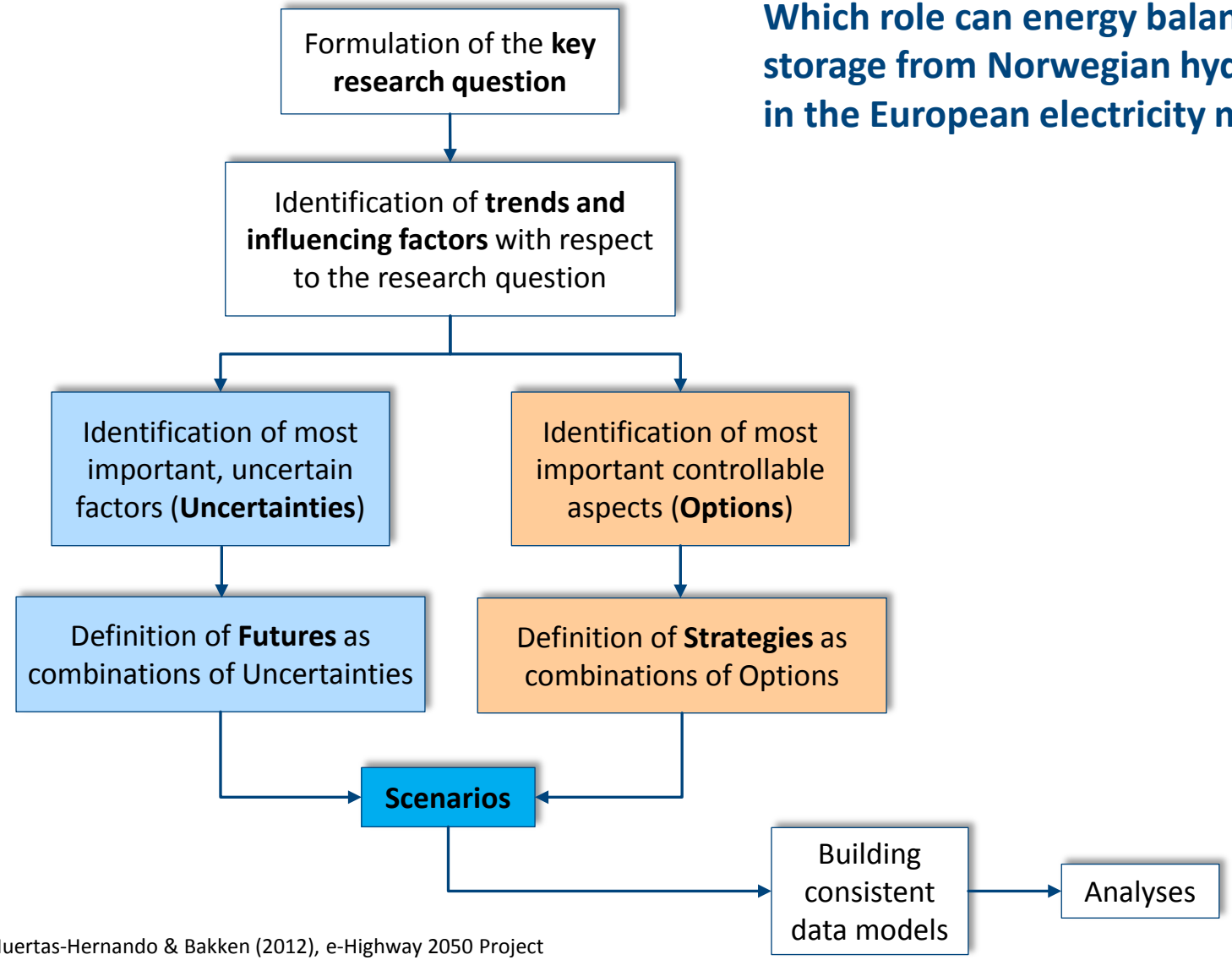
Scenario building approach



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 scenarios build on the following most important uncertainties:
  - Market framework and business models, market integration
  - Level of competition between flexible technologies in European market
  - Share of variable RES
  - Demand for flexibility from Norwegian hydropower
  - EU and national policy
- What is a consequence of policies?
- What is considered as prerequisite?

Structuring of workshop results

- Selection of most important uncertainties to be used in scenarios for the project
- Selection and modification of *Futures*
  - Compliance with defined premises?
  - Relevance for the project objectives?
  - Lack of differentiation between *Options* and *Uncertainties*?

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

Implies large amounts of balancing from Norway

yes

no

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	Medium	High	High	High
Expansion of European transmission grid	Strong/Moderate/Limited	Moderate	Moderate	Strong	Limited
Deployment of CCS	Yes/No	Yes	No	No	No
Market					
Competition from alternative flexible technologies	High/Low	Low	High	Low	Low
EU regulatory framework and market integration	Fully integrated/Day-ahead only	Fully integrated	Day-ahead only	Fully integrated	Day-ahead only
Policy					
Ambitions of countries to connect to Norway	Strong/Moderate	Moderate	Moderate	Strong	Strong
Assumptions - constant *Uncertainties*					
GHG emission reductions in Europe	High	High	High	High	High
Electricity demand	Increase	Increase	Increase	Increase	Increase
Maturity of RES technology	Mature	Mature	Mature	Mature	Mature
Maturity of DSM technology	Mature	Mature	Mature	Mature	Mature
Maturity storage technologies at distribution grid level	Mature	Mature	Mature	Mature	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	Strong	Moderate	Strong	Strong
New PSPP and upgrade of existing HSPP	Limited/Moderate/Strong	Strong	Moderate	Strong	Limited
Support of variable RES	Low/Moderate/Strong	Strong	Moderate	Low	Strong
Ambitions of Norway to build interconnectors	Low/Moderate/Strong	Strong	Moderate	Strong	Low

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

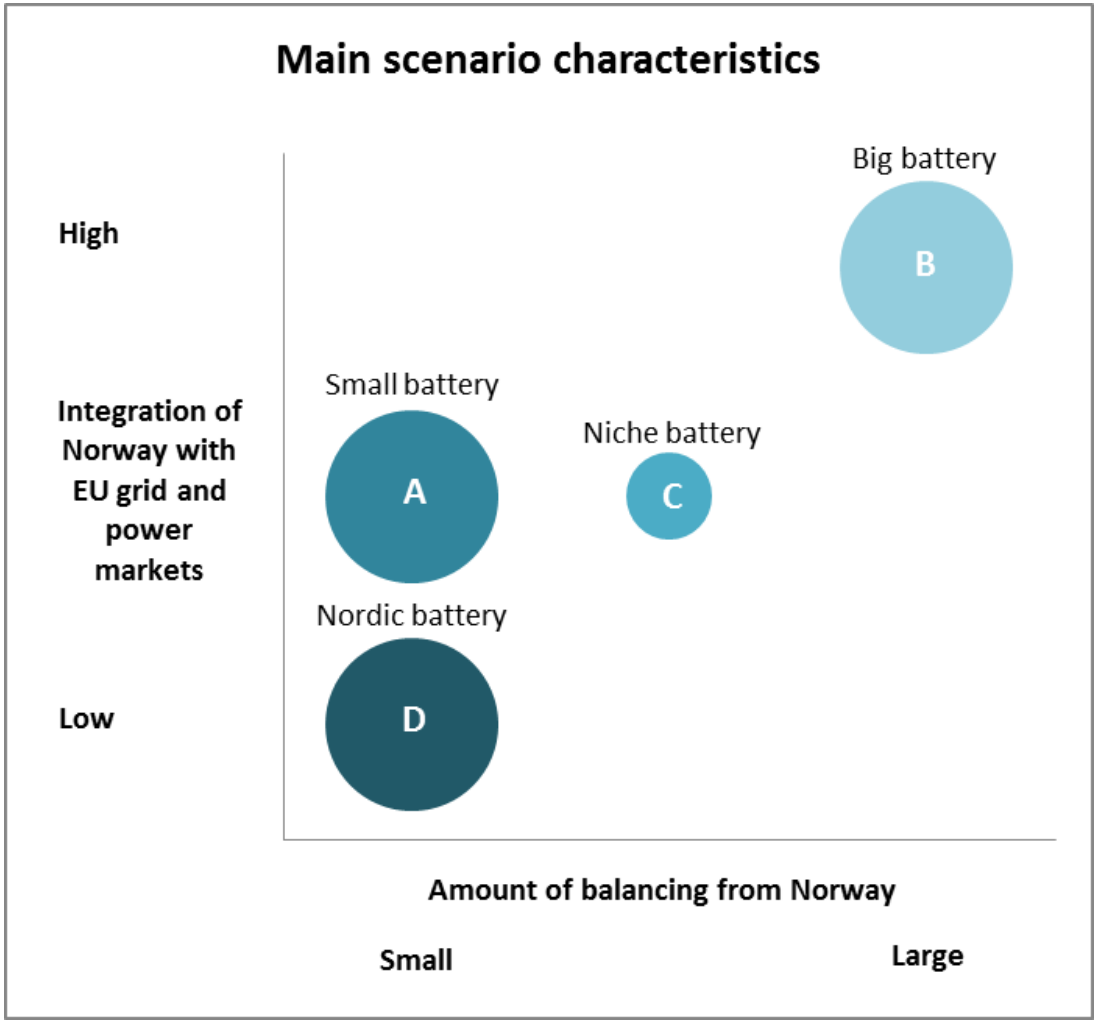
Grey shades: Scenarios with similar outcome

Borders: Four selected scenarios

Selected scenarios:

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

Scenarios


Main scenario characteristics
Big battery
B
High
Small battery
A
Integration of Norway with EU grid and power markets
Niche battery
C
Nordic battery
D
Low
Amount of balancing from Norway
Small
Large

Scenario A – Small 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 in 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 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 in 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 – Niche battery

- 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

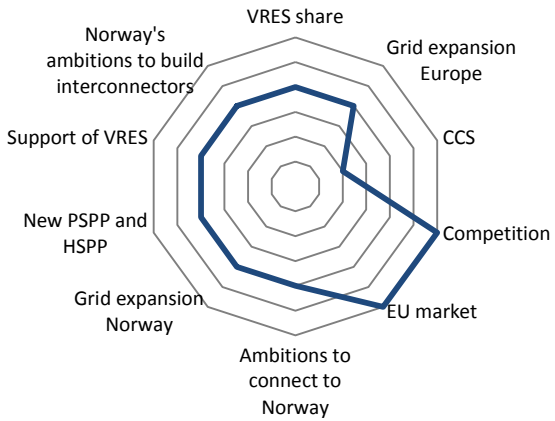
Uncertainties in Future 2	**Niche market**
Technology	
Variable RES share of electricity generation	High
Expansion of European transmission grid	Moderate
Deployment of CCS	No
Market	
Competition from alternative flexible technologies	High
EU regulatory framework and market integration	Day-ahead only
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	Low
Ambitions of Norway to build interconnectors	Strong

Scenario D – Nordic battery

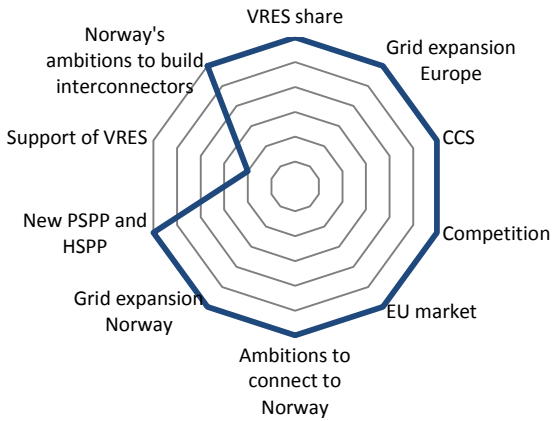
- Ambitions for exploiting Norway's hydro potential strong in EU, low in Norway (focus on Nordic Countries)
- No CCS, high RES share
- Storage technologies at distribution grid level
- Lack of flexibility and storage + low competition to Norwegian hydro
- Limited transmission grid expansion due to low 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	Strong
Ambitions of Norway to build interconnectors	Low

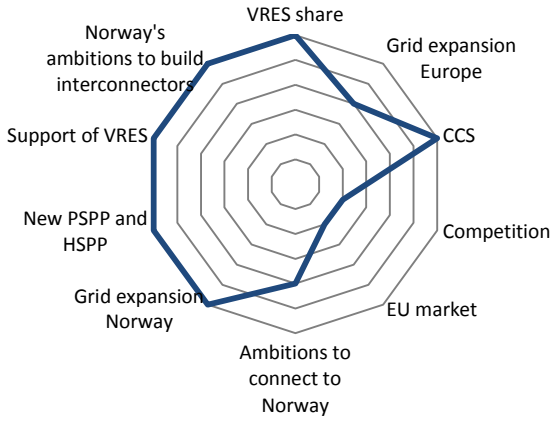
Scenario A - Small battery



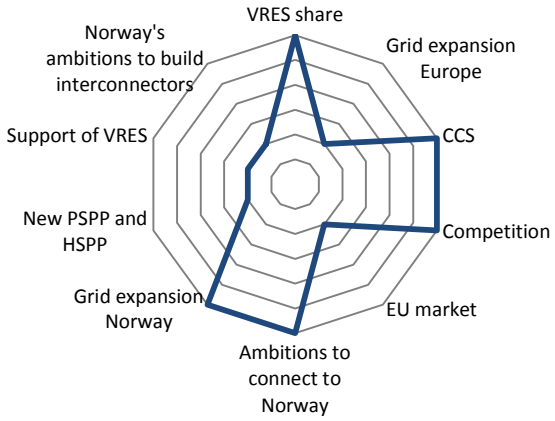
Scenario B - Big battery



Scenario C - Niche battery



Scenario D - Nordic battery







Thank you for your attention

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