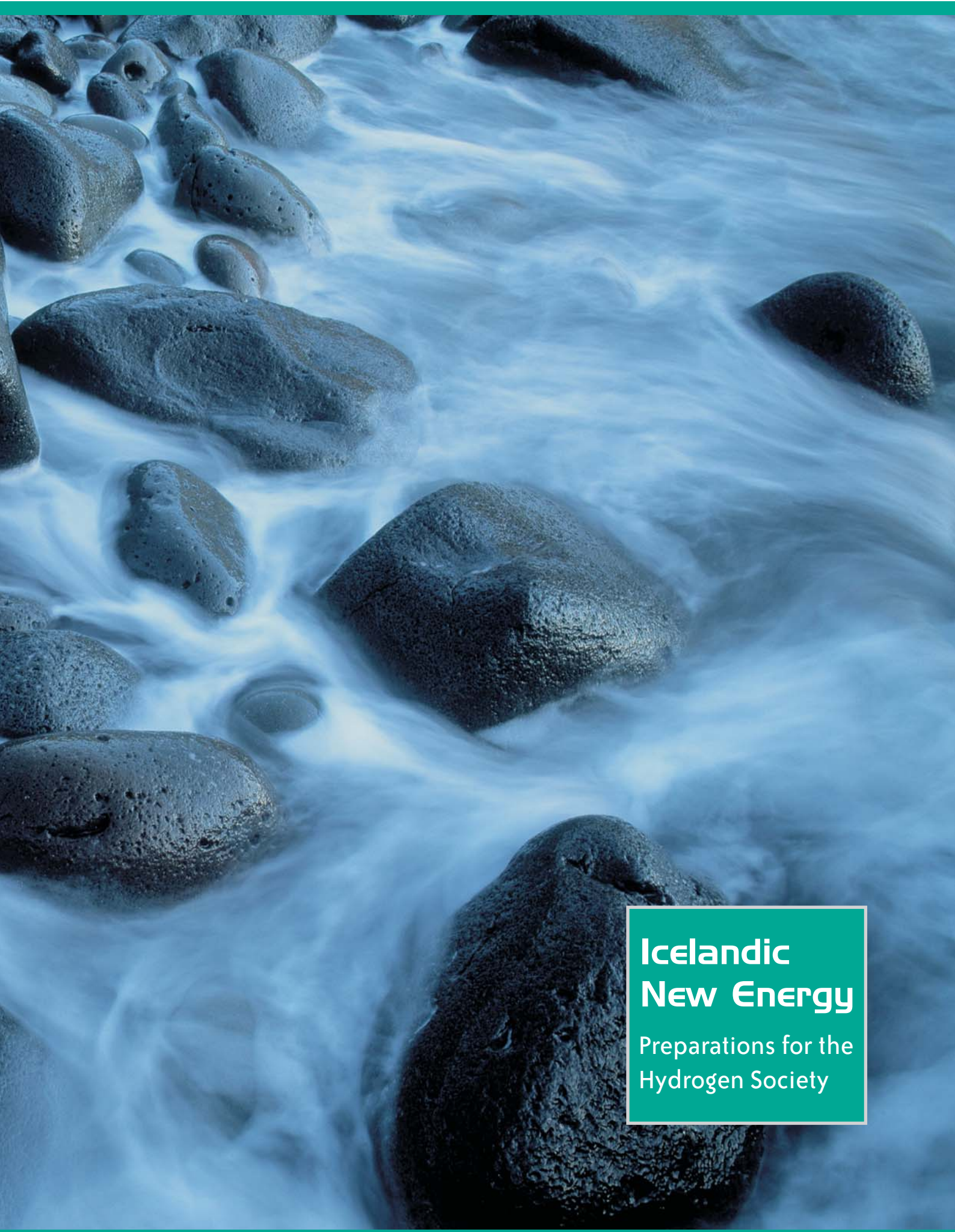


Icelandic New Energy

Preparations for the Hydrogen Society

ECTOS

ecological city transport system

Iceland: A living laboratory

Since the early days of this new millennium, Icelandic New Energy (INE) has focused its attention on the testing of hydrogen as fuel. Iceland's abundance of renewable energy resources is chief among the factors that make it a perfect location for this significant fuel transformation: to develop hydrogen into fuel that can sharply reduce Iceland's remaining reliance on fossil fuels.

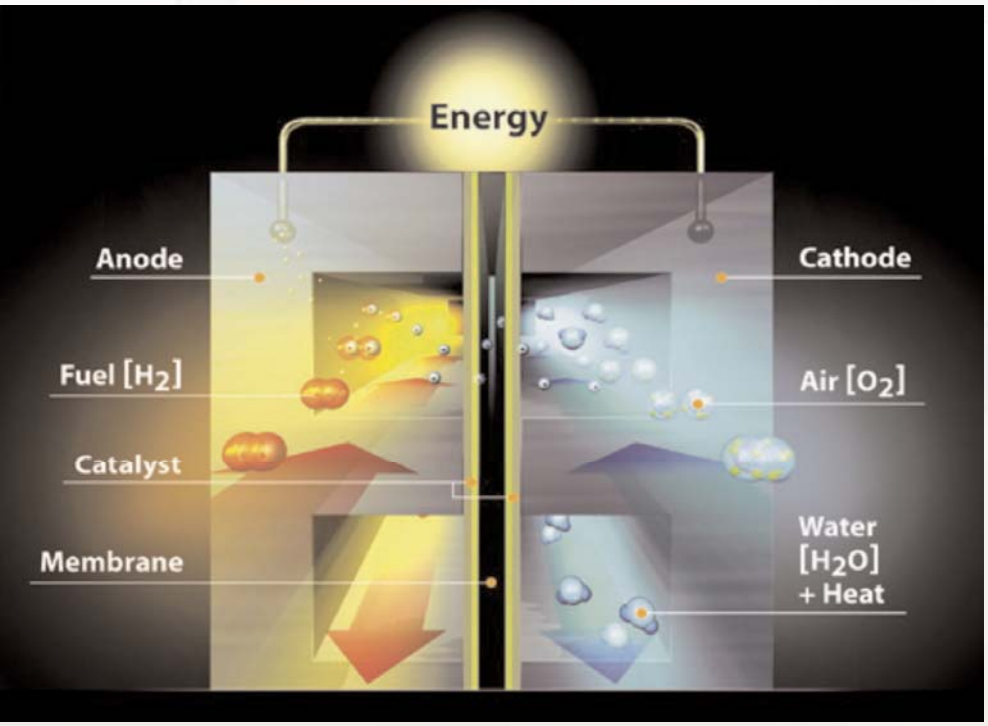
From March 2001 to autumn of 2005, Icelandic New Energy has managed the Ecological City Transport System project, or ECTOS. This has been the first real-scale demonstration project in Iceland to use hydrogen as a fuel.

During the ECTOS project, the first hydrogen production, storage and filling station has opened in Iceland and hydrogen-fueled buses have driven tens of thousands of kilometres in Reykjavik, saving great amounts of carbon dioxide emissions. Public response has indicated a widespread enthusiasm for the project and acceptance of hydrogen as a fuel.

Plans for the future include the application of hydrogen as a fuel for passenger cars, as well as for Iceland's fishing fleet. Iceland is becoming a centre for research and international discourse on the use of hydrogen fuel, a living laboratory for an experiment that could have global implications. INE's goal of Iceland's conversion from fossil fuels to hydrogen by 2050 is ambitious, but feasible.

While the current work is very forward-looking, the preparations for this project began some 30 years ago at the University of Iceland.

A vision for the future



A phrase used frequently by Icelanders is, "Þetta reddast!" – It will work out! The expression also means, "We will succeed and solve all problems". Perhaps this confident outlook was one of the driving forces that led to ECTOS: Here, any difficulty that may lie ahead is considered an opportunity, not a threat.

Bragi Arnason, a professor of chemistry at the University of Iceland, pointed out during the oil crisis in the 1970s that Iceland's abundance of water and renewable energy might be used to make a local fuel, hydrogen, to drive the country's transport and fishing sectors. He argued that hydrogen would become the fuel of the future and could be produced in Iceland from water, using electricity from the geothermal and hydropower sources in an electrolytic process.

Feasibility studies and reports were prepared during the 1970s and 1980s. Later, researchers examined the possibility of separating hydrogen from geothermal vents.

Following these preparations and public discourse on environment, technical development and fuel security, the company Icelandic New Energy (INE) was established in 1999. The Icelandic shareholders' group, Vistorka, is a combination of key players drawn from the Icelandic New Business Venture Fund, main energy companies, research institutes, academics and the government. Yet, 49 percent of the shareholders' group belong to three important international concerns, each bringing a special field of expertise: DaimlerChrysler, known for hydrogen vehicle development; Shell Hydrogen, with its design for energy distribution, including hydrogen; and Norsk Hydro Electrolysers, whose hydrogen production technologies use electrolysers.

As part of the ECTOS project, the first pre-commercial hydrogen fuel station was built and inaugurated in April 2003. From then on, the city of Reykjavik was ready to fill up its hydrogen vehicles.

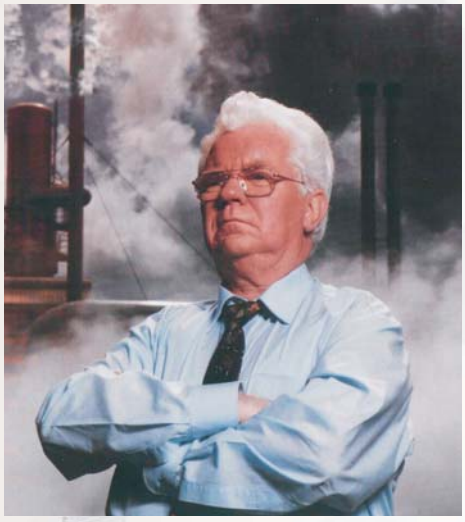
VistOrka

ÍSLENSK NÝORKA ehf
ICELANDIC NEW ENERGY Ltd.

DAIMLERCHRYSLER

Shell Hydrogen

NORSK HYDRO



Are you interested in the public political discourse in Reykjavik? Join the conversations in the "hot pots" at one of Reykjavik's geothermal pools! There is always room for more input in the invigorating outdoor spas, which are liveliest in the morning before 9 o'clock.

Further progress

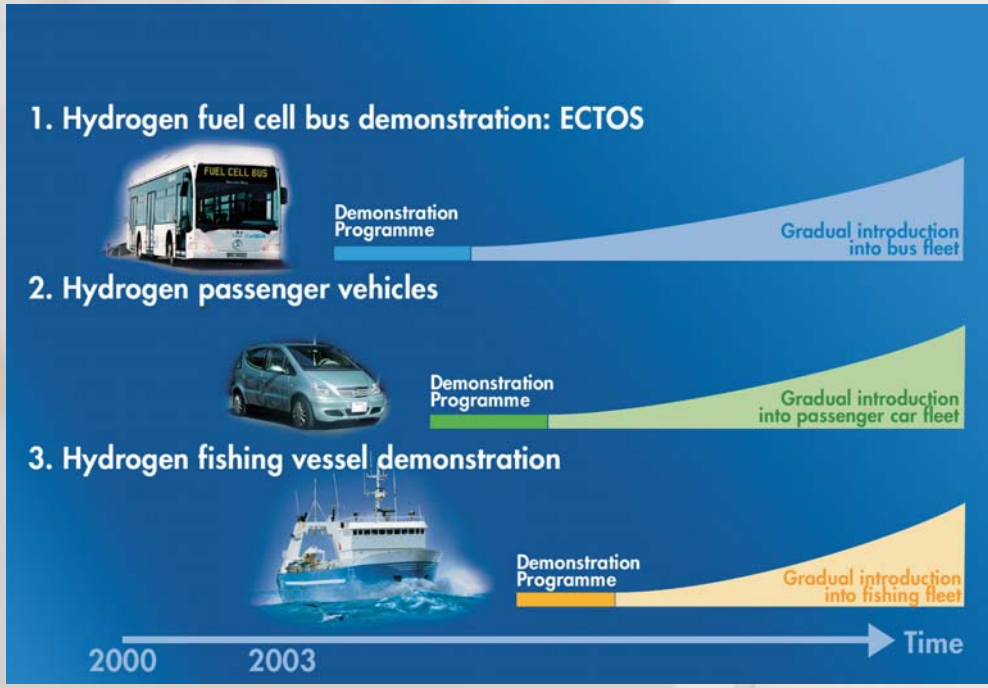
At the beginning, Icelandic New Energy was mostly active as a facilitator, aiming to create a venue for the testing of hydrogen technology. The focus so far has been on the main parts of the Icelandic energy system that are not powered by renewable energy, namely transport and marine applications.

As results have been encouraging, the company aims to build further on the compiled experience and continue with new demonstration projects, such as passenger cars and possibly minibuses or small vans. Toward this end, INE is following carefully the latest development of hydrogen engines. Internal combustion engines using hydrogen or a mix of gases could be suitable for Icelandic conditions. Using hydrogen only produced from fully renewable sources will drastically reduce the total emission from the transport sector, and such engines could form a bridge from current technology to the future of fuel cells.

Therefore a gradual introduction of the hydrogen infrastructure may pave the way for the more efficient fuel cell vehicles on the market. Additional testing of fuel cell vehicles, to build on the information gathered during the ECTOS project, will be of great interest for further grounding of the local fuel policy.

Using hydrogen on board Iceland's marine vessels will become the biggest challenge and equally the most rewarding outcome. The goal of converting from oil products to hydrogen as Iceland's main fuel within the year 2050 still seems feasible, given the high acceptance of hydrogen as an energy carrier amongst the public and Icelandic authorities.

Icelandic New Energy's Key Project



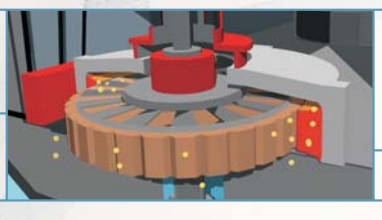
Progressing company

INE has developed from managing projects like ECTOS toward a professional research, development and consultancy company with steadily growing knowledge assets within research design, educational functions within environment, hydrogen, energy systems and integration into society.

The company does not manufacture or sell hydrogen products, but understands the importance of all links and their functions within the overall scheme. During the ECTOS demonstration period, representatives from the company have given presentations in all corners of the world, and groups that visit Iceland have attended seminars hosted by INE and the University of Iceland. These seminars will resume in September 2005, incorporating the experience from ECTOS and other activities.

Since 1999, five master's and diploma students in energy and marine engineering, environmental sciences, geography and policy studies from equal number of universities in Iceland, Germany, Norway, the United States, Denmark and Sweden have worked on their projects within Icelandic New Energy. Many more from Europe and North America have enjoyed assistance at the University of Iceland under the auspices of the science faculties. INE is grateful to all these fine scholars and their supporting institutes as well.

In addition, numerous organisations and projects have generously provided valuable information and assistance to ECTOS and the student projects. The company's dedication toward creating a hydrogen society has been encouraged during the activities of the last six years, and in the near future the citizens of Iceland, along with INE´s staff, hope to celebrate a cleaner and more sustainable future for Iceland.



Hydrogen in a fresh situation

The ECTOS project was planned for Reykjavik. In spite of the city's northerly geographic location - 63°N and 22°W - the climate in Iceland's capital city is mild during the winter and fresh during the summer. Temperatures rarely sink below -10°C in January, but stay around the freezing point. The mean temperature in summer is about 10°C, and seldom rises beyond 20°C. This is due to the fact that the country is surrounded by the temperate waters of the Gulf Stream, originating in the Mexican Gulf. Yet winds are brisk in all seasons and rainfall abundant. The winds blow usually from the sea and carry salt and ocean spray, and these conditions sometimes interfere with electricity transmission.

The socio–economic sides

Data was collected during the ECTOS project on social acceptance, environmental aspects, fuel efficiency for a Well-to-Wheel study and technological performance and availability of the equipment as well as running costs and economic evaluations.

The public acceptance of hydrogen as a fuel was first surveyed in 2001 with a telephone questionnaire. The responses indicated that the public embraced the idea of producing and using hydrogen in a positive manner and welcomed the ECTOS tests. In 2004, students surveyed Reykjavik pedestrians and passengers on board diesel and hydrogen buses and still the public acceptance measured very high. Not only were there no major social barriers to the introduction of hydrogen, but a marginal majority of respondents said they would be willing to pay a higher price for hydrogen than gasoline during the introductory phases of the conversion. A survey amongst the drivers also indicated that they are happy conducting the fuel cell buses. They claim that the fuel cell buses are quick to accelerate, and that they have smooth movements and excellent stability. People who live along bus routes also noticed that the fuel cell buses make less noise when travelling through the neighbourhood.

ECTOS

The project is supported by DG – Research, specifically the program "City of Tomorrow and Cultural Heritage"

ENERGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

The environmental issues touch on both air quality and Life Cycle Analysis for the equipment and the fuel. The electricity used to electrolyse water at the Reykjavik hydrogen station comes from the national grid. The combination of electricity sources for the grid is simple: 83 percent comes from hydropower and 17 percent from geothermal sources. A Well-to-Wheel analysis for the fuel efficiency along the whole energy chain therefore shows very low air emission for Iceland, except sulphur compounds at the geothermal sources.

The fuel cell buses

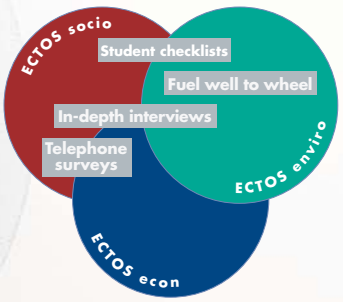
During the ECTOS demonstration, three fuel cell buses drove more than 65,000 km during the first 18 months. This amounts to saving 95 tons of CO_2 emissions, plus other polluting gases. The buses performed extremely well: no failures or major difficulties were detected during this time. The fuel cells are sensitive to the cold and were kept above the freezing point at all times, through the use of electric heaters and by monitoring the temperatures in the system. Still, the efficiency of the hydrogen buses has not been as high as expected, because the energy expenditure suffers from a high load of the auxiliary equipment, particularly during idling. That is an important lesson for the design of the next generation of fuel cell buses. Icelandic emergency response teams learned about hydrogen technology during the demonstration period, in order to better address situations that might arise when hydrogen vehicles become more commonly used. Another example of the learning value of the demonstration occurred when one of the buses grazed an overhead traffic sign in downtown Reykjavik; a good reminder that the FC buses are about 50cm taller than other public buses.

The infrastructure

A valuable component of the infrastructure, the pre-commercial electrolytic hydrogen station, is connected to the electricity grid and the water distribution service of Orkuveita Reykjavikur (Reykjavik Energy). The units of the hydrogen fuel station were delivered from Norsk Hydro Electrolysers and are a prototype of a turn key solution to a system of production, compression, storage and dispensing.

This, the first station of its kind in the world, is located at Skeljungur´s conventional gasoline station at Grjothals in Reykjavik. Constructing the station was costly: the basic components alone cost more than € 1.3 million. Running the equipment, which has a capacity to produce 60 cubic metres of hydrogen gas per hour and is designed only for refuelling three fuel cell buses as customers has been expensive. Demonstration periods are generally more costly than running a conventional system, as the failure rate and cost of maintenance of different components is usually higher. This has also been the case in Iceland, as unforeseen issues have resulted in occasional stoppage. However, all such issues have created valuable learning within both the technical and human elements of the demonstration, and all have been successfully resolved. The great value of the station has been the learning that resulted from this unique front-line training. On-the-job experience has provided invaluable lessons, and modules have been redesigned and modified to ensure a more streamlined and efficient production and distribution of hydrogen.

Safety at the ECTOS station has been a main emphasis of this part of the project, as it will be throughout. The station has been honoured by visits by many foreign dignitaries. More than 1,000 media reports on Iceland's hydrogen project, featuring the station, have been done for media outlets around the world.

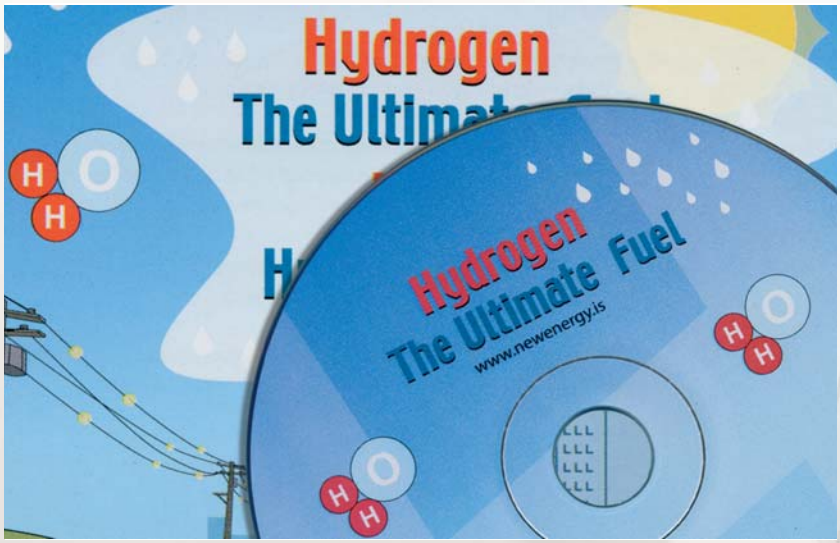


ECTOS Methods

"We heard you plan to build a hydrogen fuel station next door ... I hope we will be invited to the inauguration party ... and, no, we have no concerns for our industry even though we become close neighbours ..."

(Comment from the owner of the soft-drink factory at Grjothals).

Other projects at INE



Euro Hyport

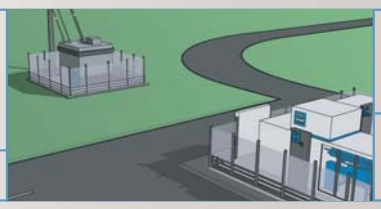
The European Commission-supported initiative EURO-HYPORT project was finished in July of 2003. The outcomes of the project included:

1. A cost analysis for a full-scale hydrogen infrastructure for Iceland, including suggested ways to implement the initial steps for the conversion. According to one of the project's main conclusions, possibly as few as six strategically well-sited hydrogen filling stations could be enough to create a H_2 customer acceptance in the capital area.
2. A feasibility study to analyse the opportunities for Icelandic energy companies to enter the "green energy" market in the European Union by exporting hydrogen or electricity, and the most economical ways of achieving that goal.
3. A CD containing simple animated educational material on hydrogen as an energy carrier. The title is: "Hydrogen, the Ultimate Fuel". The disc has been donated to all schools in Iceland and will be made available on the company's web site. For more information, visit www.newenergy.is. Pictures from this material are used in the footnotes of this brochure.

HY SOCIETY

HySociety

Icelandic New Energy participated as a subcontractor within the HySociety project, which came to an end in December of 2004 (see www.hysociety.net). HySociety was aimed at analysing hydrogen projects and initiatives undertaken throughout Europe, as well as the possible social, technical or economic barriers to implementing hydrogen as an energy carrier throughout Europe. The project management was in the hands of the Institute Superior Technologico in Lisbon, Portugal. The project is considered to have a major input into the hydrogen roadmap for Europe.



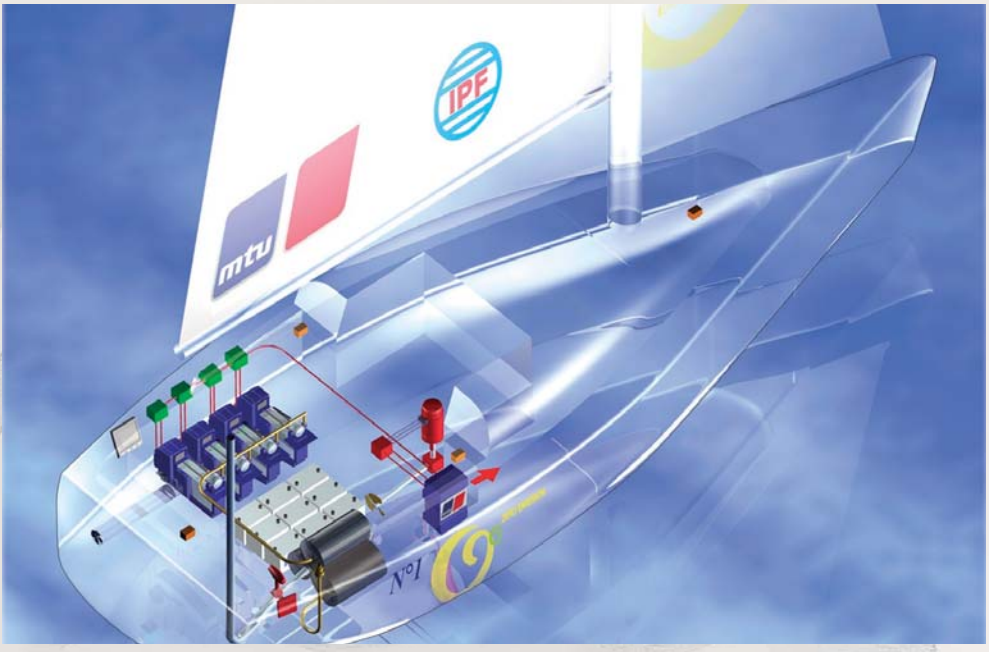
New H Ship

This 15-month project, started in February of 2004, is a specific supported action (SSA) to ensure continued work on earlier national initiatives and European Commission-funded projects concerning the use of hydrogen as fuel in marine applications. This builds on the outcomes of projects like the FC-SHIP, which ended in June 2004, and included 21 partners from six European countries studying fuel cell application in ships; and EURO-HYPORT, which ended in July 2003, and offered a master plan of an Icelandic hydrogen infrastructure, production sites, and other arrangements. The New-H-Ship will bridge the gap in this field and assist in the creation of a new European research agenda.

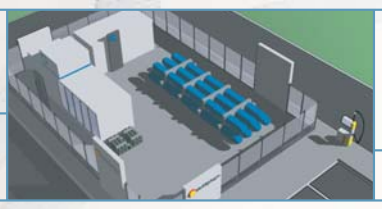
Taking fuel cells and hydrogen aboard a ship will demonstrate a fairly new technology in a completely new and somewhat difficult environment, one that is wet and salty and hard on electronic equipment. As a result, the aim of this project is to identify the specific technical and operational requirements related to the shipboard system and infrastructure for maritime fuels. As a preparation for upcoming demonstrations, the project will suggest mitigating actions for the future, so that investments and the technology for using hydrogen on board will be feasible and secure.

Main goals:

- Identifying technical barriers (showstoppers) for Fuel Cell and Hydrogen (H_2) on board ships.
- Mapping the road to H_2 driven propulsion in ships and making recommendations for further research and development.
- Creating a reference list of research and development activities regarding fuel cells and hydrogen in maritime applications.
- Identifying supporting European activities in the field of hydrogen and fuel cells in maritime applications, and pre-screening potential partners.



Biomass may become a valuable raw material for making hydrogen on many continents, yet in Iceland there is very little excess biomass to be found. The renewable material available in Iceland is water and power from geothermal and hydropower sources. A new energy era may start if energy exploitation from deep drilling or wind power plants becomes successful.



New undertakings

Steps toward the hydrogen society

1970 ➤ Hydrogen research begins at the University of Iceland.

1990 ➤ Consultations begin between the University of Iceland and Hamburgische Electricitets Werke regarding a potential export of hydrogen from Iceland to Germany.

1997 ➤ Governmental Committee on Domestic Fuel Production is formed.

1998 ➤ Political Leadership – Governmental Policy on Hydrogen.

1998 ➤ Negotiations begin between Icelandic and Global Stakeholders on hydrogen.

1999 ➤ Establishment of VistOrka (EcoEnergy) and Icelandic New Energy.

2001 ➤ ECTOS project starts.

2002 ➤ Iceland joins the IEA – Hydrogen Implementation Agreement signed.

➤ EURO-HYPORT Project starts.

2003 ➤ ECTOS project:

➤ Opening of the world's first pre-commercial hydrogen station in Reykjavik in April.

➤ The first hydrogen vehicle to be driven in Iceland is the Sprinter, produced by DaimlerChrysler.

➤ INE's conference, Making Hydrogen Available to the Public, held in April.

➤ Testing of the operation of hydrogen-powered buses commences in October.

➤ Iceland is a founding member of the International Partnership for the Hydrogen Economy (IPHE).

2004 ➤ IPHE´s milestone meeting in Reykjavik.

➤ Icelandic students win the international youth science competition in Beijing, China, for their idea on the Future Hydrogen House.

➤ New H Ship starts

2005 ➤ The ECTOS bus project comes to an end; reports on the various aspects of the experience are published.

➤ Fuel Cell A-class vehicle from Daimler Chrysler is shown in April.

➤ INE´s conference in April; HY-Pro-Files, the lessons from ECTOS.

➤ Demonstration of a Japanese fuel cell tricycle is planned on the Icelandic ring road, Highway 1.

➤ The Icelandic parliament is expected to pass a bill on specific tax reductions for hydrogen vehicles this year.

➤ A fuel cell test is planed at the Keflavik airport.

NEEDS

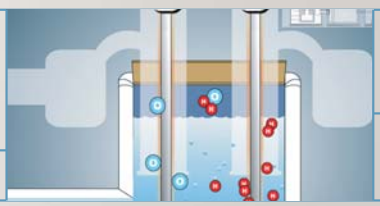
New Externalities for Energy Development, or "NEEDS", is a European Commission-funded project to estimate the environmental and social cost of various energy policies for the future. NEEDS is partly an extension of studies that estimated the prices of externalities and cumulated in the report External E published in 2003. Yet NEEDS incorporates a broader spectrum, both geographically speaking and in terms of considering sources of energy. INE's role in this project will be to provide Life Cycle Analysis on hydrogen production via electrolysis from renewable sources, and to suggest methods of measuring external costs from using renewable energy sources.

Encourage

This undertaking aims to map future energy corridors to Europe from neighbouring countries and renewable sources. It is a normal continuation of the EURO-HYPORT Project, but the general trend is to look into natural gas as Iceland's main energy source until 2030, followed by a more massive introduction of hydrogen.

"Úthrif"- Externalities from developing a hydrogen economy

INE is working within an Icelandic group of specialists that wants to develop better methodologies to evaluate external costs from developing the local energy sources and distribution systems. The project is sponsored by Rannís, the Icelandic Research Council. This is a further expansion of the socio–economic findings, and feeds information into the NEEDS project.



Passenger vehicle research, development & demonstration (RD&D)

The goal of INE is to follow the current activities with a demonstration of hydrogen passenger vehicles. Already, contacts have been established with several car manufacturers in order to get a small fleet of hydrogen vehicles for a follow-up RD&D project. It is very important to expand the learning by comparing findings from the bus project, those provided by a demonstration of passenger vehicles. In Iceland's case, internal combustion engines fitted for hydrogen could be a perfect bridging strategy to the future fuel cell vehicles.

H_2 marine applications

As roughly one-third of all emissions from Iceland comes from the country's large fishing fleet, there is great interest in continuing to evaluate the use of hydrogen in the marine environment. An initiative, the WHALE project, has been established to build on the work from the European projects FC-Ship and New-H-Ship. This project is led by an Italian initiative and has applied for European Commission funding, with the goal of demonstrating a water taxi in Venice powered by hydrogen fuel cells. Learning from such a project can then be adapted to different locations, including Iceland.

"Vetnistæknimiðstöð" – Hydrogen technology centre

Currently the key academic and research institutes in Iceland, along with private companies like INE, are creating a joint forum for hydrogen activities. The key is to establish a laboratory and a forum for all hydrogen research: Spin-offs from activities like the ECTOS project are setting the scene for new ventures in the hydrogen technology industry. This new industry could create new high-tech jobs for Iceland in the near future

$NaBH_4$ as a hydrogen carrier

A team made of members from Icelandic New Energy Ltd., Millennium Cell (USA) and the Technological Institute of Iceland has been developing a new process for producing and recycling sodium borohydride at a cost lower than the current market price. $NaBH_4$ is a very interesting storage medium for hydrogen in vehicles because of its high storage mass percentage.

The goals of the project include:

- Testing a new method for the production of sodium metal by using renewable energy, and fundamentally influencing the production economics.
- Developing and testing a complete production process for sodium borohydride.

Ripple effects

Since the founding of Icelandic New Energy, many visitors have travelled to Iceland to participate in scheduled seminars hosted by the University of Iceland and Icelandic New Energy.

The seminars give an insight into the hydrogen initiatives, the current energy situation in Iceland and an introduction to hydrogen in the international field. A few of the methods used to collect and process data during demonstration tests are presented and then the participants discuss the findings during a common lunch. Later on the participants go on an 'energy excursion', visiting the hydrogen station and the maintenance bay, taking a short trip in a hydrogen-powered bus and then exploring one of Iceland's geothermal power plants.

Television stations and radio channels around the world have broadcast stories about the hydrogen demonstrations in Iceland, which have also been the focus of documentaries made by Swiss, French, Finnish, Korean, Norwegian, American and English filmmakers. Between 300 and 400 media persons have visited INE during the last couple of years, writing hundred of articles and news releases. In total, INE has accompanied more than 2,000 foreign visitors to the company.

During the summer of 2003, the first hydrogen summer course was held in Reykjavik for University students who came mainly from the Nordic countries and North America. Lecturers came from Germany, the Netherlands and the United States. The education field is expected to expand in 2005, as seminar training continues both in and outside Iceland.

It can be said that the hydrogen initiatives have had extra benefits for the tourism industry, and aroused the interest of educational establishments. Eventually, the benefits of a successful conversion to renewable energy will have implications not just for Iceland, but for countries around the world.

The objective of establishing Icelandic New Energy Ltd. is to investigate and promote paths for eventually replacing the use of fossil fuels in Iceland with hydrogen and be a profitable entity in creating the first hydrogen society in the world

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