Energy 2020+

Report from a foresight project

Norges forskningsråd | fore sight

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The Research Council of Norway

The Research Council of Norway
P.B. 2700 St. Hanshaugen
0131 OSLO
Phone: (+47) 22 03 70 00
Fax: (+47) 22 03 70 01
bibliotek@forskningsradet.no
www.forskningsradet.no
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Introduction

The Research Council wants to encourage a broad-based, open dialogue about the ranking of priorities in research and innovation policy. As a step towards introducing more dialogue-based working methods in the planning of major research initiatives, in 2004 the Research Council launched 'Foresight' as a way of working. Five central fields were selected for the launch of Foresight projects. These were aquaculture, biotechnology, materials technology, ICT and energy, where the project *Energy2020+* was concluded in June 2005. This is the final report from the project.

Energy 2020+ was conducted under the auspices of the Research Council. Research communities, business and industry, the authorities and other stakeholders were invited to make suggestions and participate actively in the process. A number of individuals with no professional involvement in the field of energy were also invited to participate. The following is a brief description of the methods applied to the Foresight Project.

Methodology

What is foresight?

Foresight has several practical areas of application, including research and innovation, and is currently used as a general label applied to different projects and initiatives intended to influence future developments. Foresight is the subject of an animated debate in the EU and the USA. It involves a large and growing number of methods, techniques and approaches that can be applied to foresight-oriented development projects. Confidence in prognoses and classic planning methods have been impaired.

Foresight is all about professionalising discourse about the future. Foresight is about participation and involvement, about sharing knowledge and nurturing ideas, about new working methods and cooperation constellations. Foresight is knowledge-based and can serve as the basis for decisions and the ranking of priorities that are robust in the face of an uncertain future.

Four main components – four sessions

The Foresight methodology applied in *Energy 2020+* is based on a process that we have divided into four main activities and discussed in four separate sessions. The basic idea is that invited participants contribute to and shape the content and direction of the programme throughout the Foresight process. The preliminary results from each session were adapted by the secretariat in the interims between the sessions, forming in turn the foundation for the further efforts at the next session. The main assignments at the four sessions were:

- Session 1: Identification of players and factors/ forces that will impact the energy sector in 2020+.
- Session 2: Construction of mini-scenarios (events, progression, developments), including the players and factors identified at Session 1.
- Session 3: Fleshing out the mini-scenarios into more complete scenarios within certain parameters.
- Session 4: The identification of opportunities and challenges in the main scenarios that can lead to prudent initiatives and measures in the field of research; research strategy recommendations.

The process is illustrated in the figure below.

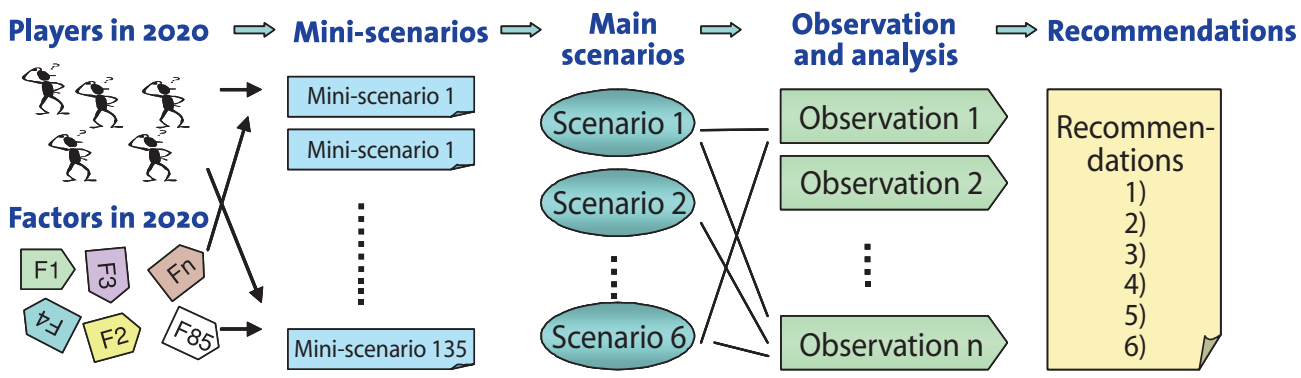

Figure 1. The main components of the Foresight process related to Energy 2020+

Session 1 – Players and factors

This session was intended to familiarise participants with our plans for implementing the scheme, as well as to carry out a group process to identify the factors and players that could conceivably impact the energy sector between now and 2020. Divided into five groups, the roughly 50 participants were confronted with the following issues:

1. Which circumstances (factors) could impact the Norwegian energy sector in the next 15 to 20 years? Make a list of the factors you think might have a major impact. Explain why you think they are important.
2. Which players (decision makers, institutions, companies, government agencies, etc.) could conceivably influence the development of the energy industry in the run up to 2020? They need not be important players at present, but can just as well be potential future players expected to have a major impact in future. Make a list of the most important players and explain why you have chosen them.

The session resulted in a collection of 70 factors, divided into eight main categories:
• The environment
• Resources
• Technology
• Expertise
• Attitudes, demographics and social conditions
• Market conditions and economic development
• Politics
• Conflicts

Further, agreement was reached regarding a list of 60 players divided into nine main categories:
• Supranational authorities
• Major energy companies
• Manufacturers of goods and services
• Superpowers
• Opinion-makers
• The general public
• Human resources developers
• National authorities
• Extremist organisations

The overall list of factors/forces and players formed the point of departure for session 2.

Session 2 – Mini-scenarios

At the second session, participants were divided into eight groups and asked to draw up mini-scenarios based on the identified main categories of players and factors. A mini-scenario is a brief, limited description of a development trend or event related to a few players and/or factors. The different groups were introduced to the different main categories to ensure a variety of mini-scenarios in which all relevant players and factors were discussed. The assignment was worded as follows:

1. The group is to draw up at least five mini-scenarios about what the situation might be like in 2020, given the assigned factors and players. Use the template from the examples you have reviewed. The mini-scenarios should be inherently different and each should be consistent/coherent within the assigned structural parameters. Give each mini-scenario a descriptive title.

Altogether, 132 mini-scenarios were drawn up. The following is an *example* of a mini-scenario:

Mini-scenario:
New Norwegian industry based on CO_2 management supplies the world

"The initiatives FutureGen in the USA and its parallel Hypogen in Europe have succeeded. They have achieved their ambitions to produce power from fossil fuels accompanied by CO_2 management. The IEA's forecast for the percentage of power production featuring pollution-free technology was adjusted up from 17 per cent to 30 per cent, corresponding to the power output of 1000 Kårstø facilities. Norway has managed to capitalise on its R&D investments and, by playing a leading role in pilot projects and R&D, not least through the EU, has managed to move into the forefront in this area. Collective national efforts and the establishment of the new COO-NOR in 2005 have resulted in tremendous success. The company has grown and now supplies CO_2 purification technology all over the world. Counting its multitude of subcontractors, the company now accounts for 20 per cent of Norway's export revenues."

The mini-scenarios were recorded on paper, adapted and systematised according to which development dimensions they discussed. The project group

subsequently reviewed them to determine which type of main scenarios should be developed in the third session.
The 132 mini-scenarios are presented in Attachment 2 to the report (in Norwegian only).

Session 3 – Development of the main scenarios

Session 3 established six groups to combine and process the mini-scenarios from Session 2 to make more comprehensive main scenarios. The mini-scenarios drawn up in session 2 were analysed in advance by the project group, forming the basis for the selection of eight dimensions, described in more detail on page 15. Of the eight, three were chosen as the most important.

Thus the groups were to develop the main scenarios under different conditions with a view to the three dimensions under which the mini-scenarios were categorised. These dimensions were 1) technological change, 2) sustainability and 3) Norwegian influence. More about the main scenarios follows.

Session 4 – Challenges and opportunities revealed by the mini-scenarios, and the ensuing initiatives

This was the last session that brought the external participants together. The point of departure for the session comprised the six main scenarios drawn up on the basis of Session 3. Against that backdrop, the participants were invited to identify challenges and opportunities brought to light by the six scenarios.

Afterwards, a process was conducted to assess which R&D initiatives and other initiatives it would be advisable to implement today to deal with these opportunities and challenges.

The total set of opportunities, challenges and initiatives was then analysed to identify common features, among other things. Collectively, the six scenarios cover a broad sample space. Accordingly, elements that recur in several scenarios constitute a strong platform for robust recommendations.

On the basis of these observations, the project group made its first proposal for strategic recommendations. During this phase, the project group deliberately chose not to let the recommendations be influenced by their own opinions, but to base them exclusively on what had appeared during the process. The recommendations were presented at the conference *'Choices 21'*, inviting comments and observations from four specially-invited commentators and others. These preliminary recommendations, comments and the project group's final recommendations are presented in more detail further on.

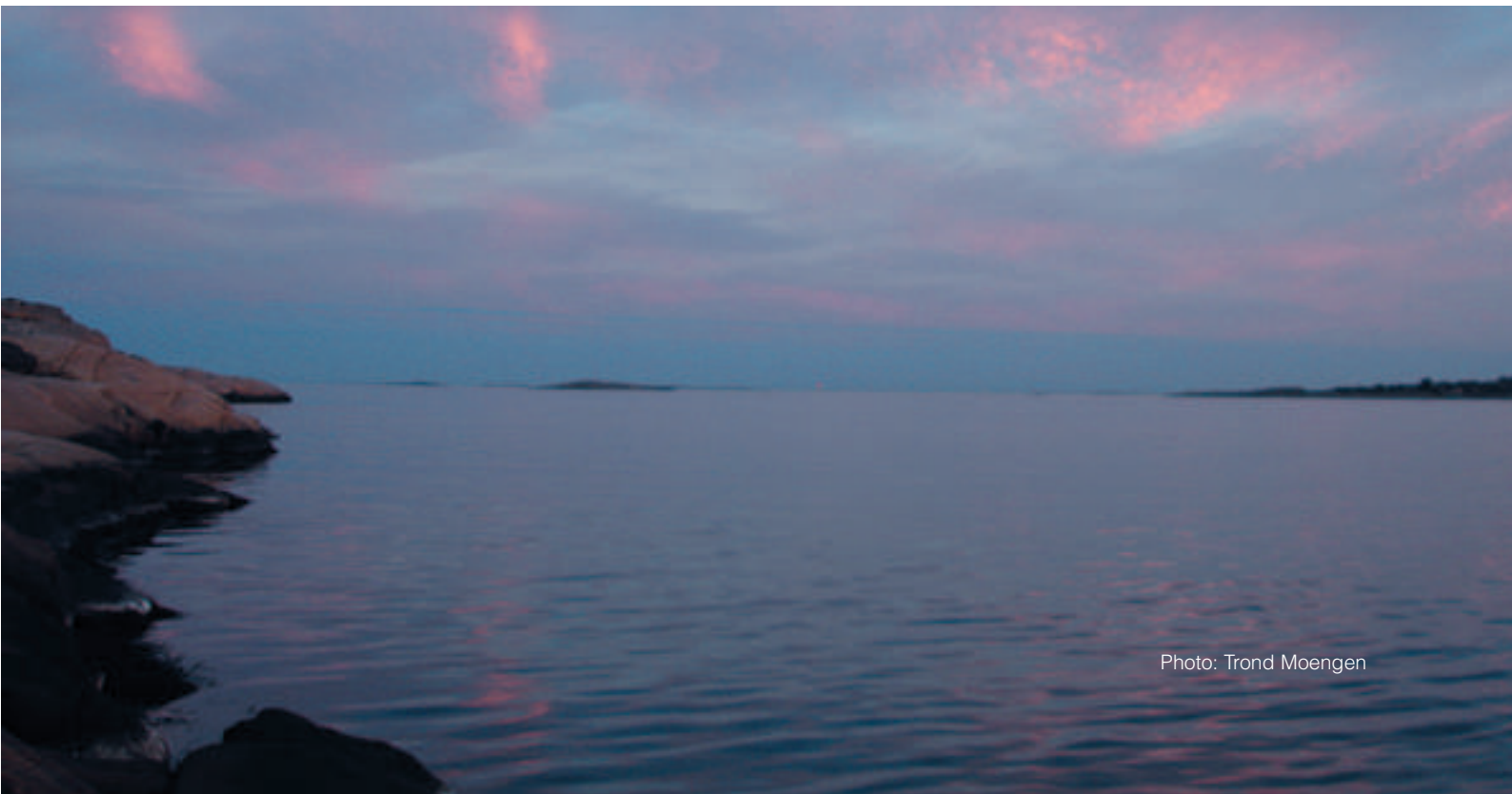

Photo: Trond Moengen

The six main scenarios

Assumptions underlying the scenarios

During the process, the project group focused in particular on clarifying which forces, factors and players are expected to be important in the next 20 years and beyond. As described above, the most important information for doing this emerged during the sessions. Through post-analyses of the material from the mini-scenarios in Session 2, the project group identified the most important dimensions that impact and to some extent set the parameters for the scenarios envisaged. The most important dimensions identified by the project group are:

- Sustainability: to what extent is it possible to envisage depletion of the world's finite resources, and what is being done to protect important environmental resources such as untouched wilderness, biodiversity, etc., and what are the consequences of this?
- Technological change: to what extent can technological breakthroughs be expected, and what are the consequences if breakthroughs fail to materialise?
- Norwegian influence: which role do or can Norway or Norwegian players be expected to play in the shaping of the future energy systems and markets in Norway and abroad?

The assumptions underlying the descriptions of these three dimensions are decisive for which future scenarios one can expect to see in the field of energy, and likewise which strategic initiatives should be implemented and can be expected to be viable. These three dimensions were used as variables in the design of the six main scenarios.

In addition to the three main dimensions, the following dimensions were identified as important;

- Market orientation: a high degree of market orientation means market laws and market players have a decisive impact on future development;
- Governance: a high level of governance can play a decisive role for national and supra-national authorities;
- Level of conflict: a high level of conflict may imply a high degree of terrorism, military conflicts between countries and regions, and strong cultural and ethnic differences;
- Solidarity: a high degree of solidarity means that collective solutions are common and that solidarity with fellow human beings the world over and with future generations prevails;
- Globalisation: a high degree of globalisation means that development is dominated by international capital interests that operate across national frontiers and with an extensive international division of responsibilities.

		Scenarios					
No.	**Dimension**	*1 - Flower Power*	*2 - The New Clear Deal*	*3 - Full Speed Ahead with Norway*	*4 - The Future in the Hands of Others*	*5 - Advances – step by step*	*6 - Actually, it´s all rather boring, except for the weather*
1	Technological change	H	L	H	H	S	L
2	Sustainability	H	H	L	H	S	H
3	Norwegian influence	H	L	H	L	S	L
4	Market-orientation						
5	Governance						L
6	Level of conflict						
7	Solidarity						
8	Globalisation						

Table 1. When drawing up the six mains groups, the groups that formulated the scenarios were governed by the three main dimensions. The group could vary the other dimensions as desired.
H = high degree L = low degree

Given these constraints, in session 3 the groups drew up six main scenarios that are presented in this chapter.

A short version of the six scenarios is presented on the preceding page under names chosen by the groups themselves and characterised by variations in the three main dimensions. The complete scenarios are available in Norwegian only.

The scenarios are *not* intended to be complete scenarios in the sense that they provide a complete, exhaustive description of a future situation and how to get from here to there. They are the groups' immediate responses to the challenges posed to them, where the point was to elicit a description of the situation they feel might develop in the light of the assumptions that apply.

Photo: Trond Moengen

The scenarios – short version

Flower Power

The world in 2020+ is characterised by creative global solutions to age-old problems. Finite resources are consumed at a reasonable pace and in a manner that preserves important environmental resources such as untouched wilderness and biodiversity. The cost of solar energy is 1/10 of today's, and CO_2 is separated and injected into the ground. The storage problems associated with nuclear waste have also been solved. Hydrogen has seen a breakthrough as an energy carrier in the transport sector after revolutionary solutions were found for both hydrogen storage in nanomaterials and fuel cells based on organic materials. The turning point came when the world's largest economy, China, posed stringent requirements for emissions from cars so that Chinese cities would survive the tremendous growth in the car population.

The low global level of conflict is closely related to the issue of poverty being moved to the top of the agenda, and solidarity being redefined from traditional distribution solidarity to inclusion solidarity, i.e. inclusion in the global development of markets and technology. In 2022, the WU – The World Union – took over from the World Trade Organisation – WTO – and the United Nations – UN. This was because markets were increasingly subject to supranational provisions and constraints, implying little governance through conventional means of regulation, but strong governance relative to the instruments available for innovation policy. Europe has redirected its attention to China, and away from the USA which is in the throes of the deepest crisis in the country's history, including depression, mass unemployment and a huge trade deficit.

Norway plays an important part in global energy policy and promotes development in fields such as solar energy, CO_2 management and the production of smart houses. Norwegian-developed CO_2 management based on natural gas is applied in connection with China's vast coal reserves, making China self-sufficient in environment-friendly energy. Norway is also focusing on tourism and is now considered one of the 'greenest' countries in the world.

The New Clear Deal

After 2020, the situation is distinguished by a new world order, where sustainability is the primary criterion for all decisions. The fierce climatic change up to 2020 and universal acknowledgement that it is attributable to the increase in greenhouse gases provided fertile conditions for international consensus. The dramatic famine of 2020, when 700 million people died as a result of failed harvests, made it clear to everyone that something had to be done.

G8 called on the UN to establish an agency to take the administrative decisions needed to bring the system into balance again. The measures imply quantitative limits on the production, sale and use of fossil fuels. The level has been reduced by 10 percent, and violators are punished. The total focus on sustainability, defined as "entailing no emissions to the atmosphere", has brought about a change in attitudes. In choosing between the plague and cholera, a common understanding developed, along with agreement that nuclear power was the only viable path since major technological breakthroughs had failed to materialise. The new policy was

Borrowed from REC (Renewable Energy Corporation)

named 'The New Clear Deal'. Solar and wind power facilities were built, but since the technology had stood still for the past 20 years, the contribution has been modest.

International trade in goods has been limited to a minimum, and in 2022 the world experienced an economic recession for the first time ‘in living memory’. Opportunities for personal transportation are limited because every family has been allocated an annual petrol ration. Tracked electric-based infrastructure has been developed and has led to changes in people's settlement and living patterns. Now people have to expect to use more time getting about, to travel less and to spend more time with family and friends. The dramatic weather is a constant reminder of the current situation, but otherwise surveys in Norway indicate that people are more content with life now than in 2015 when everything was running full speed ahead.

Full speed ahead with Norway

Significant technical breakthroughs made it profitable to continue an energy system based mainly on fossil fuels. Consideration for sustainability is still secondary both because the consequences of global pollution are diffuse and because the emergence of China and India as global power centres has the swift development of affluence as its highest priority. Moreover, the consequences of environmental changes are also very unevenly distributed, entailing substantial advantages for some countries and regions, and formidable disadvantages for others.

Norway has strengthened its position in the field of energy both as a manufacturer of equipment for efficient oil production from marginal fossil resources and gas hydrates, and as a result of its ground-breaking work with the wireless transmission of energy. However, the cost of achieving this position has been high. Large parts of the Oil Fund have been spent, and Russian oligarchs have bought stakes in key enterprises in Norway. Most of Norway's hydropower and wind power has been developed, and there is little left of untouched wilderness or the Social Democratic principle of equality.

Photo: Reuters/SCANPIX

The Future in the Hands of Others

Frightening climatic events triggered a massive global innovation process in the energy sector that brought extremely positive results. Clean nuclear energy and renewable energy resources are now financially feasible, and electricity can be transported without losses. A sustainable energy system has been established using hydrogen and electricity as energy carriers.

Global development takes place through sophisticated interaction between smoothly functioning market processes and judicious, environmentally-aware authorities. The authorities are concerned with sustainable development, which they facilitate by providing good framework conditions and avoiding micro-management (top-down management). The rapid commercialisation of fusion technology is indicative of how effective innovation processes have become.

Norway has ended up on the sidelines through decisions that gradually reduced its cooperation and interaction with Europe and the rest of the world; technical/scientific research and development are an area in which we have fallen behind. We neglected to continue developing our opportunities in nuclear energy, gambling everything on the development of CO_2-free fossil fuel that will naturally be of little interest now that gas and oil are used exclusively for the production of proteins (fish feed) and valuable special products. Since we failed to set up a national Hydrogen Programme in 2005, we also missed out on the hydrogen trend. Interest in technological research and education is currently at rock bottom.

The world is characterised by a high degree of globalisation, although it only benefits the well-developed countries of the world. It is still a struggle to secure food and affluence 'FOR EVERYONE'. This is because the world's sense of solidarity is at a low level. We do not care about other people's pain; our focus is on solving our own problems.

Advances – step by step

The situation in 2020+ is a result of incremental development in all directions. There is a high degree of globalisation except in the field of energy supply and other vital infrastructure, where regional

Statfjord A. Photo: Statoil

Photo: Trond Moengen

Climatic changes have resulted in more environmental awareness among the general public. Environmental awareness is in vogue. More focus on the environment and little confidence in politicians, as well as the formidable market power wielded by the energy companies have caused consumers to organise. They have acquired so much power that they are pressuring the energy companies into more environment-friendly energy solutions.

Owing to its rather lethargic approach, Norway is not in the mainstream of international developments. There are almost no industrial jobs left, and new technological solutions are imported. Interest in science and technological competence are lower than ever, and university education in these areas has been reduced dramatically or been expatriated. Norway has become a nation that produces raw materials, and provides services based on untouched wilderness. The service sector accounts for almost all employment in Norway.

interests dominate. New production capacity can barely manage to keep up with the ever-increasing demand for energy. The global conscience allocates sufficient resources to develop technology that protects the environment.

Actually, it is all rather boring, except for the weather!

Revenues from oil and gas activities have given Norway a false sense of security, just as many feared. Despite the fact that the world's consumption of fossil resources has not increased much lately, considerable global climatic changes are taking place as a consequence of sins of the past. This has caused the weather in Norway to be 'wetter, warmer and wilder', making the country an attractive destination for thrill-seeking wealthy Asians.

The GDP has stagnated compared with the level at the change of the millennium. Politicians no longer enjoy credibility among the members of the general public. The authorities' role has therefore been reduced considerably, and trends in the field of energy have been left to market forces. Radical technological changes are conspicuously absent. The major energy companies have entered into very powerful international alliances.

Photo: Robert S. Eik

Observations and recommendations baset on a review of the scenarios

Collectively, the six scenarios cover a broad range of issues and each of them identifies a wide range of opportunities and challenges. The scenarios were developed with different emphasis on important dimensions, and they also end differently. All in all, they therefore contain a large number of interesting elements, each of which merits comments and detailed analysis. Despite the fact that they end differently, there are also similarities and common elements in several of them.

This review focuses in particular on the common features that were identified when reviewing these basically completely different scenarios. This has been the source of some interesting observations that are presented below.

Observations

1) Sustainability – the nuclear alternative

In a number of the scenarios that were drawn up, the nuclear power alternative was re-addressed when the consequences of greenhouse gas emissions became severe and sufficiently obvious. The discourse typically runs along the lines of a 'plague or cholera' discussion, and this was especially clear in the scenarios in which there were no strong technological breakthroughs and where new renewable energy sources had not had the desired impact. Nuclear power can be considered 'sustainable' since it has no emissions in terms of greenhouse gases. Notwithstanding, there can be significant safety problems related to operations and waste management (half-life = 26 000 years). More nuclear power in the scenarios was, however, supported by technology for fail-safe nuclear power and expectations that the waste issue can be 'properly' resolved.

Nuclear power as a possible 'wild card' in a future regime where the effects of greenhouse gases become very clear, poses exceptionally challenging questions related to opportunities, challenges, Norwegian participation and the strategic recommendations, if any, they ought to imply.

2) Sustainability – renewable solutions

New renewable energy sources play slightly different roles in the different scenarios. However, all the scenarios are largely based on available renewable capacity, and on environmental effects having a major impact on the pricing of power. The ratio of renewable energy varies; the most critical factors are the degree of obvious environmental problems and the extent to which there are breakthroughs or formidable improvements related to the production of electricity from solar energy. Wind power and bioenergy develop more incrementally in the scenarios.

3) Sustainability – CO_2 management

Several of the scenarios also anticipate the availability of CO_2 management linked either to the pro-

Photo: Trond Moengen

duction of power or to hydrogen from fossil energy carriers. This coincides with the ambitions underlying the Norwegian initiative in this area today. The importance of CO_2 management increases, given that it is also expected to also apply to the use of coal.

4) The intrinsic value of renewable energy
A classic debate that has raged in Norway for decades is 'Norway as a supplier of raw materials'. An examination has been made of other countries that have a higher degree of industrial added value, e.g. Sweden and Finland with Nokia. However, the fact is that such industry is subject to constant and growing competition, not least from lower cost countries, which puts constant pressure on the margins. Most of the scenarios include expectations that renewable electrical power entails added value *per se*, undermining the business-related reasons for refining natural gas or hydropower domestically.

5) Technological change – hydrogen
One technological change that appears repeatedly in several of the scenarios is related to a genuine breakthrough for hydrogen as an energy carrier. This entails the development of cost-efficient solutions for production, storage and conversion. Production typically takes place through electrolysis from renewable resources and from fossil fuels based on CO_2 management. There may be several storage solutions, and no winners were identified explicitly. As regards end users, there was a momentous breakthrough for fuel cells.

6) System change
Common to all the scenarios is that they describe changes in the power supply system compared with what we know today, be the changes major and based on technological breakthroughs or more incremental changes that evolve in more of a 'business as usual' type of scenario. Some features of these changes are closer links between transport and the stationary energy supply, and the integration of decentralised production solutions, as well as decentralised, more autonomous production solutions.

7) Production – end use
The scenarios are traditionally Norwegian with a view to the focus being placed on the production side and envisaging major technological breakthroughs. Thus the scenarios are in fact mainly production-oriented. Less ground-breaking solutions are pointed out on the end-user side. One exception, which is, however, mentioned in several of the scenarios, is the emergence of low energy houses or even zero energy houses. These building solutions are self-sufficient in energy, generally based on super insulation and the local production of electricity, for example, based on solar cells.

8) The forgotten challenges of hydropower…?
It is worth noting that the scenarios refer to Norwegian hydropower as having been developed – and thereby fully exploited. Surprisingly little was otherwise said about what is needed to continue the large-scale production of hydropower-generated electricity. Perhaps it does not require special attention, but in any event, one feature of all the scenarios is that hydropower has been developed and is an important prerequisite for electrical power in the Norwegian system. Very little attention was devoted to Norwegian hydropower expertise in the scenarios drawn up by the six groups.

9) Bioenergy – forgot or not exotic enough?
The category ‘forgot...?’ should probably also include bioenergy. The use of bioenergy was mentioned sporadically in some of the scenarios, and given the potential one must assume exists for the use of bioenergy in Norway, it was somewhat surprising that bioenergy was not given a somewhat more prominent role in more scenarios, not least since bioenergy is a CO_2-neutral source of energy.

10) Thematically interdisciplinary – materials technology
One general characteristic of many of the technological changes described is that they require breakthroughs or improvements in materials technology. Materials technology plays a key role in development in the fields of hydrogen, new renewable energy sources and gas power accompanied by CO_2 management. Materials will also be essential for bringing low and zero energy houses to fruition.

11) Thematically interdisciplinary – focusing more on scientific and technical expertise
One final observation that also appeared repeatedly refers to concerns about the slow deterioration of Norwegian expertise in the natural sciences and technical subjects. This is because the lack of status and interest are leading to a lack of recruitment and will eventually reduce the quality of both teaching and research. There is a great deal of focus on this in several of the scenarios and the proposed solutions vary from attitude-shaping to the import of labour from the third world as is seen in the USA.

The project group´s final strategic recommendations

Based on the suggestions of the invited commentators, other suggestions under the auspices of Choices 21 and the project group's own suggestions, the project *Foresight Energy 2020+* resulted in a final set of strategic recommendations.

The recommendations are anchored in a far-reaching and transparent process to which a large number of players have contributed observations and suggestions. The way in which the recommendations have been elicited provides assurance that the recommendations are viable relative to several development tracks for Norway's energy supply and international development trends. The final recommendations are presented below.

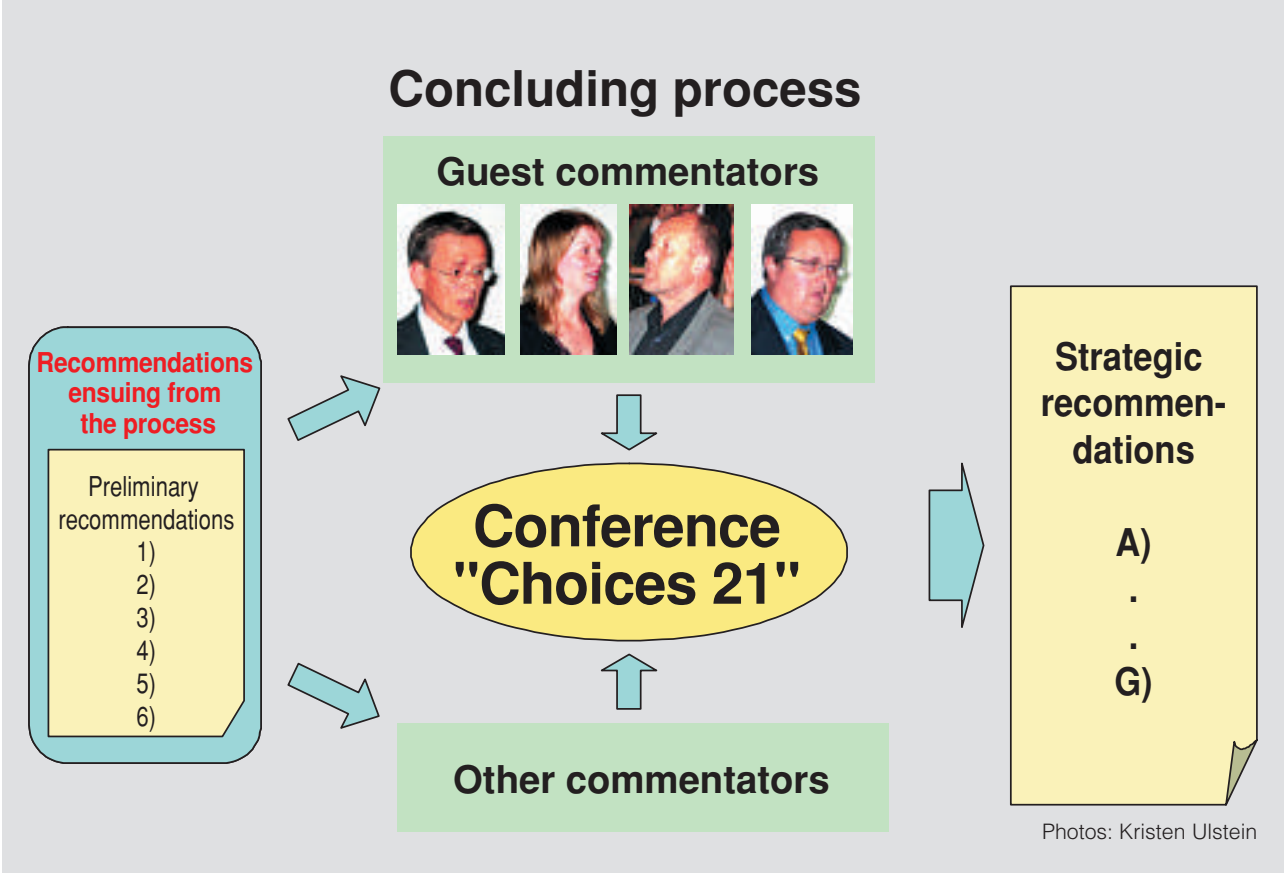

Figure 3. The final recommendations are based on input and comments.

A: Renewable energy – heat and electricity

It would be a viable R&D strategy to continue developing technology and solutions for renewable power production. International demand for renewable electricity will increase continuously – in nearly every conceivable environmental and market-related regime. Such a strategy will also be relevant relative to energy contributions to the Norwegian energy system and with a view to domestic economic development and wealth creation.

Moreover, attention to renewable heat production will be advisable and important. Renewable heat production will also play an important part in Norway's energy restructuring.

The ranking of priorities based on relevant technologies/fields should be based on the following main criteria:

- anticipated market trends for the technology
- Norwegian players' industrial and professional expertise
- Norwegian research communities' expertise
- relevance to the Norwegian energy supply

B: Hydrogen

Norway should be taking part in the collective international efforts being made to promote hydrogen as an energy carrier for transportation-related and stationary purposes. The international efforts are extensive, and Norwegian resources must be

focused on fields in which there are
- Norwegian research skills and expertise
- the potential for an industry to further develop solutions
- a strong Norwegian resource base

Although extensive use of hydrogen has a long-term perspective, it is natural to take what today's Norwegian players see as a natural first step as a point of departure. Thematic areas of obvious interest are:
- storage solutions for hydrogen
- hydrogen from natural gas accompanied by CO_2 management
- hydrogen production based on electrolysis

C: Gas power accompanied by CO_2 management

This is a 'particularly Norwegian' field of interest today, but that will not necessarily be the case in a few years. The fact is that there are special driving forces in Norway that could open opportunities for a technological head start and for the development of solutions of such a nature that they may also be applied to other fossil energy carriers (coal, etc.). This could result in substantial markets for the Norwegian supply industry in terms of both technology and knowledge. The further management and utilisation of CO_2 are also essential for CO_2-free solutions. This is also a thematic structure which, regardless of whether the subject at hand is CO_2-free gas power, coal-fuelled power, or hydrogen production, etc., opens further opportunities for Norwegian suppliers of technology, oil and gas.
- Given its point of departure, Norway should continue to work with CO_2 capture: CO_2 separation, management and deposits or other active use of CO_2. A closer link to oil and gas activities might make it easier to find good solutions for further management.

D: Energy-related materials technology

Material science has already formed the basis for the success of many Norwegian research communities and industries in the field of energy. Comprehensive knowledge in this area will be a prerequisite for solving several of the challenges facing us. Clear emphasis on new renewable energy sources, hydrogen and gas power with CO_2 management will require access to high-level materials expertise. Accordingly, it is important that the strategic focus on materials technology has an approach that is relevant for the challenges that need to be resolved in the field of energy and in a way that allows Norwegian expertise and Norwegian players to play a decisive role. Some such areas are:
- Hydrogen: storage in solids, storage under high pressure, fuel cells (catalytic converters, membranes,) electrolysis (catalysts)
- renewable energy sources: solar cells, wind power (e.g. wings), saline power (membranes)
- CO_2-free energy solutions: (membranes, catalytic converters)

C: Focus on energy use – energy conservation and savings

In a nutshell, one might say that the increase in Norway's energy consumption over the past 100 years has always been met by developing new production capacity. This type of solution cannot last forever. Energy restructuring is therefore an important part of Norway's new energy policy. This includes more focus on end use relative to new access. A large part of today's energy consumption takes place in the building and construction sector. One distinctive characteristic of Norway is that we waste a lot of energy, not least by using high-quality energy (electricity) to cover low-quality needs (heating). This is not a sustainable situation, since such unnecessary 'leakage' on the end-user side places needless pressure on the resources available.

Meanwhile, we have a correspondingly large potential for improvement. This can be handled through the development of new technology and new solutions that result in the considerably more efficient exploitation of energy, releasing high-quality energy that can be used for applications that require electricity. Some central fields of research are:
- building-related technology and building-related systems (integrated flexible energy solutions)
- thermal storage systems
- improved thermal insulation systems
- local production of power/heat/cooling
- utilisation of solar energy and ambient heat

F: Instruments and incentives for efficient, environmentally-appropriate energy management

In addition to the fact that good technical solutions are available, the design of effective instruments to promote choices that lead in the right direction will

be absolutely decisive. In this context, research to learn more about the energy system, policy, user behaviour, etc. will be decisive as documentation for the decisions taken and the correct shaping of the parameters under which energy systems are to operate.

Prudent utilisation of the resources will require, among other things, appropriate incentives to encourage the players to make the right choices. This refers to players on the production side and end users alike. The introduction of an energy market that is expanding at the international level, limited access to energy resources, energy as a factor input and the basis for value creation and social welfare and, not least, environmental problems are factors that make the development of good governance mechanisms and incentives essential. The great complexity that must be taken into account will require more knowledge about these synergies. This has traditionally been an important field of research in Norway and must continue to be so.

G: The energy system of the future

Comprehensive expertise on the energy system is important for further developing the country's energy supply in future. Several new challenges are manifested more clearly now than just a few years ago, e.g. a more delicate power balance, security of supply, downstream integration with end-users, the decentralisation of power and heat production, more district heating solutions, integration between stationary energy supply and the transport sector, to mention just a few. This entails far greater complexity that what has been the case previously.

- The energy system must be a strong area of expertise for Norwegian research communities and the Norwegian energy industry.

Foto: Trond Moengen

Energi 2020+

Norges forskningsråd
Stensberggata 26
Postboks 2700 St. Hanshaugen
0131 OSLO

Telefon: 22 03 70 00
Telefaks: 22 03 70 01
www.forskningsradet.no