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HydroBalance Workshop on Scenario Development, 24-25 March 2014 in Amsterdam, Netherlands	Workshop participants, CEDREN members and other interested recipients
AUTHOR	DATE
Julian Sauterleute	22/05/2014

Workshop on the development of scenarios for large-scale energy balancing and storage from Norwegian hydropower

Summary of the HydroBalance Workshop at ECN in Amsterdam, Netherlands

24-25 March 2014

Contents

1 Introduction

This document summarises the outcome of the workshop on the development of scenarios and business models for large-scale energy balancing and storage from Norwegian hydropower within the project *HydroBalance – Large-scale balancing and energy storage from Norwegian hydropower*. The workshop took place on March 24th and 25th 2014 and was hosted by ECN, the Energy Research Centre of The Netherlands, in Amsterdam.

The HydroBalance project is part of the research centre CEDREN and will develop a roadmap for the deployment of large-scale energy balancing and storage in Norway. The roadmap will show potential developments of using the flexibility and storage potential of the Norwegian hydropower system in order to balance and store energy and provide related services to the European electricity market. The roadmap aims at pointing out steps in the process of deploying the flexibility of Norwegian hydropower with large amounts of pumped storage, drawing time lines for such use of hydropower until the year 2050, and addressing drivers and limitations regarding the political framework, environmental requirements, public acceptance, business models and investment needs.

The primary objective of *HydroBalance* is to address key challenges to the use of Norwegian hydropower for large-scale energy balancing and storage related to technology, economy, environment and society. The project will draw pictures of the future for the use of hydropower flexibility towards 2050, assess alternative solutions to cover the need for energy balancing and storage, analyse different markets and business models, investigate environmental consequences in reservoirs, and evaluate regulatory conditions with respect to public acceptance.

HydroBalance will build scenarios for the potential exploitation of the hydro storage and pumped storage potential in Norway and provision of energy balancing and storage to the European electricity market. The main purpose of the scenarios is to define the scope, boundary conditions and framework for the analyses carried out in the other work packages. These scenarios are an essential step in the roadmap development; they provide the basis for the analyses whose results will feed back into the roadmap later in the process.

The workshop had its focus on scenario development, while one of the four sessions was dedicated to the work package Business Models. The first session was an introductory session with presentations* of perspectives from other countries that are relevant for the development of the HydroBalance scenarios. The second and third session were dedicated to group work on scenario development (see also Appendix A1). The goal of the group work was to get valuable input for building the scenarios and to achieve active participation of the project partners in the scenario building process.

*The presentations are available on the CEDREN e-Room:
https://project.sintef.no/eRoomASP/DlgChooseClient.asp

2 Workshop process

Two group work tasks were designed. In the scenario building process, they are located in the definition of possible *Futures*, according to Figure 1. The first task was on the selection of the most important *Uncertainties*; the second one on the description of possible *Futures*. Three groups worked in parallel on the same tasks, and each of them presented their results in plenum afterwards. The same groups continued with working on the second task, based on the results of all groups from the first task.

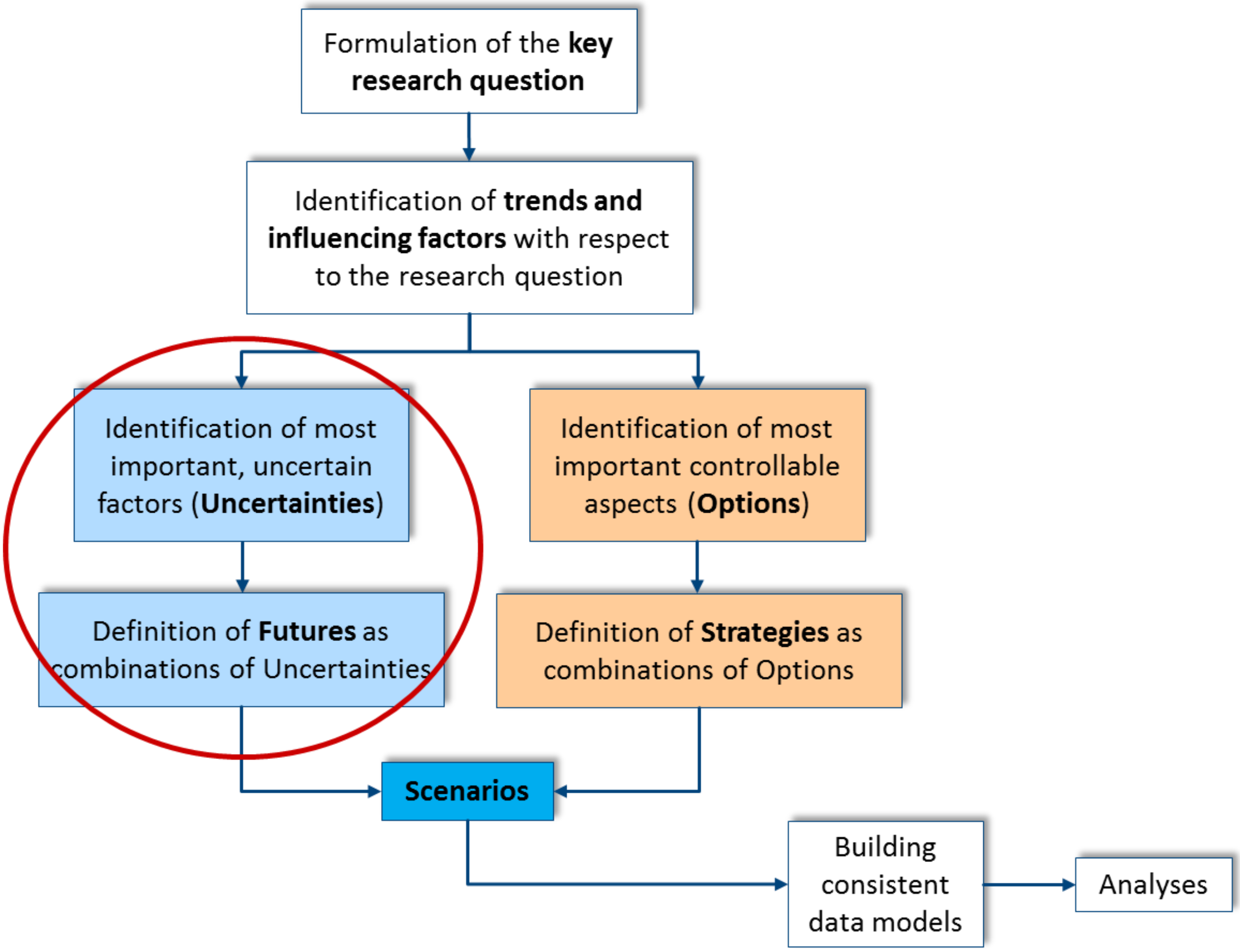


Figure 1: Schematic illustration of the scenario building process in the *HydroBalance* project. The red circle indicates where in the scenario building process the group work tasks during the workshop were located: Selection of most important *Uncertainties* and Definition of *Futures*.

3 Premises for the scenarios

3.1 Key research question:

The scenarios are to be developed in relation to the following focus, formulated as a question:
Which role can energy balancing and storage by Norwegian hydropower play in the future European electricity market?
Selection of important uncertainties, main drivers for the scenarios and prioritisation of drivers are to be made from the perspective of this key focus.

3.2 Time horizon:

HydroBalance will build scenarios reaching until the year 2050. Relevant steps on the time line towards 2050 are 2030 and 2040.

3.3 Geographical extent

The focus of *HydroBalance* is on the potential of the Norwegian hydropower system for flexibility from hydro storage and pumped storage. The target customers and demand for balancing services are located in the countries around the North Sea. Therefore, the geographical extent of the focus area comprises Norway, Sweden, Denmark, Germany, Benelux, the United Kingdom and France. However, these countries' energy systems cannot be considered isolated from the rest of the European system. Hence, other European countries will be considered, but on a less detailed level (e.g. higher aggregation for representation in models).

4 Group work tasks

The group work consisted of two tasks (see also Appendix A2). The first one concerned the categorisation and prioritisation of influencing factors along two scales ranging from certain to uncertain and unimportant to important. The suggested categorisation of influencing factors, which the groups used as starting point for their discussions, is given in Figure 2. The second task dealt with the selection of the main drivers for the scenarios (most important *Uncertainties*) and the definition of *Futures* as combination of the main drivers:

Task I

Discuss the uncertainty and importance of the given factors (Figure 2) in relation to the key research question. Which changes would you make, and why? Are there any factors missing that you would consider?

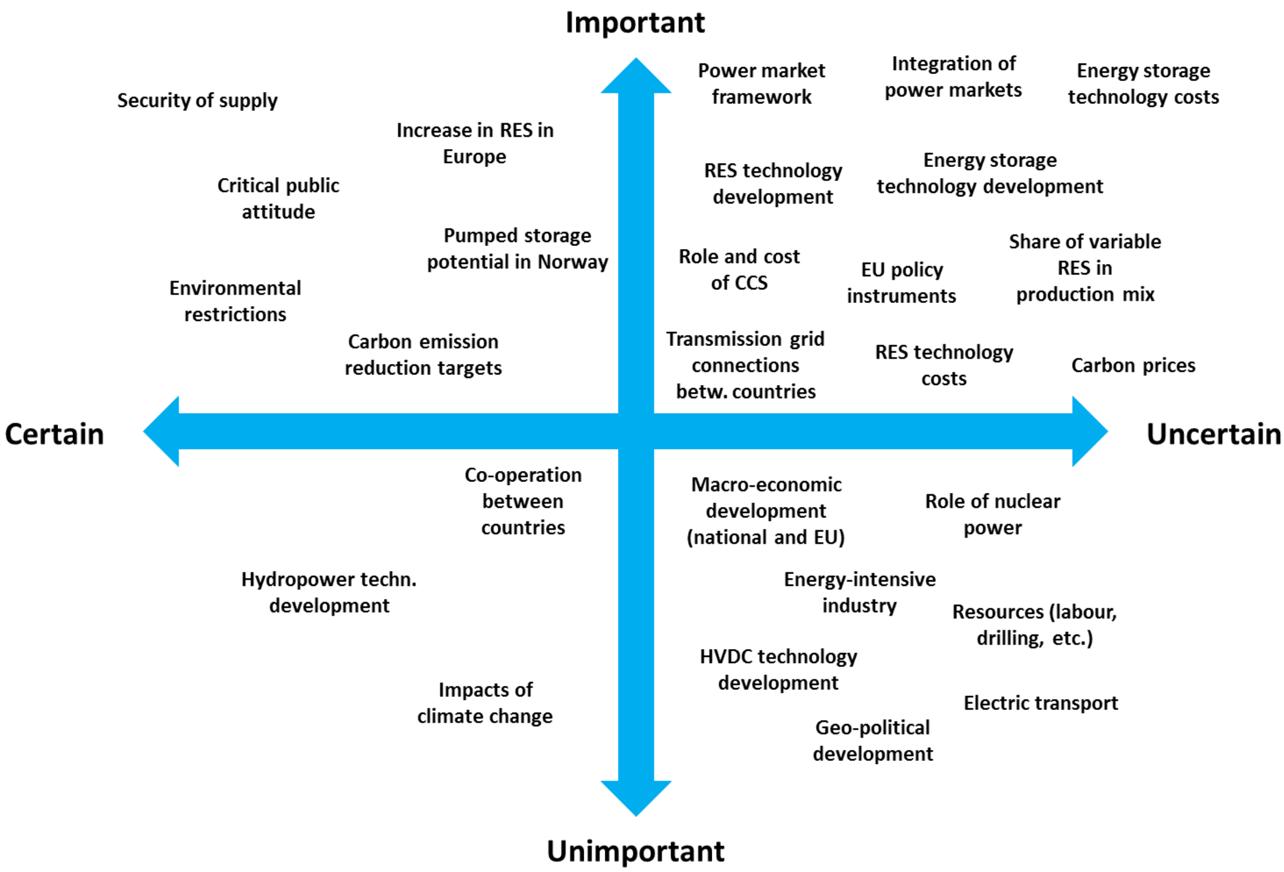


Figure 2: Categorisation of influencing factors in relation to the key research question as it was suggested to the groups as starting point for discussion in Task I.

Task II

a) Based on the results from group work I, identify the two or three most important, uncertain drivers. Combining the main drivers will result in possible *Futures*.
b) How do the main drivers affect the HydroBalance project? Describe the possible *Futures* resulting from combinations of the main drivers qualitatively/in words.

5 Group work results

Task I

Figure 3, Figure 4 and Figure 5 show how the groups categorised the influencing factors regarding their (un)importance and (un)certainty.

Group 1

The share and types of RES was considered to be among the most important uncertainties and taken as a starting point. Another important uncertainty that was pointed out are the costs and availability for alternative technologies providing flexibility, including storage, at a centralised level, while it was assumed to be less important at distributed level. The power market framework and how various markets are organised (integration of balancing markets, intra-day markets, balancing responsibility, etc.) as well as costs and capacities of interconnectors were seen as important and uncertain. RES policy instruments and carbon emission reduction targets were considered as unimportant, since they do not set the prices in the markets, but the technology costs do.

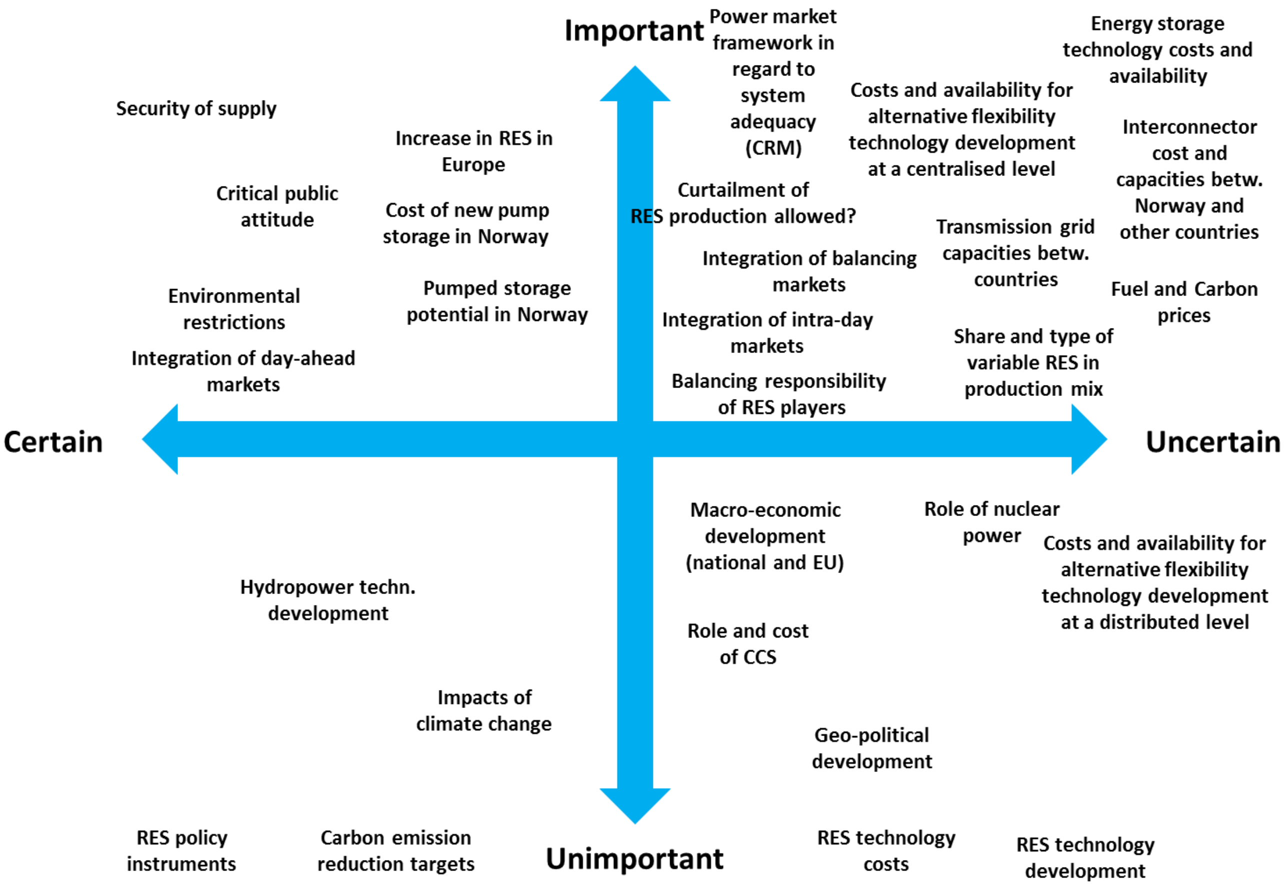


Figure 3: Result of Task I, Group 1.

Group 2

Policy was considered both important and uncertain. The group differentiated between national and international level: On the one hand, the Norwegian policy for the integration with the European power system, on the other hand policy instruments at EU level. Energy storage technology costs were assumed to certainly decrease and to be important, but the level to which costs decline is uncertain. Transmission grid extensions between countries in Europe were seen as important uncertainty because on one side, interconnections from Norway are needed, and on the other side more connections between other countries reduces the demand for flexibility from Norway. Carbon prices and costs and flexibility of CCS as well as demand response were other elements considered as important and uncertain. Increased energy efficiency and the power market framework were assumed to be relatively certain. The local versus global sides of environmental impacts (local natural resources vs. climate mitigation) were pointed out, but considered as rather certain and unimportant.

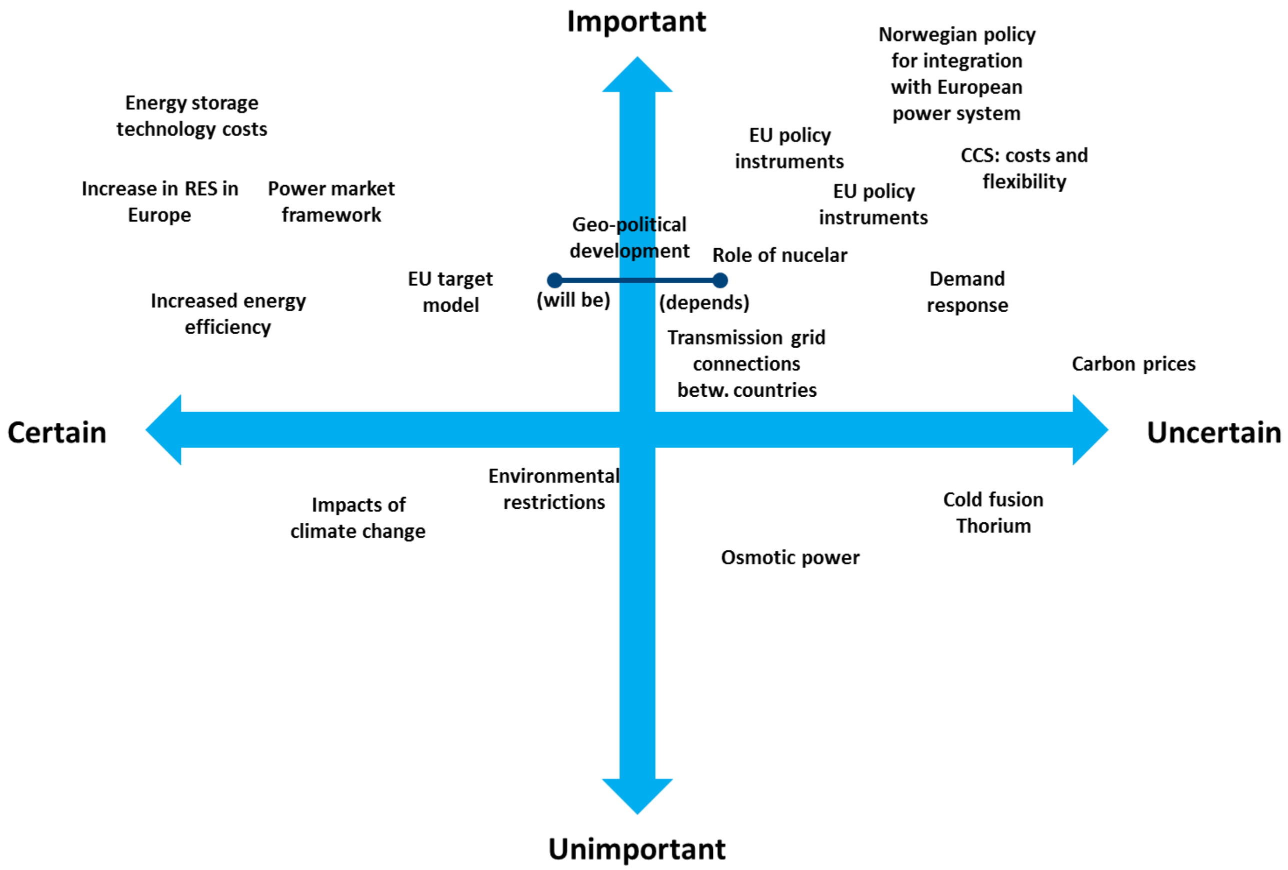


Figure 4: Result of Task I, Group 2.

Group 3

Integration of multiple power markets, the share of variable RES, policy on EU level, transmission grid connections and demand side response were considered as important and uncertain. National and European economic development was also regarded as rather important but uncertain, because a dependency to required investments was seen. The group placed geo-political development among the most important and uncertain factors, because it impacts security of supply and national self-sufficiency, which are important issues for countries and influence to what degree other countries are willing to make themselves dependent on energy delivered by other countries (e.g. EU countries being dependent on flexibility from Norway). Development of energy storage technologies and costs were considered as uncertain but rather unimportant, because large-scale storage over long time periods was assumed to not have any other competitive alternatives than hydro and pumped storage. A critical attitude of the public was regarded as certain and important, and alike for environmental impacts, the local vs. global aspect of it was pointed out.

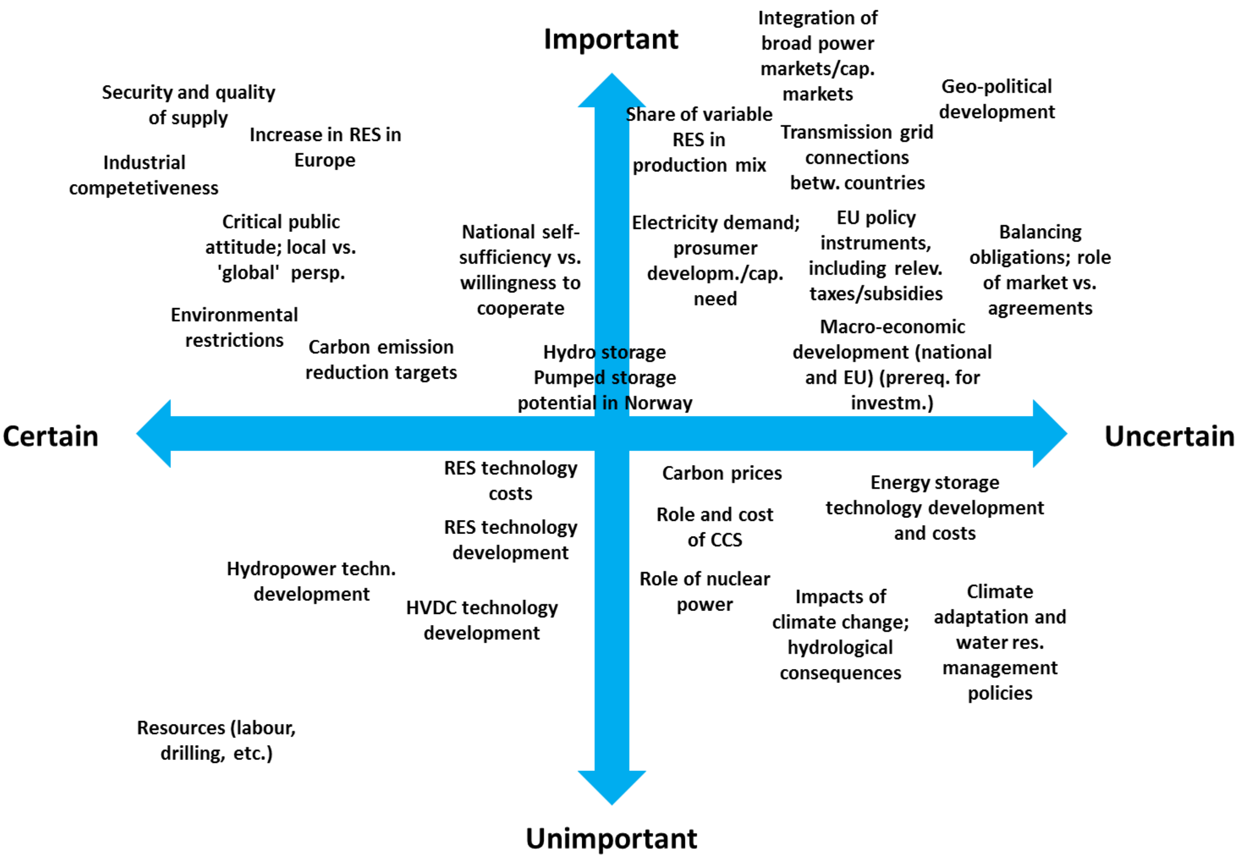


Figure 5: Result of Task I, Group 3.

All groups made substantial changes to the suggested categorisation of the influencing factors (Figure 2). Similarities in the results of Task I were:

1. Increase in RES in Europe, security of supply and a critical public attitude were regarded as certain and important.
2. Transmission grid connections between countries and either the power market framework and integration of markets, or policies determining the markets were considered as uncertain and important.

Task II

<u>Group 1</u>

Most important *Uncertainties*:

1. Share of variable RES in energy mix
2. Costs and availability of alternative technologies for flexibility at centralised level

These main drivers were chosen assuming the following prerequisites:

- Increase in variable RES in Europe, while the share is uncertain
- Power market framework on EU level is established, markets are integrated
- Market for balancing power/flexibility is established on EU level
- Interconnectors Norway - Europe are constructed, European transmission grid is strengthened

Possible *Futures* (Figure 6):

The combinations of two different states of the two main drivers yielded four *Futures*:

1. *Limited*: A medium share of variable RES and high competition from alternative flexible technologies result in limited possibilities for balancing power from Norwegian hydro, because the demand for

flexibility is mostly covered by other flexible technologies than Norwegian hydro in the European market. Hence, small volumes/capacity of the Norwegian hydropower system is utilised and provided to the European market.
2. *Medium*: A medium share of variable RES and low competition from alternative flexible technologies lead to good possibilities for balancing power from Norwegian hydro. Moderate volume/capacity is utilised and provided to the European market.
3. *Niche market*: A high variable RES share in combination with high competition from alternative flexible technologies gives a large demand for flexibility from Norwegian hydro. However, as flexibility from Norwegian hydro is in competition with other technologies in the European market, Norwegian hydropower mainly provides certain types of (e.g. long-term) balancing to the European market.
4. *Various flexibility*: A high variable RES share combined with low competition from alternative flexible technologies results in very good possibilities for Norwegian hydro. Since the central European power system cannot cover its demand for flexibility, the Norwegian hydropower system is utilised for providing balancing power of various type.

The resulting *Futures* may vary somewhat (sensitivity) depending on the balancing capacity of the Norwegian hydropower system, the types of variable RES and fuel and carbon prices.

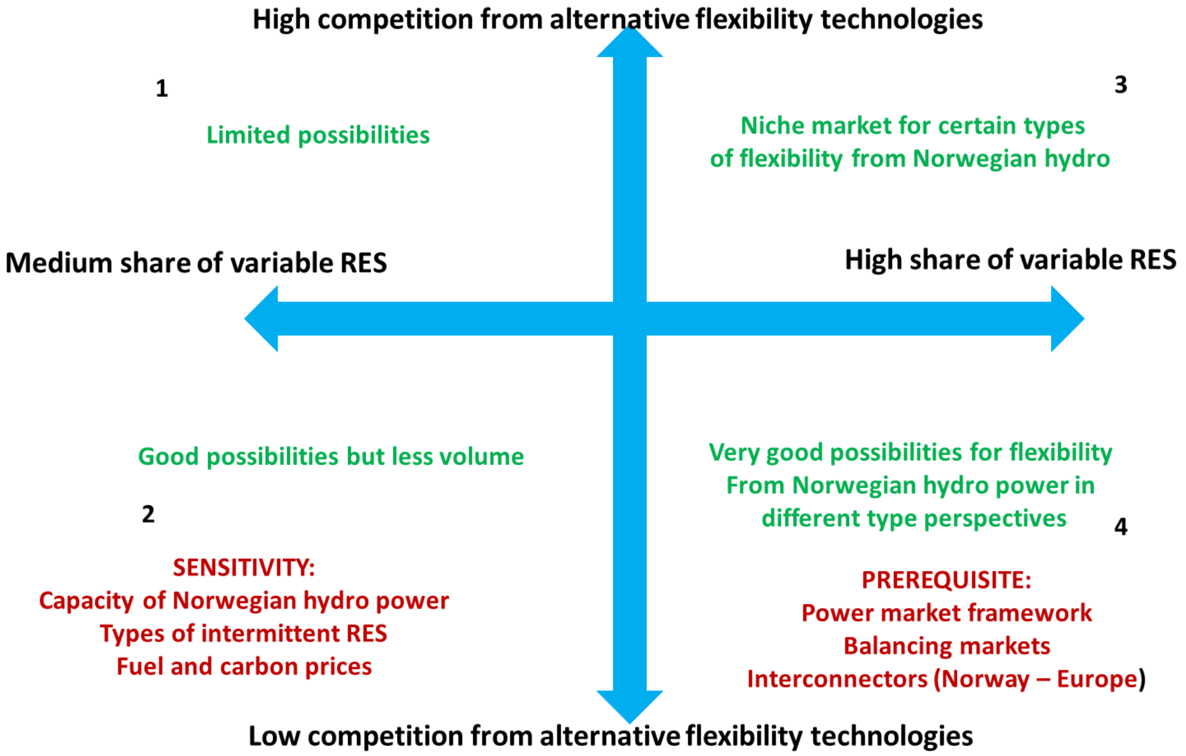


Figure 6: Four *Futures* resulting from medium/high variable RES share combined with high/low competition between Norwegian hydropower and alternative technologies for providing flexibility; increasing demand for balancing from Norwegian hydropower from *Future* 1 to 4.

<u>Group 2</u>

Most important *Uncertainties*:
1. EU and member states policy, particularly on transmission grid and markets
2. Norwegian policy for integration with European power system (positive public attitude, active involvement of authorities, transmission grid)

3. Technology development: level of energy storage technology costs, costs and flexibility generation units with CCS, demand side management

Possible *Futures* (Figure 7):

Fully integrated (1): EU policy creates integrated power markets in the EU, access of the central/western European market to Norwegian hydropower and a strong European transmission grid. The Norwegian government focusses on the topic and makes a policy that leads to good interconnection with the central/western European power grid as well as public acceptance for building necessary infrastructure (generation and transmission) and markets effects (e.g. electricity prices). The EU achieves its emission and RES targets; carbon price is high.

a) *Fully integrated* combined with availability and competitiveness of alternative flexible technologies with Norwegian hydro, such as energy storage, CCS and demand side management; moderate to high demand for balancing from Norwegian hydro.
b) *Fully integrated*, but available alternative flexible technologies are not competitive with Norwegian hydropower. Highest demand for balancing from Norwegian hydropower.

Nationalism (2): EU policy leads to national power markets, and the access of the central/western European markets to Norwegian hydropower is on about the level as today.

a) In Norway, there is no focus on the topic, so that the interconnections to the European markets are not strengthened. Alternative flexible technologies are competitive with Norwegian hydropower. This results in that the EU can achieve its emission and RES targets; carbon price is high. No demand for balancing from Norwegian hydro.
b) In Norway, focus on policy leads to new connections to central/western European power markets based on bilateral agreements with EU member states. The need for them arises from alternative flexible technologies not being competitive with Norwegian hydro. However, this results in that the EU cannot achieve its emission and RES targets; carbon price is low. Low to moderate demand for balancing from Norwegian hydro.

Non-interested Norway (3): EU policy creates integrated power markets in the EU, access of the central/western European market to Norwegian hydropower and a strengthened European transmission grid. However, Norwegian policy leads to no further interconnections to the European markets and limited public acceptance for building infrastructure and markets effects.

a) Availability and competitiveness of alternative flexible technologies ensures that the EU achieves its emission and RES targets; carbon price is high. No demand for balancing from Norwegian hydro.
b) Available alternative flexible technologies are not competitive with Norwegian hydro; hence, the EU has to take high costs to achieve its emission and RES targets. No to low demand for balancing from Norwegian hydro.

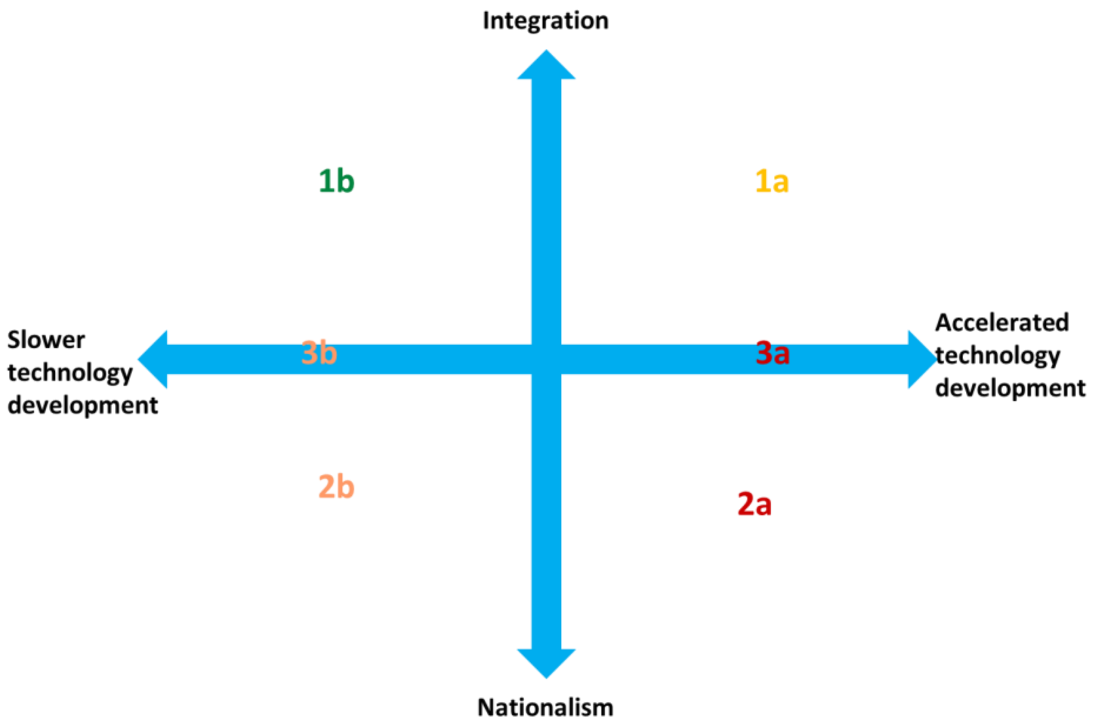


Figure 7: Six *Futures* as a result of combining EU-wide integrative policy versus nationalistic policy and low versus fast technology development (competitiveness of alternative technologies providing flexibility). The resulting level of balancing power provided by Norwegian hydropower is indicated by colours: none (red), low (light red), moderate (yellow), high (green).

Group 3

Most important *Uncertainties*:

1. Power market framework for short-, medium- and long-term balancing
2. Regulatory regime and business models for interconnectors
3. Demand for flexibility from Norwegian hydropower

The group regarded it as important to differentiate the market framework for the power market and the interconnectors. The main drivers were selected assuming that flexibility from Norwegian hydropower is competitive with other technologies and economically viable, at least regarding specific types of flexibility (i.e. long-term balancing). Hence, demand is given, at least at a moderate level. Transmission grid expansion and construction of interconnectors was not regarded as main driver because this was assumed to be a step-wise, parallel development which is triggered by other elements, like market framework, when they are realised. Furthermore, the framework for the balancing market and the regulatory regime and business models for interconnectors were assumed to result from corresponding policy on both EU and Norwegian level. Strong increase in variable RES in Europe was taken as a prerequisite.

Possible *Futures* (Figure 8):

1. *Critical security of supply*: Moderate to large demand for flexibility, depending on the variable RES share, in unfavourable market/business model conditions for both the balancing market and interconnectors results in situations with critical state of security of supply.
2. *Continental solution*: The combination of favourable framework for the balancing market with unfavourable regulatory framework and business models for interconnectors leads to a situation where Norway provides some balancing power to the European market, but mostly the large demand for flexibility in Europe is covered by other flexible technologies.
3. *Bilateral agreements*: Regulatory conditions for interconnectors are favourable, but an unfavourable balancing market framework induces bilateral agreements between Norway and neighbour countries. This only allows for provision of small amounts of balancing power from Norway.

4. *Small hydro battery*: Both balancing market framework and regulatory framework /business models for interconnectors are favourable. However, moderate demand for flexibility form central/western Europe (e.g. due to competition from alternative flexible technologies) limits investments into infrastructure and the amount of balancing power provided by Norway.
5. *Big hydro battery*: Both balancing market framework and regulatory framework /business models for interconnectors are favourable. Large demand for flexibility from central/western Europe results in large investments in both grid expansion and interconnectors. Norway delivers large amounts of balancing power.

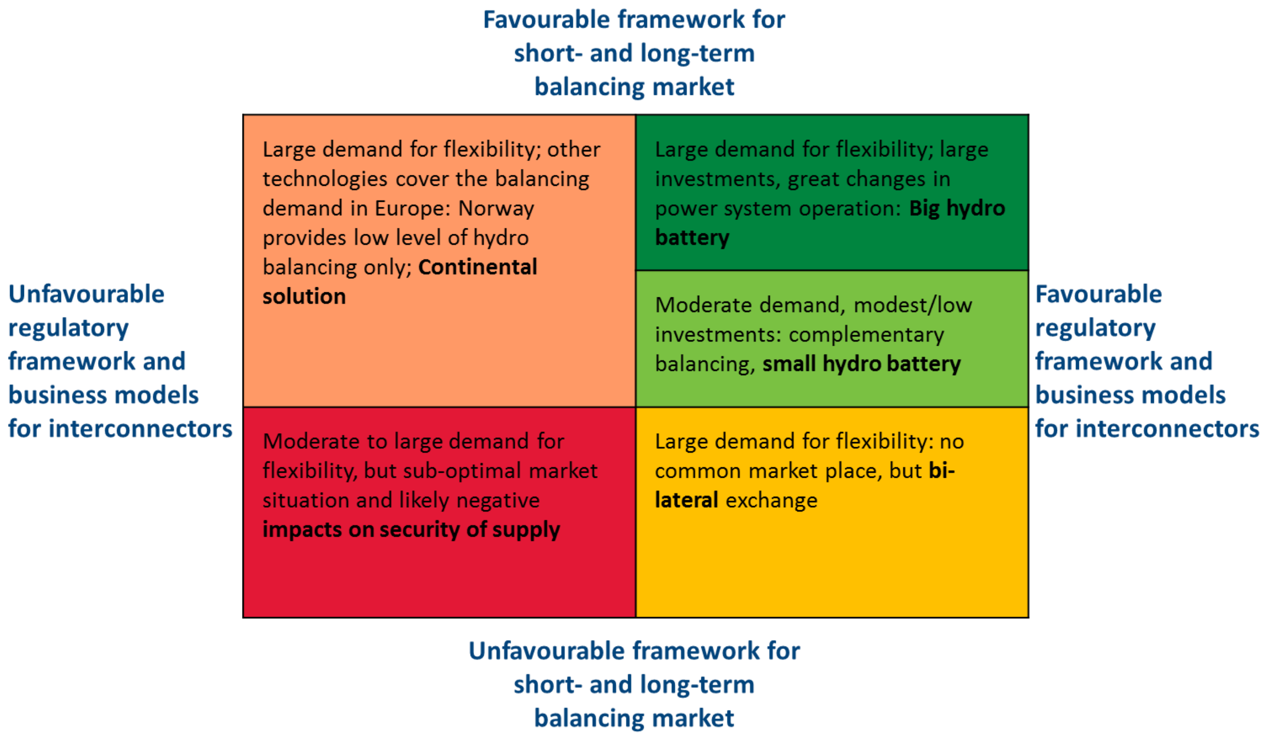


Figure 8: *Futures* as combination of (un)favourable balancing market framework and (un)favourable regulatory framework and business models for interconnectors. The resulting amount of balancing power provided by Norwegian hydropower is indicated by colours: none (red), low (light red), moderate (yellow), high (light green), very high (dark green).

6 Conclusions

In all groups the following factors were among the most important uncertainties, driving the possible *Futures*:

- Market framework and business models, integration of markets across Europe
- Level of competition between flexible technologies on European market
- Share of variable RES in Europe
- Demand for flexibility from Norwegian hydropower
- EU and national policy

In general, it was recognised that for some factors (e.g. policy, environmental impacts), it is important to differentiate between geographical perspectives/levels. On the one hand there is the EU level, on the other hand there is the member state level, which includes national policies, and Norwegian policy in particular.

Throughout the group work it became clear that the selection/prioritisation of the main drivers depends on which level the perspective on the energy system is set on, and which elements are considered as prerequisites for other developments. Examples are:

- The increase in the share of variable RES in the European energy system can be considered as a prerequisite, because the share has been rising throughout the last years, and there are policies in place that support this development, at least until 2020. However, it is uncertain how large exactly the share will be.
- The market framework and business models are very likely to be a consequence of policy, both on EU and national level, determining the economic viability of flexibility by Norwegian hydropower.
- The demand for balancing by Norwegian hydropower is a basic requirement for making a business case, and can be seen as being determined by the share of variable RES in the European energy system and how strong alternative flexible technologies will compete on energy balancing and storage provided by Norwegian hydropower.

Appendices

A1 Workshop agenda

A2 Group work tasks

A3 List of participants

A1: Workshop agenda

HydroBalance Workshop on Scenario Development

24-25 March 2014

at Energy Research Centre of the Netherlands (ECN)

Radarport Building, Radarweg 60, 1043 Amsterdam

Agenda

Monday, 24 March

09.30-10.00	**Arrival and registration**
	Intro and presentation of relevant scenario studies in Europe
10.00-10.25	Welcome, introduction and background for the workshop *Atle Harby and Julian Sauterleute, CEDREN/SINTEF Energy Research, Norway*
10.25-10.50	Scenario analyses in relation to large-scale balancing at ECN *Paul Koutstaal, Energy Research Centre of the Netherlands*
10.50-11.15	Pathways for energy storage in the UK *Jonathan Radcliffe, Centre for Low Carbon Futures, United Kingdom*
11.15-11.40	Development of scenarios for pumped storage in the eStorage project *Derek Riezebos, DNV GL, Netherlands*
11.40-12.05	Working with energy scenarios – scenario building and analyses *Ingeborg Graabak, CEDREN/SINTEF Energy Research, Norway*
12.05-13.30	Lunch break
	Group work on scenario development
13.30-13.45	Introduction to group work I *Julian Sauterleute, CEDREN/SINTEF Energy Research, Norway*
13.45-15.45	Group work I: Discussion of (un)certain and (un)important factors
15.45-16.15	Coffee break
16.15-17.15	Summary of group work and discussion in plenary
20.00	Dinner in central Amsterdam

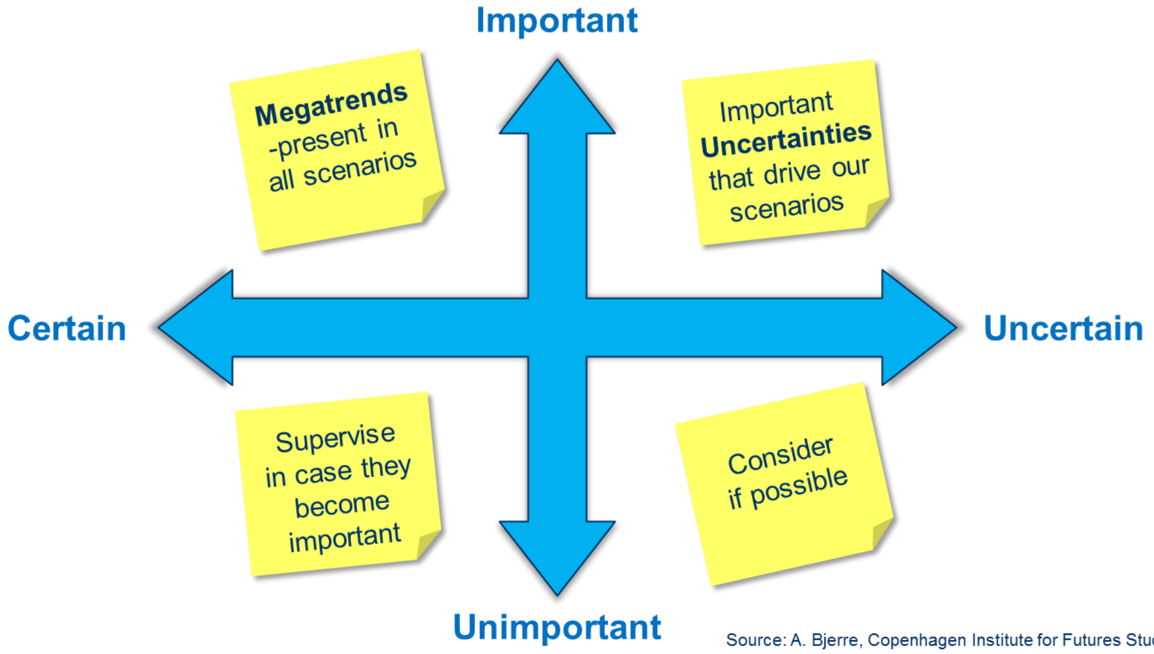
Tuesday, 25 March

08.30-08.45	Introduction to group work II
08.45-10.45	Group work II: Selection of main drivers and description of possible futures
10.45-11.00	Break
11.00-11.45	Summary of group discussions in plenary
11.45-12.00	Discussion and wrap-up of scenario group work in plenary
12.00-13.00	Lunch
	Session on business models
13.00-13.25	Plans for HydroBalance work package 3 - Business Models *Ove Wolfgang, CEDREN/SINTEF Energy Research, Norway*
13.25-13.50	Utilization of hydropower's flexibility, and transmission capacity allocation *Hege Eiken Hartveit, Statkraft, Norway*
13.50-14.15	ECN's approach and methodology for analysing the value of flexibility *Ozge Ozdemir, ECN, Netherlands*
14.15-14.30	Break
14.30-16.00	Discussion on WP3: - Participants' interest and views - Methodologies and focus - How can alternative scenarios be addressed in practice?
16.00	End of workshop

A2: Group work tasks

Group work I

Scenarios are inherently uncertain. They are a means to deal with uncertainty, structure trends, prioritise or weigh influencing factors, simplify the real world, and handle assumptions consistently. The first group work task will address both uncertainty and importance of various influencing factors. These factors can be divided into four categories along the two scales: from uncertain to certain and unimportant to important (see figure below).



Source: A. Bjerre, Copenhagen Institute for Futures Studies

Task: Discuss the uncertainty and importance of the given factors in relation to the key research question [Which role can energy balancing and storage by Norwegian hydropower play in the future European electricity market?]
Which changes would you make, and why?
Are there any factors missing that you would consider?

Group work II

Selection of important uncertainties (main drivers) and definition of possible Futures:

a) Based on the results from group work I, identify the two or three most important, uncertain drivers. Combining the main drivers will result in possible Futures.
b) How do the main drivers affect the HydroBalance project? Describe the possible Futures resulting from combinations of the main drivers qualitatively/in words.

A3: List of participants

Name	Affiliation	Country
Agnes Nybø	DVN GL	Norway
Atle Harby	SINTEF Energy Research	Norway
Bernd Calaminus	EnBW	Germany
Damien Folliot	EDF	France
Derek Riezebos	DVN GL	Netherlands
Håkon Egeland	Statkraft	Norway
Hege Eiken Hartveit	Statkraft	Norway
Ingeborg Graabak	SINTEF Energy Research	Norway
Jonathan Radcliffe	Centre for Low Carbon Futures	United Kingdom
Jørgen Knudsen	SINTEF Energy Research	Norway
Julian Sauterleute	SINTEF Energy Research	Norway
Michaela Harasta	E.on	Germany
Ove Wolfgang	SINTEF Energy Research	Norway
Ozge Ozdemir	Energy Research Centere of the Netherlands	Netherlands
Paul Koutstaal	Energy Research Centere of the Netherlands	Netherlands
Trygve Doble	Agder Energi	Norway

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Renewable energy respecting nature

CEDREN Centre for Environmental Design of Renewable Energy

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH