



## A vision for the future today

For decades, successive Icelandic governments have actively promoted the utilisation of the country's abundant renewable energy resources in harmony with the environment. This policy is

based on exploration and investigation of Iceland's abundant hydropower and geothermal resources.

Today, Iceland has now reached the position of having eliminated fossil fuels from all stationary energy needs, and renewable resources account for more than 70% of the country's primary energy supply. It is now the government's goal to go even further, and head towards a carbon-free future in which indigenous renewable energy will replace fossil fuels as far as possible. This applies equally to public transportation, and the policy and priorities on hydrogen are a central feature in this vision.

In 1998, the Icelandic government made a clear policy statement towards a hydrogen economy. The document's long-term vision envisages that hydrogen produced from renewable energy sources could replace fossil fuels in the country's transport sector and fishing fleet as soon as this becomes technically and economically feasible.

A clean, energy efficient fuel that can be derived from diverse sources, hydrogen as an energy carrier is promising for Iceland due to the country's abundance renewable energy resources from which to produce it. The aim of the Icelandic government's hydrogen policy is to make further use of domestic renewable energy, and reduce pollution and the emission of greenhouse gasses, with all the attendant benefits for the environment, economy and public health. In this way, Iceland will also contribute further to the global effort to protect the climate.

### International platform for hydrogen research

Research on the production of synthetic fuels, mainly hydrogen, from Iceland's renewable resources has been conducted at the University of Iceland for decades, resulting in close international co-operation in this field.

Building on this foundation, a major goal of Icelandic government policy on hydrogen is the creation of a favourable international platform for research and testing within the country, based on close co-operation between the public and private sectors and offering a unique framework for future development and collective expertise. While Iceland is not capable of making major advances in this area on its own, major steps can be taken in co-operation with other nations, agencies and key industry operators worldwide.

Icelandic governmental policy on hydrogen can be classified into five main categories.

- On-going policy formulation
- Favourable framework for business
- International co-operation
- Research
- Education and training

Public and private co-operation work on policy formulation on hydrogen will continue. As the problems to be solved are global in nature, emphasis will be placed on international consultation and co-operation. As a nation, Iceland realises the importance of working with others on the hydrogen issue in order to make it an integral part of a global agenda to succeed.

### Framework for investment and research

Iceland's successful exploitation of its geothermal energy and hydropower has been one of the main driving forces behind the nation's prosperity over the past few decades. Direct foreign investment in power intensive industries is important in this development.

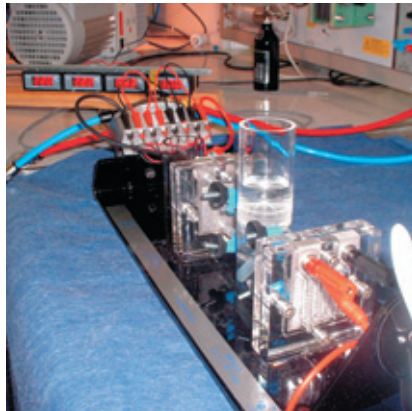
Icelanders enjoy one of the world's highest standards of living and most technologically advanced societies, and a modern, thriving economy. Liberal rules on foreign investment, business-orientated corporate legislation, accessible public administration and a well-educated, flexible workforce all combine to welcome the foreign investor, not the least in the area of hydrogen development.

### Ministry of Industry and Commerce

The Ministry of Industry and Commerce is in charge of promoting and operating Icelandic government policy on energy and hydrogen in close co-operation with other ministries and stakeholders.

### 10 steps towards a hydrogen economy

- 1970 Three decades of hydrogen research beginning at the University of Iceland.
- 1990 Consultations between the University of Iceland and Hamburgische Electricitets Werke
- 1997 Governmental Committee on Domestic Fuel Production
- 1998 Political Leadership – Governmental Policy on Hydrogen
- 1998 Negotiations between Icelandic and Global Stakeholders on Hydrogen
- 1999 Establishment of EcoEnergy & Icelandic New Energy, ECTOS Project
- 1999 onwards – International co-operation, EEA, bilateral, IPHE
- 2003 (April) Opening of the world's first hydrogen station built on the site of a conventional filling station
- 2003 (October) – Testing of the operation of three hydrogen-powered buses commences.
- 2003 On-going work efforts and consultation on hydrogen research programmes and policy.



### Reykjavik - a sustainable city

Reykjavik enjoys the unique advantage of being a progressive, modern capital city with ready access to plentiful sources of clean geothermal energy, ensuring that its inhabitants enjoy ready access to clean air and unpolluted water.

In keeping with the city's declared ambition of becoming the world's most sustainable capital, Reykjavik is working according to an ambitious policy based on the use of sustainable energy sources with minimal intrusion into the natural environment.

As part of this policy, the city is currently participating in the ECTOS project, testing hydrogen buses by operating them for the next two years as a part of the city's public bus fleet.

# Experience innovation expertise

As an old Icelandic saying goes, necessity teaches a naked woman to spin, and living in a country totally lacking in any fossil fuel sources of its own has driven Icelanders to become highly

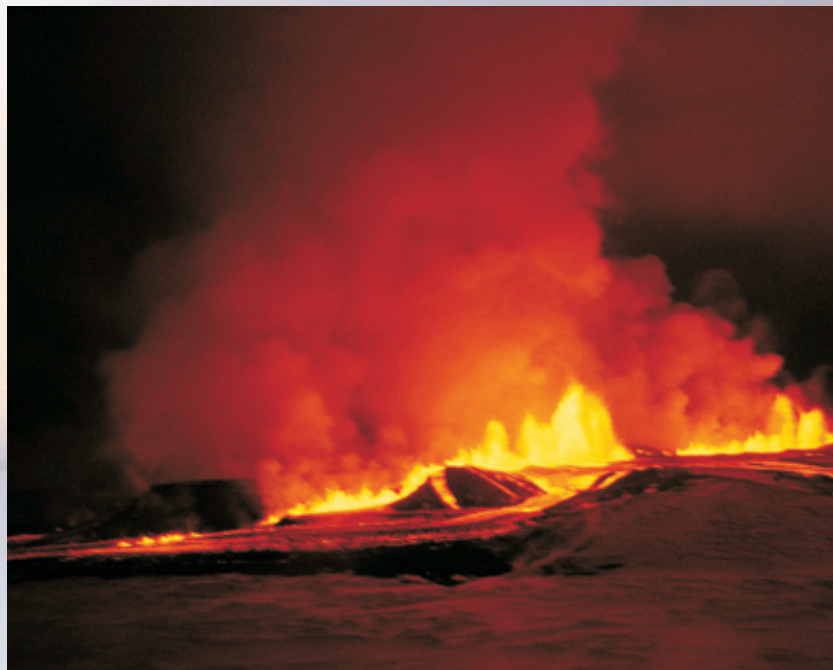
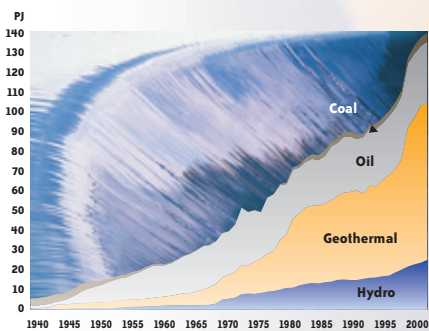
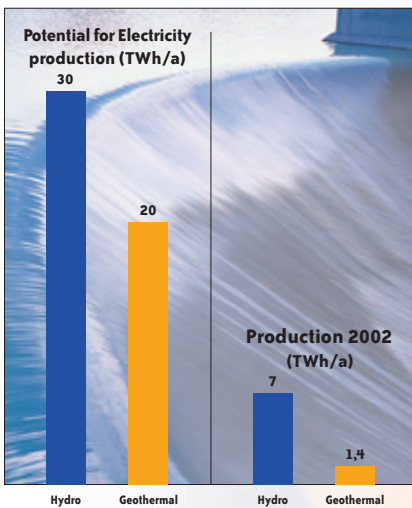
creative in their use of their country's indigenous renewable energy resources.

Helping them achieve this is the remit of Orkustofnun (The National Energy Authority). From surveying to utilisation, the authority is responsible for the exploitation of hydropower and geothermal energy in keeping with Icelandic government policy on developing these resources in harmony with the environment. As such, Orkustofnun is also involved in assessing the potential of hydrogen production as a source of energy in Iceland.

Long-standing use of hydropower and geothermal energy has made Iceland one of the world's leaders in the field, and Orkustofnun, and its offspring Iceland GeoSurvey, global centres of excellence, knowledge and expertise. For over a quarter of a century, the Orkustofnun has hosted the United Nations University geothermal training programme, where young scientists from the developing countries and emerging market economies have been trained in geothermal exploration and usage. At the same time, Icelandic scientists and engineers have worked as international consultants in over 30 countries worldwide, mainly in the field of geothermal energy.

## Untapped potential

To date, Iceland has harnessed only a small proportion - about 15% - of its natural energy potential, and this does not include what could be derived from wind power. If utilised to the full, the remainder would be sufficient to serve the entire electricity needs of a country the size of Denmark.



During the global oil crises of the 1970s, a concerted effort was made to replace imported fossil fuels with geothermal energy as a source of space heating throughout Iceland. Today, close to 90% of the country's houses and buildings are heated using natural hot water, and the remainder by renewable, hydro-generated electricity. As a result, there are basically no greenhouse gas emissions from stationary energy use in Iceland. Two-thirds of such emissions come from the nation's cars and fishing fleet, and the remainder largely from industrial processes, mainly aluminium smelters.

Today, Iceland has reached the stage where over 70% of its primary energy consumption is met by domestically produced renewable energy. Like the rest of the world, however, the country is forced to use fossil fuels in the form of petrol and oil to drive its motor vehicles and fishing fleet, all of which must be imported.

Producing hydrogen from water using electrolysis powered by local hydropower and geothermal energy would not only provide Iceland with its own source of domestically produced clean fuel, but also eliminate the need for expensive - as well as polluting - fossil fuel imports.

## Powering progress

In 2002, electricity production in Iceland totalled over 8 TWh, the highest level per capita in the world. Converting all the country's cars and fishing vessels to hydrogen fuel-cell power would require an additional 4.5 TWh of electricity per annum to produce sufficient hydrogen by electrolyses from fresh water, a natural resource in which the country also abounds.

Through extensive experience, expertise and on-going commitment to innovative research on the exploitation of sustainable, renewable energy resource, Orkustofnun and its sister organisation are making a major contribution towards creating a hydrogen future for both Icelanders and the world at large, and will continue to do so in years to come.

## Working together

**Orkustofnun** is an administrative and regulatory agency, and a global source of expertise on energy issues. The agency, and more recently its sister organisation, Iceland GeoSurvey, has worked for over half a century on research into hydropower, geothermal energy and assessing Iceland's energy potential. An international centre of excellence and expertise, Orkustofnun works closely with the following agencies:

- The International Energy Agency (IEA)
- European Union
- Nordic Project for Energy Research
- International Geothermal Association
- International Co-operation on Drilling (ODP, IDDP)
- WMO, UNESCO

**Hitaveita Suðurnesja hf** operates an innovative geothermal resource park in southwest Iceland based around the Svartsengi co-generation power plant, the first of its kind in the world to generate both electricity and potable district heating water. Auxiliary features include the well-known Blue Lagoon and spa complex.

**Reykjavík Energy** operates the world's largest domestic heating system, using clean, natural geothermal energy. The company provides hot water to the homes of more than half of Iceland's population, and also generates electricity using turbines powered by natural steam.

**Landsvirkjun** (The National Power Company) is the largest electricity producer in Iceland. Its operations are based totally on hydropower and geothermal energy, and its production is sold wholesale to local utilities and directly to power-intensive industries.

## Fuel for the future

Hydrogen has been on the research agenda at the University of Iceland for the past three decades. Through its pioneering work on hydrogen as a fuel and its participation in the first steps towards establishing a

hydrogen society for the future, the university is now challenging the current dominance of rapidly depleting fossil fuel resources.

At the same time, the University of Iceland provides research opportunities and education designed to support Iceland's vision of creating a sustainable society capable of providing for its own fuel needs, so giving emerging researchers the opportunity to become leaders in the field of energy technology.

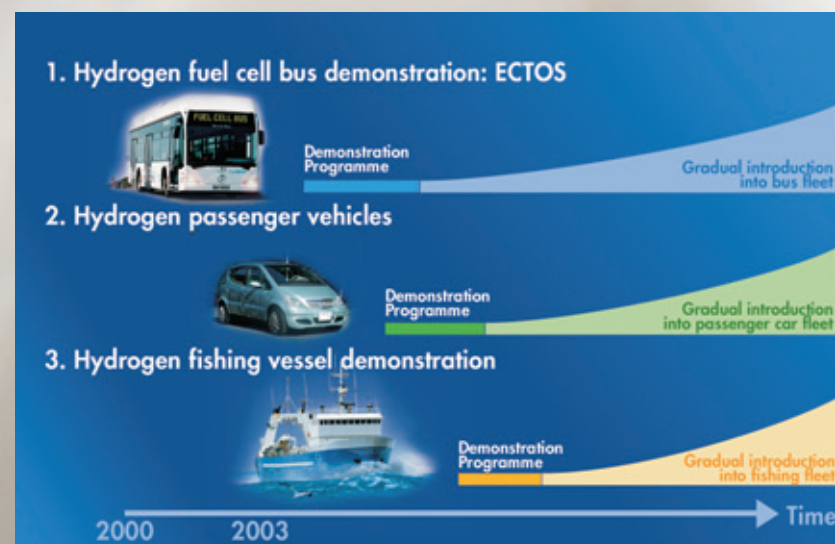
The University of Iceland and the Technological Institute of Iceland are currently working together on establishing a hydrogen systems analysis laboratory to further strengthen research activities and cooperation.

### Icelandic New Energy Ltd.

A spin-off from the research activities at the University of Iceland, the seed company Icelandic New Energy (INE) was formed in 1999. While creating a hydrogen society is both an ambitious and long-term objective, the current success of the Icelandic hydrogen project may in many ways be linked to the company's innovative structure, depicted on the chart below.

One of INE's major shareholders is VistOrka, a company which serves to unite business venture funds, key energy companies, academic institutions and the Icelandic government with key international players in hydrogen technology, such as DaimlerChrysler, Norsk Hydro and Shell Hydrogen.

The first step towards investigating the potential of hydrogen as a practical source of sustainable energy was taken on March 1, 2001, with the launch of the EU-funded ECTOS-project. Following two years of preparations, the world's first hydrogen refuelling station located on the site of a conventional



### University of Iceland

The cradle of Iceland's efforts to create a hydrogen society, the University of Iceland is currently conducting extensive research programmes on the storage and production of hydrogen, hydrogen systems analysis, and the socio-economic implications of the use of hydrogen as energy carrier.

### IceTec – Technological Institute of Iceland

IceTec's role in environmental issues is becoming an increasingly important part of the company's operations. By participating in a variety of hydrogen research and demonstration projects, it has become an active partner in developing and introducing tomorrow's fuel.

### Icelandic New Energy Ltd.

INE's mission is "to investigate the potential for eventually replacing the use of fossil fuels in Iceland with hydrogen-based fuels, thereby creating the world's first hydrogen society".

### VistOrka

VistOrka functions as a communication and advisory platform for various aspects of the hydrogen energy business and applications developments, and is an active participant in several of the on-going research and demonstration projects currently being conducted in Iceland.

### ECTOS

ECTOS is a 7 million project supported by the European Commission DG-Research "City of Tomorrow and Cultural Heritage"

filling station and open to the general public was formally opened on April 24, 2003. Six months later, the three hydrogen buses participating in the ECTOS project arrived in Reykjavik, where they will operate as part of the city's public transport system for the next two years.

The goals of the ECTOS project are not only to gather information on the technological performance of the hydrogen-powered buses and Iceland's hydrogen infrastructure, but also to conduct research on the socio-economic and environmental implications of the use of hydrogen as an energy source. If Iceland is to become a hydrogen-based society in the foreseeable future, then according to the principles of sustainable development, decisions should be based on total benefits and costs, based on life-cycle costs.

### Future Vision

Icelandic New Energy's vision is for Iceland to become independent of fossil fuel imports within the next five decades. While technological developments can and will influence the speed at which - and whether - this becomes a reality, it is clear that the research and demonstration projects already in place, coupled to strong political support, give Iceland a major advantage on the road towards becoming the world's first hydrogen society wholly based on a renewable energy chain.



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