Icelandic New Energy

Further steps to Hydrogen Society

SMART-H_2

sustainable marine and road transport

Iceland: A Living Laboratory

Since the turn of the millennium, Icelandic New Energy (INE) has focused on testing hydrogen as an energy carrier or fuel, supporting theories with applied research. Iceland has based its economy on renewable energy. Apart from transportation on land and sea, all local needs for electric power and heat derive from hydropower and geothermal energy. Using hydrogen for transportation is simply a logical extension of the existing infrastructure: water is the raw material and renewable power the driving force in the making of this clean, renewable fuel. If the transportation sector were to be run on local renewable energy sources, then carbon emissions from Iceland could be reduced sharply as would Iceland's reliance on fossil fuels.

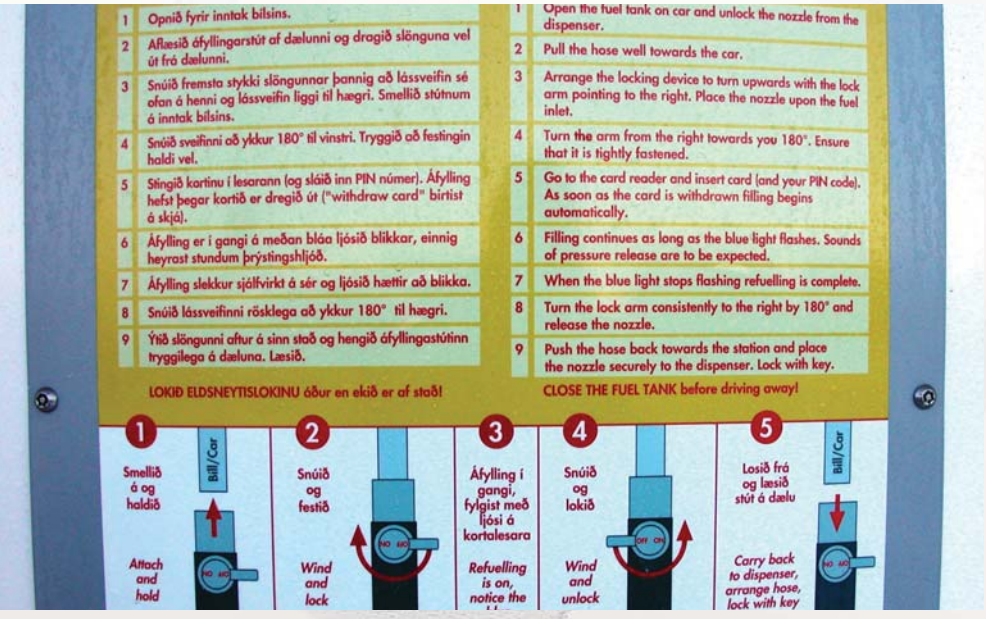
Between 2001 and 2005, INE managed the EU-funded "Ecological City Transport System" project (ECTOS) running three Hydrogen fuel cell Citaro buses and operating a hydrogen refuelling station. The buses were operated within Reykjavik's public transport system. The trials were well taken by both the public and politicians. Due to its positive outcome, the field-testing was extended through the HyFLEET:CUTE project until January 2007. After the test time had concluded, the buses were dismantled and reused as spare parts for other buses. The lessons from the project led to many novelties in bus design and sped up the worldwide marketing of clean transport. The fuel cell buses will be commercially available in 2010.

INE and VistOrka have now launched their next major hydrogen project: "Sustainable Marine and Road Transport – Hydrogen in Iceland," or SMART-H_2. The project involves the use of up to 30, H_2 vehicles, and the testing of an auxiliary power unit involving a hydrogen fuel cell on board a whale watching ship.

Iceland has become the centre of applied hydrogen research, and the focus of international discourse as a living laboratory for testing alternative fuel types and drive trains-technologies that could have global implications.

INE's goal from 1999 of using hydrogen systems as the main energy source by 2050 still stands firm.

A Vision in Progress



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. Other shareholders are three international concerns, each bringing a special field of expertise: Daimler AG, known for hydrogen vehicle development; Shell Hydrogen, with its design for energy distribution, including hydrogen, and StatoilHydro, whose hydrogen production technologies use electrolysers.

VistOrka

ÍSLENSK NÝORKA ehf
ICELANDIC NEW ENERGY Ltd.

DAIMLER

Shell Hydrogen

StatoilHydro

The forerunner of the hydrogen initiatives in Iceland was research led by chemistry professor Bragi Arnason at the University of Iceland, following the crisis in oil prices in the 70's. The energy authorities supported the first feasibility studies on how a hydrogen fuel system could be integrated into the current energy network.

Exciting possibilities lie in extending the energy availability beyond the existing grid into electrolytic hydrogen production stations and battery plug-ins close to residential areas and fishing ports.

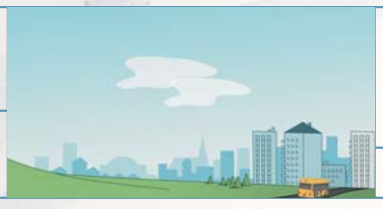
Major progress has been made in the last 40 years. Iceland has become a world leader in verifying the potential of H_2 as the fuel of the future, actively participating in key stakeholder groups such as the International Partnership of the Hydrogen Economy, International Energy Agency, North Atlantic Hydrogen Association and the Joint Technology Initiative.

INE is responsible for all major practical research on H_2 in Iceland, compiling experience from continuous operation since 2003.

Unique company

At this stage, INE is the only company in the world that has been responsible for operating hydrogen fuel cell buses, a commercial hydrogen refuelling station, various brands of hydrogen vehicles, stationary fuel cell testing for back-up power and ongoing hydrogen marine fuel cell research. INE has also collected data on technological performances, designed research approaches, participated in building policy, life cycle analysis and stakeholder management as well as conducted surveys and performed feasibility studies.

Furthermore, the company is responsible for all research in relation to field-testing. As such, INE has a unique record and broad experience that cannot be paralleled. Icelandic New Energy has been highly sought after for consultancy due to its broad experience in the field. The last few years have generated a very steep learning curve for the company, resulting in a varied portfolio. Cooperation with many international organisations and



Courageous or foolish? Building geothermal power plants on high temperature areas was criticised by many as a waste of time and money. Now, knowledge of geothermal energy applications is exported to many developing countries.

institutes, as well as INE's shareholders, has in turn provided valuable information and assistance in the quest for a cleaner and more sustainable future. For that support, we are very thankful.

Further progress

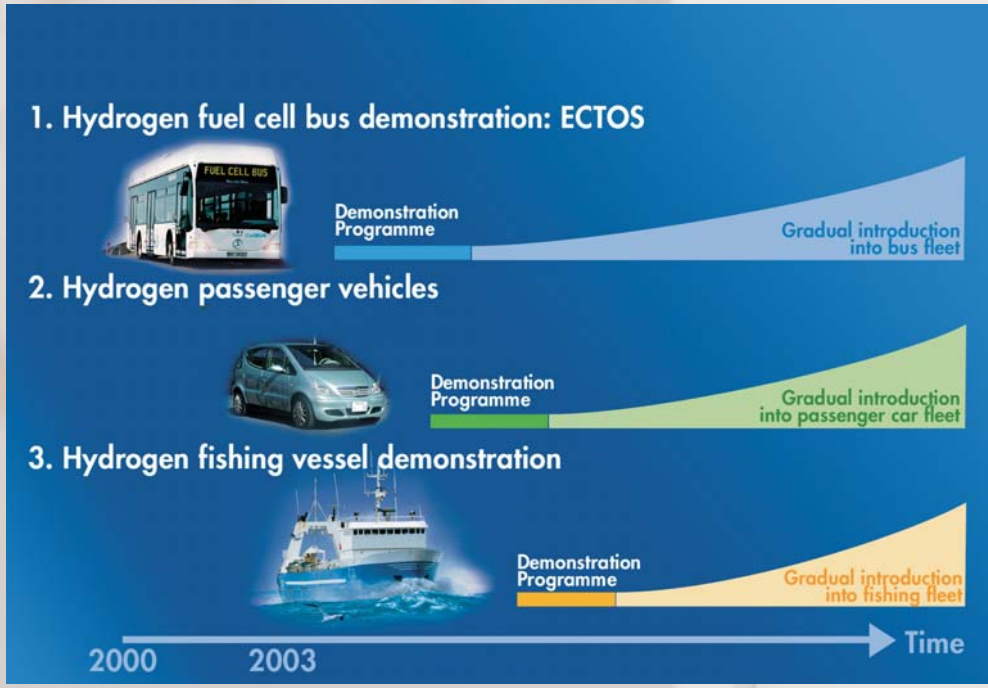
At first, Icelandic New Energy acted mostly as a facilitator, aiming to create a venue for testing hydrogen technology. The focus so far has been on land and sea transport. Results have been encouraging and the company aims to continue with new experimental projects, such as passenger cars and possibly minibuses or small vans. In addition, hydrogen filling facilities need to be added into the distribution system.

Toward this end, INE and VistOrka carefully monitor the latest developments in hydrogen engines and hybrid options. Internal combustion engines using hydrogen or a mix of gases could be suitable for Icelandic conditions. Using hydrogen that is fully produced from renewable sources could dramatically reduce emissions from the transport sector, and such engines could form a bridge between current technology and the future of fuel cells. A gradual introduction of the hydrogen infrastructure may take off, paving the way for the more efficient fuel cell vehicles that will arrive later in the public sector.

Further testing of fuel cell vehicles will build on the information gathered during the ECTOS project, and serve in grounding the local fuel policy.

Using hydrogen on board Icelandic ships will become the ultimate challenge, and equally the most rewarding. The goal of converting from oil to hydrogen as Iceland's main fuel by 2050 still seems both feasible and possible, given the high acceptance of hydrogen as an energy source amongst the public and Icelandic authorities.

Icelandic New Energy's Key Project



Hydrogen in a Fresh Situation

In 2001, Icelandic New Energy launched the Ecological City Transport System (ECTOS), thereby taking the lead in hydrogen and fuel cell experiments in Europe. The project was supported through the EC 5th framework program under DG research, specifically the "City of Tomorrow and Cultural Heritage" program. The project was designed to fit Reykjavík's conditions, although the European Commission urged other municipalities to follow in the ECTOS footsteps as well, which led to the CUTE project (Clean Urban Transport for Europe).

The buses were integrated into the public transport system on various routes, and both the buses and the hydrogen refuelling station were highly visible landmarks of the exciting project. Public awareness was aroused and fuel security and clean transport became a major issue in public discourse. The experiment was extended from the planned two-year period into the Hyfleet-Cute until January 2007.

Since 2007, Icelandic New Energy has focused its field-testing on other types of vehicles: two of the buses were dismantled and used for spare parts while the third bus was placed in a transport museum.

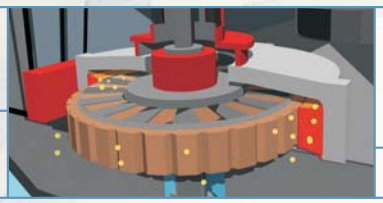
Infrastructure

The hydrogen refuelling station was inaugurated in April 2003, designed to provide fuel for three buses. It has been in continuous use and, after a small refurbishment in 2007, is now open for public use as a normal commercial service station. The hydrogen station is at Grjothals, on the same lot as a Shell petrol station. It is highly visible as you leave the city going east.

A card reader and monitor system is mounted on the station, interacting between the customers, the vehicle, and the station. Each car is equipped with a Smart Card containing basic information about the vehicle. The customer is asked to insert the figure on the odometer each time the vehicle is refilled. The station's computer registers the vehicle, inserted kilometres, time and amount of hydrogen taken. The hydrogen station monitors the filling speed and amount of fuel because it is important never to surpass the pres-

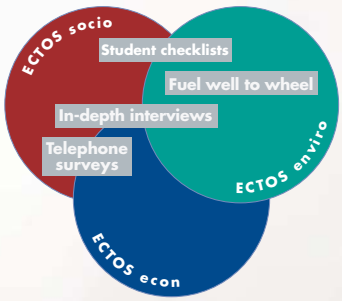
Media Coverage

News of the hydrogen field-testing has been frequently reported in the international media, and many guests have visited INE. Officials have attended meetings and presentations, and have had discussions with student groups, teachers, potential industrial partners, interest groups, presidents and politicians. Television stations and radio channels around the world have broadcast stories about Iceland's hydrogen projects, which have also been the focus of documentaries made by Swiss, Italian, French, Finnish, Korean, Norwegian, American, English and Japanese film makers. Around 500 media people have visited INE during the last few years, writing hundreds of articles and news releases. In total, INE has welcomed more than 3,500 visitors. It can be said that the hydrogen initiatives benefited the tourism industry, and aroused the interest of educational establishments. Eventually, the benefits of a successful conversion to renewable energy will have implications not only for Iceland, but also for the entire planet.



ECTOS

The Ecological City Transport System – fuel cell bus tests in the public transport system in Reykjavik is supported by DG – Research



ECTOS Methods

Reported results from the ECTOS project

- *Total operation figures:*
  - *144,192 km driven*
  - *8,324 operating hours*
  - *Availability of vehicle 92% of the time*
- *27,000 kg of hydrogen used*
- *Saved over 70,000 l. of diesel,*
- *Reduced CO2 emissions by 200 tons*
- *Over 90% of the public has a positive attitude towards hydrogen testing*
- *The public associates hydrogen most often with water and clean fuel*
- *The public claims to feel safe and trusts technology. In 2004, 40% of the public were willing to pay up to 20% more for operating vehicles on hydrogen rather than gasoline. Now, they are actually paying 60% more for the gasoline as compared to prices in 2004.*

sure limits. Hydrogen is not released from the dispenser unless proper procedures are carefully followed to prevent any mishaps.

This information, as well as the number of brakedowns, material and spare-part use and need of maintenance forms the basis of some performance criteria used in the research. The fuel cell cars also register temperature, and eventually the pressure when filling begins and ends.

Research

During the ECTOS project, several public surveys were conducted on the buses and the project, and information on the experience was gathered from the hydrogen-bus drivers.

The surveys were conducted both before the buses appeared in traffic, and later in the test phase. An overwhelming majority claimed to approve of the tests, and the public connects hydrogen with water and clean energy carriers rather than weapons, explosions or danger.

Forty percent of the public claimed they were prepared to pay up to 20% more for hydrogen mobility than for gasoline to facilitate the introduction. This was in 2004, but since then the price of gasoline has risen about 60%.

Students at the University of Iceland, as well as students from Stuttgart, undertook several of the research projects in ECTOS. Collaboration between Icelandic New Energy and the University has been formalised through contracts and common funding for new specified research topics for the SMART-H_2 project. All outcomes of the ECTOS project are available in the form of 19 reports on INE's website under "Publication." Report no. 17, "Total impact assessment of the ECTOS project," starts with a four-page list of conclusions where all members of the ECTOS consortium were asked to submit their own lessons from the project.

The main lesson was that in a systems perspective, it is feasible to run public transport with hydrogen fuel cell buses.

Optimization on fuel management and efficiency, endurance over extended periods of time, and production of hydrogen for large markets, as well as impacts on education and the work market, need further studies.

SMART-H_2 in Iceland 2007-2010

The Sustainable Marine and Road Transport – H_2 in Iceland (SMART-H_2) project is the next level in hydrogen demonstration and research and follows the major outline of the ECTOS/HyFleetCUTE experiments. The goal of the project is to gather information from the experience and use of between 20-40 personal H_2 vehicles, as well as a large passenger vessel with an H_2 auxiliary power unit. The project will also continue operating the hydrogen production, storage and filling station and add to the H_2 distribution system.

Cooperative effort

The project is a cooperative effort between VistOrka and Iceland New Energy. VistOrka provides most of the funding for the project. The total cost is estimated between €6.5-8 million of which partners in VistOrka provide €3-4 million.

INE emphasises the use of fuel cells in the project as they are regarded as the key to the development of a clean and efficient way of deploying hydrogen. The first SMART-H_2 step was to introduce a Daimler F-Cell vehicle as part of the company's fleet in July 2007. Two cars joined the fleet in 2008: a second F-Cell A-Class in March and a fuel cell Ford Focus in April. The intent is to increase gradually the number of fuel cell cars as they become available. The brands come from Japan, Europe and the United States.

VistOrka has also decided to evaluate the performance of various alternative vehicles, such as those powered by H_2-Internal Combustion Engines (ICE), methane engines, plug-in battery vehicles and plug-in hybrids as part of the research effort within the SMART-H_2 project. Results from these tests will then be comparable to the testing of the hydrogen fuel cell vehicles.

SMART-H_2

The project was made possible throught the generous facilitation of Hertz in Iceland, Reykjavik Energy and The National Power Company Landsvirkjun

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.

Research activities

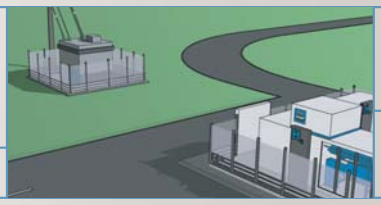
The main focus of the SMART-H_2 project is to expand the understanding of how new fuel types fit the Icelandic context, i.e. local availability, production costs, performance of vehicles, necessary infrastructure, public acceptance and other factors. Collaboration with the University of Iceland is mainly intended to support MSc students from the Department of Sustainable Resource Management. The fields of study can touch on technology, feasibility and economics, infrastructure extension, cost benefits analysis, impact assessment, externalities, stakeholder management, etc.

Methane from landfills has been used to power public vehicles for several years in Reykjavik, and battery vehicles are available in the market. Imported ethanol is also available. Coordinated data collection may give rise to general trends regarding costs and benefits and customer attitudes. The outcome should be supportive for decision makers.

The possibilities of establishing hydrogen stations using the current energy network have been studied, and the electricity needed to power electric vehicles has been estimated. During the hydrogen bus operation, INE conducted various social, environmental and economic studies, and research within SMART-H_2 will cover some crucial gaps. Icelandic New Energy and the University of Iceland held a workshop in January 2008 to gain insight into stakeholders' preferences for new fuels and to collect ideas for research and mitigation actions for CO2 emissions from transportation vehicles.

Conclusions from preliminary investigations on establishing a hydrogen society in Iceland are available. By testing a mixed fleet and adding results from Life Cycle Analysis, Well to Tank studies, additional testing of extended infrastructure and economic analysis, we can accumulate quite extensive information.

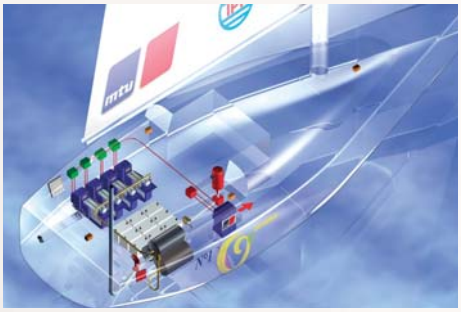
However, further analysis regarding the interface between customers and energy and fuel providers, as well as vehicle performance in the climate, scale of infrastructure, economics, maintenance services, and balance between import and export, are of utmost importance to understand fully the potential impacts of the integrating energy carriers on an isolated, yet modern, society.



we're making the fuel of the future

Marine Demo Within the SMART-H_2

Placing fuel cells and hydrogen on-board ship will demonstrate a relatively new technology in a completely new and somewhat difficult environment – one that is wet, salty and generally harsh on electronic equipment. However, the benefit for the whale watching tourists is obvious: there will be fewer fumes, less noise, and steam from the power unit will not pollute the ocean environment. When the boat encounters whales, the captain can turn off the main engine and offer close and silent observation. How's that for added value?



Ships and boats, specifically in the fishing sector, are large users of fossil fuels and major contributors of greenhouse gas emissions from Iceland. Exploring the possibility of running ships on hydrogen is therefore of major interest to stakeholders.

INE coordinated an EU-supported project called New-H-Ship 2004-2006 using results from an earlier EU project, the FC-Ship. New-H-Ship evaluated the technical and logistic barriers of using H_2 and fuel cells on-board fishing vessels. The conclusion was that no major technical barriers for applying fuel cells and hydrogen at sea were found. The project also suggested mitigating actions to prevent investing too much before the technology and storage methods were considered secure and economically viable. Therefore small-scale tests would be most feasible to overcome the investment costs in testing hydrogen systems in marine conditions.

Based on these findings INE, VistOrka and other partners launched an Auxiliary Power Unit (APU system) on-board the whale watching ship Elding in April 2008. The main goal of the test is to provide a sturdy yet functional, system design connecting both proven and heretofore conceptual components. Each module, and the system as a whole, go through a strict certification process to ensure safe handling and operations. Reports will be compiled on performance, endurance, and maintenance through regular inspections. Another crucial point is the secure delivery of H_2 to the harbour and safe refuelling of vessels.

The key components of the experiment are:

- 10 kW fuel cell (Ballard, system integration by H_2-Logic)
- 350 bar Dynatek storage vessels, but only working on 200 bars as the hydrogen will be trucked in at that pressure
- Batteries in a hybrid system setup that can provide a maximal output of 15kW

In addition, there will be a showroom that displays and explains the system and the local energy chain. As part of the total SMART-H_2 project, those responsible for the auxiliary unit will conduct various studies that can facilitate the development of optimal design and performance. They anticipate gaining valuable information that can give rise to expanded marine fuel cell systems and commercialisation of the units. Already the preparation on-board Elding has contributed considerable knowledge and practical information.

Research and Development Projects

Steps toward the hydrogen society

1970 ➤ Hydrogen research begins at the University of Iceland.

1990 ➤ Discussions begin between the University of Iceland and Hamburgische Electricitets Werke regarding the 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 (see photo on pg. 10).

➤ 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.

➤ US Senatorial delegation, comprising John McCain, Hillary Clinton, Susan Collins, Lindsey Graham and John Sununu, visited Iceland in April for a briefing on Iceland's hydrogen projects (see photo on pg. 11).

➤ 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 ends; reports on the various aspects of the experience are published (www.newenergy.is).

➤ Fuel cell A-class vehicle from DaimlerChrysler is unveiled in April.

NEEDS

New Externalities for Energy Development, or "NEEDS," is a European Commission funded project to estimate the externalities of various future energy technologies. NEEDS is partly an extension of studies that estimated the prices of externalities which cumulated in the report External-E published in 2003. New and future energy technologies based on fossil fuel, nuclear power, solar towers, solar PV, fuel cells, biomass, gas, marine energy, offshore wind-energy plants and others are analysed from a life cycle perspective. The NEEDS project concludes in 2008.

Encourage

Energy corridors into Europe is a compilation of energy sources that can be imported to the EU in the next decades. Its outcome is posted on www.ecn.nl/publicaties/. INE used work included in the EURO-HYPORT project, but the general trend is to look into natural gas as Europe's main energy source until 2030, followed by a more massive introduction of hydrogen.

HY-Approval

A cooperative project involving 26 partners (including China). The aim of the project is to develop a "handbook for approval of hydrogen refuelling stations" that will be used to certify public hydrogen filling stations in Europe. This handbook will be issued on the web to assist those who intend to build, operate, monitor and approve of the design and managment of hydrogen refuelling stations. Harmonisation has been lacking in the member states and therefore different sets of rules still apply for the various contries. For further information, please visit the project's website www.hyapproval.org

Create Acceptance

A project concluded in February 2008 with very good results. The project has developed a support tool for project managers who want to approach stakeholders in a systematic way. The tools give examples on how views and alternative ideas have been successfully accounted for in project design. The methods were tested on a variety of renewable energy projects throughout Europe. INE's SMART-H_2 project has been used as a showcase for testing the management tool. For further information, visit www.esteem-tool.eu

Roads2Hycom

This project uses quantitative techniques to assess European and global technology, hydrogen infrastructures, and the needs of generic community types that define thresholds required for successful hydrogen community application. It considers the technical, commercial, safety and socio-economic aspects of hydrogen technology. Roads2Hycom feeds the results into the hydrogen part of the newly established Joint Technological Initiatives, a new EU research and industrial development initiative.

SUGRE

Sustainable Green Fleets is an accompanying measure within the EC 6th framework program that promotes alternative propulsion, and mainly focuses on captive fleets, but not exclusively land transport. The main objective is to promote and support the conversion of fleets to alternative propulsion (ranging from bio-fuels, methane as fuel to hybrid systems comprised of combustion engines, and electric propulsion systems) and the energy efficient usage of them.

Úthrif (Externalities from geothermal powerplants)

INE is working within an Icelandic group of specialists who are developing improved methodologies for evaluating external effects of using geothermal energy. Geothermal areas have distinctive ecosystems that endure high heat, steam, exposure to airborne hydrogen sulphide and high mineral contents in the ground water. The same areas are attractive for tourists as well as researchers in biochemistry and microorganisms. The project is sponsored by Rannís, the Icelandic Research Council. Project manager is the Icelandic Innovation Centre, which conducted an LCA study on the geothermal powerplant at Nesajvellir. Engineers, biologists, geologists, economists and students are currently looking into the changes that may follow the construction of geothermal powerplants on landscapes, microbes, fresh water and soil in high heat areas. Hydrogen vents naturally from a few geothermal sources in Iceland, and there are plans to produce hydrogen from hydrogen sulphide emissions in context with geothermal powerplants. In 2006, 26.5% of Iceland's power was derived from geothermal energy in six powerplants in Iceland.

- INE's conference in April; HY-Pro-Files, the lessons from ECTOS.
- Testing of a Japanese fuel cell tricycle is planned on the Icelandic ring road, Highway 1.
- The Icelandic parliament passed a bill on specific tax reductions for hydrogen vehicles.

2006

- A stationary fuel cell is put to test at Keflavik International Airport.
- The buses from ECTOS are used during a whole year within the HYFleet:CUTE project to check on the endurance of the bus and hydrogen station. The performance of the buses proves to be excellent.
- INE participates in the EU projects: Encourage, Create Acceptance, Roads2HyCom, HyApproval, NEEDS.
- North Atlantic Hydrogen Association (NAHA) founded; INE becomes the secretariat for NAHA.

2007

- The hydrogen fuel cell buses are dismantled and integrated into other public vehicles. One is donated to the transport museum in Skogar.
- The SMART-H_2 in Iceland is formally announced. VistOrka funds the field testing of up to 30 cars according to availability for three years.
- First hydrogen car to arrive is FC A-class from DaimlerChrysler.
- The hydrogen station is declared open for the public; instructions and card reader mounted to facilitate monitoring and public use.
- Skeljungur takes over the commercial operation of the hydrogen station.
- 10 retrofitted hydrogen-battery hybrids are integrated into service fleets and offered as rent-a-cars by Hertz.
- Prof. Thorsteinn Sigfusson shares the Energy Globe award presented by Russia's president, Vladimir Putin.
- Icelandic hydrogen is established as an industrial manufacturer.

2008

- Reykjavik's Energy becomes the largest shareholder in Icelandic New Energy.
- INE produced a brochure to support 7000 companies and communities in Iceland in formulating a sustainable transport policy and to show corporate social responsibility.
- Auxiliary power unit on-board Elding is inaugurated.
- Second Daimler FC-A class put into service.
- FC Ford Focus arrives and put in use.

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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