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Nordic Hydrogen Energy Foresight 2030

Foresight Brief No. 11

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Sponsors: Nordic Energy Research (25% of budget),
Nordic Innovation Centre (25% of budget),
The remaining 50% of the budget was shared by 16 other partners: Risoe National Laboratory (DK), VTT (FIN), Swedish Defence Research Agency (SE), NTNU (NO), University of Iceland (IS), AGA (SE), Vattenfall (SE), H2 Forum (SE), Norsk Hydro (NO), Wärtsilä (FIN), ABB (FIN), Fortum (FIN), Energi E2 (DK), Danish Gas Technology Centre (DK), IRD Fuel Cells (DK) and Danish Association of Engineers (DK)

Type: International cross-border foresight covering the five Nordic countries and the home rule governments of Green-land, the Faroe Islands and Åland. Sector specific foresight on hydrogen and fuel cells

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Duration: January 2003 – June 2005 **Budget:** €751,000 **Time Horizon:** 2030

Purpose

The overall aim of the Nordic Hydrogen Energy Foresight was to find long-term promising ways for Nordic stakeholders of exploiting hydrogen in the drive to meet the **3 Es: Energy Security, Economic Growth and Environmental protection**. More specifically, the aim was to build a Nordic Research and Innovation Area in hydrogen and fuel cells, contributing with a bottom-up approach to the European Research Area.

Objectives and Design of the Nordic Hydrogen Energy Foresight

Following a mapping of foresight activities in the Nordic countries in 2002 (Eerola & Jørgensen, 2002), a proposal was made by various stakeholders from academia and industry to conduct a foresight on hydrogen at Nordic level. At that time, the international focus on hydrogen was at its uptake. Iceland was at the forefront in setting hydrogen on the political agenda and in the other Nordic countries there were important R&D undertaken within key hydrogen technologies. Also, the diversity among the Nordic countries as well as well established political and economic collaboration in research, innovation and energy represent some unique and interesting opportunities for exploring different pathways to the hydrogen economy. The Nordic H_2 Energy Foresight had the following objectives:

- To develop socio-technical visions for a future hydrogen economy and explore pathways to commercialization of hydrogen production, distribution, storage and utilization.
- To contribute as decision support for companies, research institutes and public authorities in order to prioritize R&D and to develop effective framework policies.
- To develop and strengthen scientific and industrial networks.

The **EFMN** is financed by the **European Commission Directorate General for Research** as part of a series of initiatives intended to provide a **Foresight Knowledge Sharing Platform** for foresight practitioners and policy makers in the European Union. More information on the EFMN and on the Foresight Knowledge Sharing Platform is provided at **WWW.EFMN.INFO**

Expert Judgement and Quantitative Analysis

The Nordic H_2 Energy Foresight put equal weight on process and content, both for the intrinsic quality of the outputs of the process and for the networking and commitment it created. Therefore, the project centered on a sequence of four workshops, bringing together project partners and experts from industry, energy companies, research, and governmental authorities. Expert judgments and discussions in these workshops were assisted and challenged by formal quantitative systems analysis and technology assessment.

In order to make the management of the complex foresight process easier the Nordic H_2 Energy Foresight project was designed to consist of twelve work packages with clear deadlines and budget outlines. The preliminary document analyses (WP1) and expert interviews (WP3) were carried out in the beginning of the process to support the modeling work and systems analysis (WP4) and to prepare relevant introductory material and working procedures for the interactive workshops (WP5-8). It was also considered important to launch the project website (WP2) in an early phase of the process. The idea was to support the communication between the project partners and to provide an efficient means for disseminating relevant information to a wider public. Dissemination of information took also place in the context of international conferences (WP9). Analytic work and reporting by the project core group (WP10) was carried out between and after the workshops. An important part of this analytic work was the integration of the qualitative and quantitative results. The modeling of the Nordic hydrogen energy system proceeded in parallel with the other working packages and the analytic work continued up to the Nordic Conference where the integrated results were presented (WP11). Some feedback from the participants was collected already during the foresight process. A more profound process evaluation (WP12) was included in the end of the process.

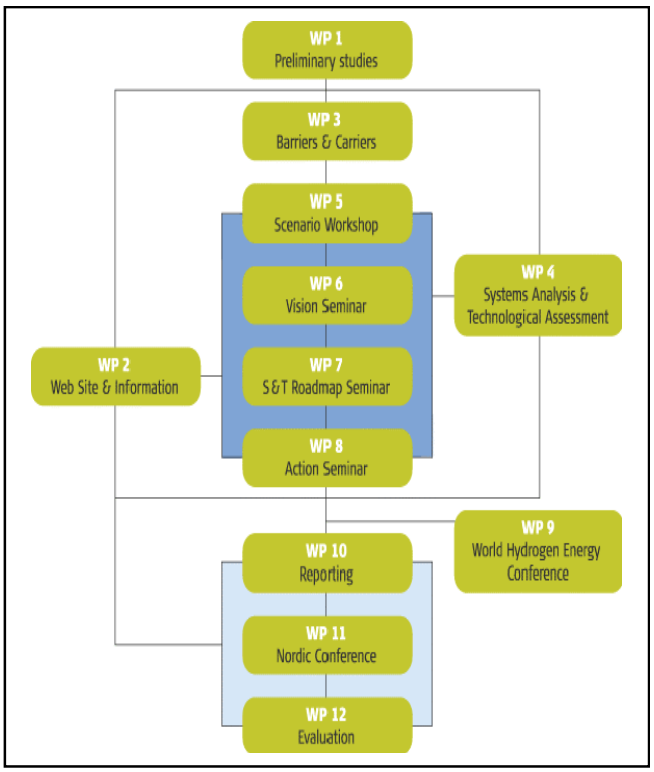

Figure 1. Project Design

Future Visions

Making the Future in Hydrogen

At the Scenario Workshop, external scenarios were developed for Nordic hydrogen energy introduction. On the basis of brainstorming and group discussions, a matrix of three first-period scenarios (2003—2015) set against three second-period scenarios (2015—30) was constructed. The general rationale for considering external scenarios is that many conditions of great importance to Nordic H_2 energy introduction are beyond the control of Nordic decision-makers:

- **B – Big Business is Back** is a global economy dominated by US multinationals and US big business-oriented policy approach. Major physical investments are not particularly helped by the prevailing quarter-to-quarter capitalism. There is very little interest for global environmental issues. Oil prices are moderate. However, H_2 energy is still believed to be a likely component in future energy systems.
- **E – Energy Entrepreneurs and Smart Policies** is a global economy dominated by entrepreneurs and venture capitalists, and with policy actors apt at harnessing the power of innovation for societal purposes. The energy sector is characterized by a tendency towards decentralization. There is some interest for global environmental issues. Oil prices are moderate.
- **P – Primacy of Politics** is a Europe-centric economy characterized by co-operation between governments and big business and with a great interest in large-scale investments in, for example, energy and transport systems. There is some interest for global environmental issues. Oil prices are high due to security-of-supply problems and the high oil price is an important driver for energy sector change.

The following 9 scenarios for formulated by combining these

three visions with three alternative second-period developments:

- hydrocarbon security-of-supply problems,
- undisputable CO_2 problems &
- a smooth path to the future'.

Eventually scenarios B3, E1 and P2 were chosen to form the framework for the subsequent work.

Developments 2015-30 External sce-narios 2003-15	1. Hydrocarbon security-of-supply problems	2. Undisputable CO_2 problems	3. A smooth path to the future
B – Big Business Is Back			B3 Big vision 6%
E – Energy Entrepreneurs and Smart Policies	E1 Big vision 15%		
P – Primacy of Politics		P2 Big vision 18%	

Figure 2 - External Scenarios for Hydrogen (The color represents ease of Nordic H_2 introduction with green, yellow and red indicating low, intermediate and high degrees of difficultly. The % refers to hydrogen's share of the total Nordic energy system in 2030 excluding industrial consumption).

Energy consumption in the Nordic area was divided in four main types: electricity, transport, space heating and "others". The fourth type covers use of heat energy in the industrial sector. In systems analysis and assessment of external scenarios, it was assumed that hydrogen technologies would not replace existing energy technologies in the industrial sector. Further, the share of hydrogen for stationary applications, i.e. electricity and heat production, was assumed to be approximately the half of the "big visions".

The evolution of the hydrogen as an energy carrier was assumed to grow exponentially from 2005 to 2030 and after 2030 a transient period was assumed up to 2050. Hydrogen is not an energy source in itself, but is produced from a basic source of energy. For the Nordic countries as well for the rest of Europe, the main energy source for hydrogen production over the next 25 years will be natural gas - especially in the B3 scenario. In the two other scenarios, natural gas might play a smaller but still important role. Renewable energy sources will provide most of the rest. The energy sources for hydrogen production in the three scenarios were settled by 2030 to:

	Natural Gas	Renewables (or nuclear)
Scenario B3	70%	30%
Scenario E1 & P2	50%	50%

Table 1 - Sources for Hydrogen Production

Identifying the Most Feasible Routes to the Hydrogen Economy

Through a participative roadmap exercise the sequence of implementation and the inter-dependence of the hydrogen technology visions from today and until 2030 were roughly outlined. Furthermore, business opportunities for Nordic equipment industry and energy market opportunities for the energy companies in the Nordic countries were identified in three areas:

- **Hydrogen Production and Transmission:** According to the model calculations, steam reforming and biomass gasification seem to be the most competitive technologies for hydrogen. With the scenario assumptions, the needed capacity (MW H_2 out from production units) of steam-reforming, biomass gasification and electrolysis units in 2030 were 1200-12000 MW, 1300-4000 MW, and 400-1300 MW, respectively. The approximated Nordic market sizes in 2030 for the base scenarios were €1-3B for hydrogen production, and from €4-12B for hydrogen transmission.
- **Stationary Use:** Niche applications of hydrogen/fuel cell based APU (Auxiliary Power Unit) and UPS (Uninterruptible Power Supply) form some of the first steps on the road. Both hydrogen and natural gas driven fuel cells for domestic and decentralized CHP (combined heat and power production) are seen as important steps towards the hydrogen economy in the Nordic countries. In the longer term, hydrogen driven CHP must be implemented in large-scale to arrive at the visions for 2030. In the scenario calculations, FC CHPs seem to be the most competitive for heat and power production in the long-term. The heat and power production with hydrogen fuelled fuel cells in 2030 is 2200-6700 MW, while with gas engines the maximum energy production capacity is 200-300 MW only. The Nordic market sizes in 2030 for the base scenarios were €1-4B for stationary applications.
- **Transport:** Introduction of hydrogen in the Nordic transport sector will follow the same paths as in the rest of Europe. The first steps will be special vehicles, busses and fleets. A special Nordic issue might be the use of hydrogen in the marine sector. Another Nordic niche might be special vehicles where H_2/FC systems can improve the functionality of these vehicles. In 2020, about 1-4 million hydrogen vehicles and in 2030 about 3-8 million hydrogen vehicles are needed to fulfill the 'big visions' for hydrogen energy in the Nordic transport sector. The number of fuelling stations needed in 2020 was estimated to 1000-4000 and in 2030 to 3000-8000, respectively. These scenarios for hydrogen supply per station were based on the assumption that 50% of the vehicles were powered by an internal combustion engine and 50% equipped with a fuel cell drive train.

Towards the Nordic Innovation and Research Area in Hydrogen

Nordic H2 Energy Foresight identified a number of Nordic business opportunities within industrial equipment and energy markets services. The suggested Nordic action strategy is formulated to promote these opportunities.

Business Opportunities

A range of business opportunities for identified in both equipment and energy markets. These were characterized in three main categories:

- Production and transmission of hydrogen,
- Use of hydrogen in the transport sector,
- Stationary use of hydrogen for power and heat.

Sources and References

A summary report and background papers can be found at www.h2foresight.info.

'Technology Foresight in the Nordic Countries' by Eerola, A. & Joergensen, B. H. was published by Risoe National Laboratory in 2002 and is available on www.risoe.dk.