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HYDROGEN IN ICELAND: Some lessons from a University spin-off project

Thorsteinn I. Sigfusson

Professor of Physics University of Iceland
and Chairman Icelandic New Energy Ltd.

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Iceland has almost no fossil resources but plenty of sustainable energy

Iceland has harnessed about 8TWh out of its

potential of more than 55TWh(el.)

in the form of hydroelectric or geothermal energy

GHG emissions

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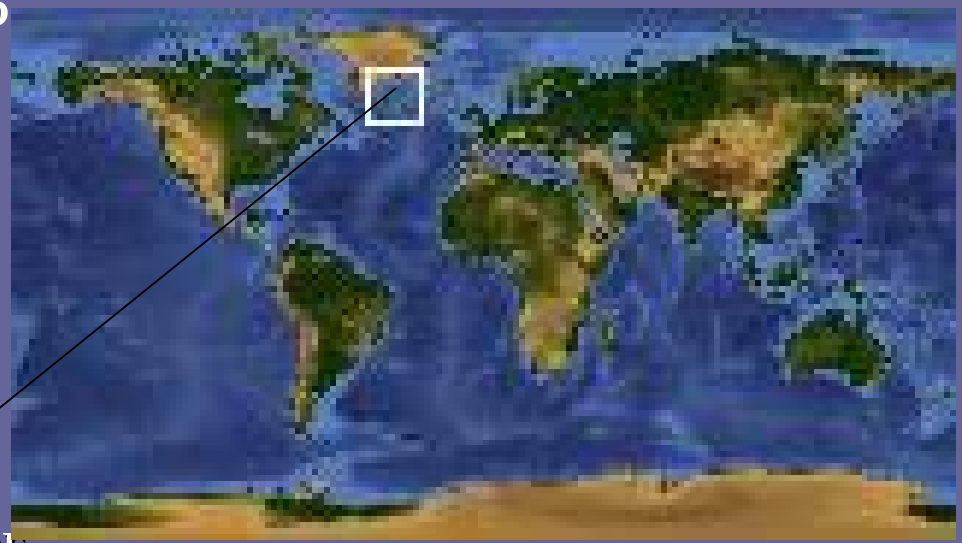
CO_2 from imported fuels :

The transport sector: 1/3

Fishing: 1/3

Industry in general: 1/3



Total anthropogenic CO_2 emission:

3.000.000 tonnes annually or about

11 tonnes per capita

H-Background

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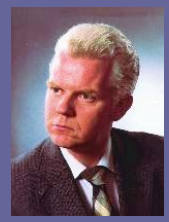

- 25 years research, University of Iceland
- initiated by Professor Bragi Arnason

- 1990: Meeting between the University of Iceland, and various German companies and institutions

- 1997: Ministry of Industry and Commerce appoints a committee on "Domestic Fuel Production"
- 1998: Negotiations between Icelandic and European partners

- 1999: Formation of Icelandic New Energy and a memorandum from the Government of Iceland deciding to aim for a hydrogen energy economy

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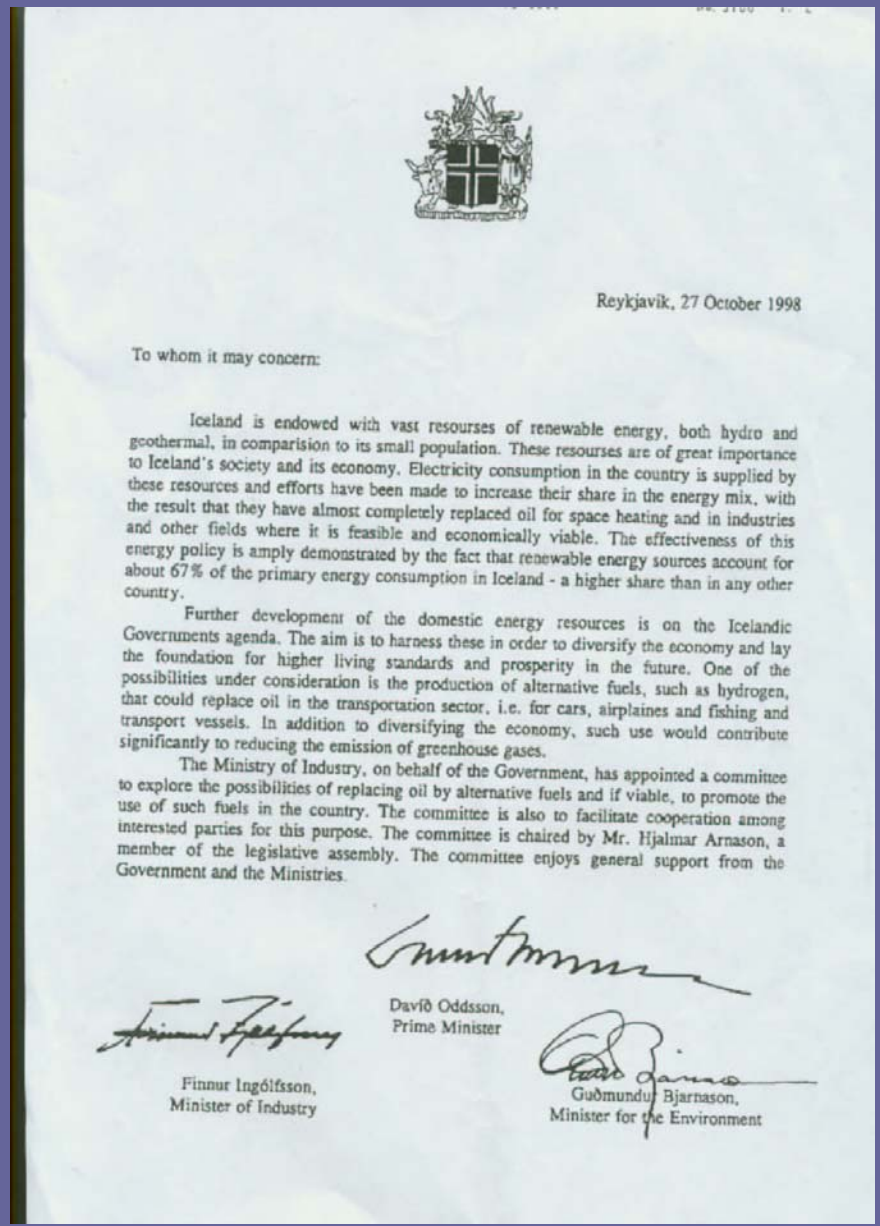
CLEAR POLITICAL LEADERSHIP:

The Prime Minister

The Industry Minister

The Minister of Environment

Signed the Intention of the Government of Iceland 27.10.1998



Reykjavik, 27 October 1998

To whom it may concern:

Iceland is endowed with vast resourses of renewable energy, both hydro and geothermal, in comparision to its small population. These resourses are of great importance to Iceland's society and its economy. Electricity consumption in the country is supplied by these resources and efforts have been made to increase their share in the energy mix, with the result that they have almost completely replaced oil for space heating and in industries and other fields where it is feasible and economically viable. The effectiveness of this energy policy is amply demonstrated by the fact that renewable energy sources account for about 67% of the primary energy consumption in Iceland - a higher share than in any other country.

Further development of the domestic energy resources is on the Icelandic Governments agenda. The aim is to harness these in order to diversify the economy and lay the foundation for higher living standards and prosperity in the future. One of the possibilities under consideration is the production of alternative fuels, such as hydrogen, that could replace oil in the transportation sector, i.e. for cars, airplaines and fishing and transport vessels. In addition to diversifying the economy, such use would contribute significantly to reducing the emission of greenhouse gases.

The Ministry of Industry, on behalf of the Government, has appointed a committee to explore the possibilities of replacing oil by alternative fuels and if viable, to promote the use of such fuels in the country. The committee is also to facilitate cooperation among interested parties for this purpose. The committee is chaired by Mr. Hjalmar Arnason, a member of the legislative assembly. The committee enjoys general support from the Government and the Ministries.

Davíð Oddsson,
Prime Minister

Finnur Ingólfsson,
Minister of Industry

Guðmundur Bjarnason,
Minister for the Environment

The Mission behind Icelandic New Energy

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To set up a joint venture company to investigate the potential for eventually replacing the use of fossil fuels in Iceland with "hydrogen based fuels" and create the world´s first hydrogen economy"

Icelandic New Energy Ltd (INE)

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Majority shareholder: 51%

Icelandic Holding Company

VistOrka hf (EcoEnergy)

VistOrka shareholders:

Icel. New Business Venture Fund

Reykjavik Energy

The National Power Company

Sudurnes Regional Heating Corp

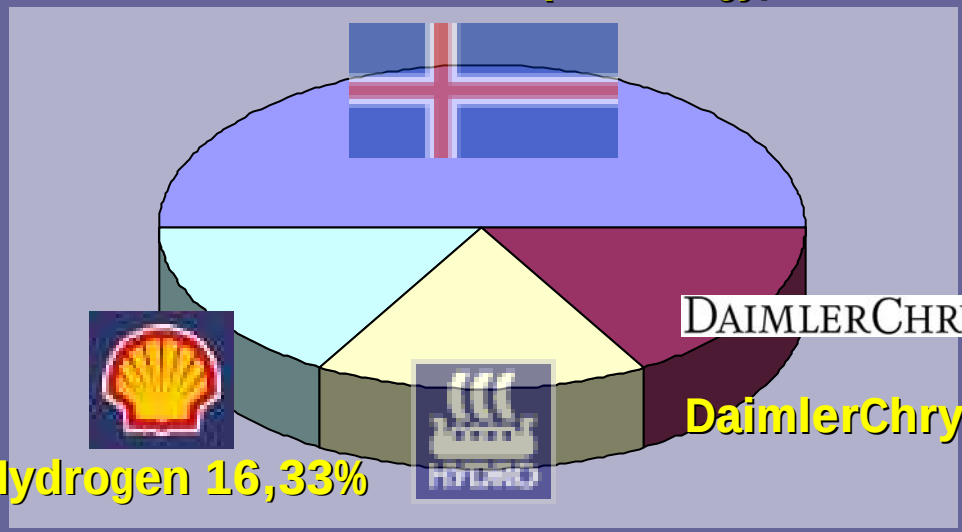
University of Iceland

The Technological Institute of Iceland

Fertilizer Plant

Aflvaki hf

Government of Iceland



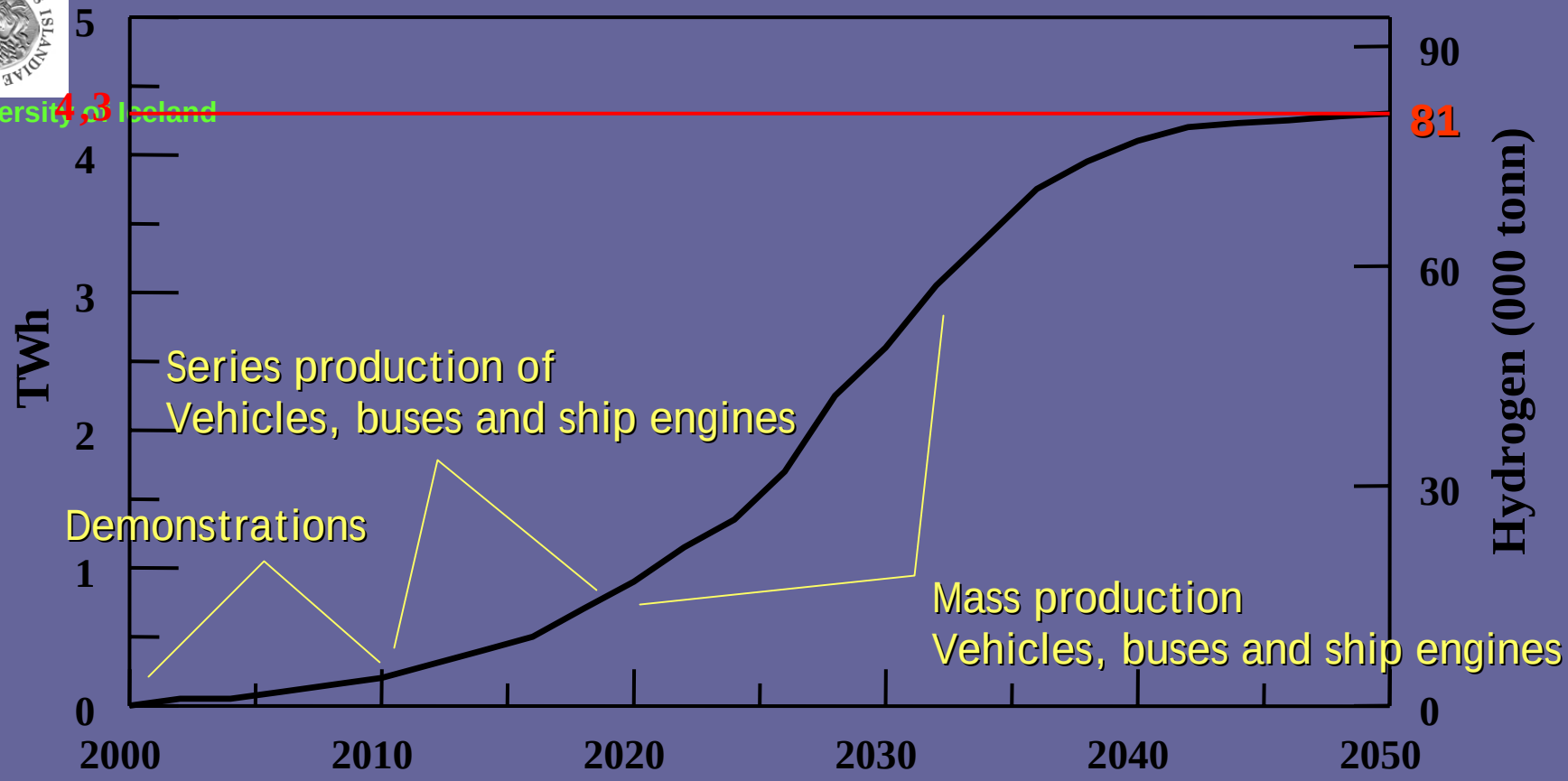
Shell Hydrogen 16,33%

DaimlerChrysler 16,33%

Norsk Hydro 16,33

CEO J.B.Skulason

Estimated energy use for the hydrogen society



Forecast for the development of the usage of hydrogen as a fuel in cars and ships. Technical developments during the next few years could considerably influence the graph.

Why Iceland and hydrogen?

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1. Iceland has the unique circumstances to enable operating a "hydrogen based fuel project" in a CO_2 neutral environment
2. Iceland has similar standards and transportation system as most other developed countries and therefore the results can easily be adapted elsewhere
3. Iceland has experience in converting from one energy source to another

Why Iceland and hydrogen? (cont.)

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4. It is very important that the project makes a big impact (real-scale project)
5. The new technology needs to be evaluated under severe weather conditions
6. The government of Iceland has announced that it is aiming to transform Iceland into a hydrogen society in the near future

Key Projects

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1. Fuel cell bus demonstration: ECTOS

Demonstration program

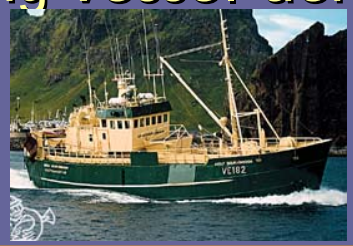
Gradual introduction into bus fleet

2. Fuel cell passenger vehicles

Demonstration program

Gradual introduction into passenger car fleet

3. Fuel cell fishing vessel demonstration



Demonstration program

Gradual introduction into fishing fleet

2000 2002 Time

The ECTOS-project (2001-2005)

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- The ECTOS-project is a 4 year project 2001-2005.
- The project can be split into two key phases:
  - The first two years
    - Preparation, establishing infrastructure, maintenance facility, economic/social research, etc.
  - The second two years
    - The actual demonstration of three H2 buses and commercial infrastructure

European Cities in CUTE and ECTOS

Reykjavik

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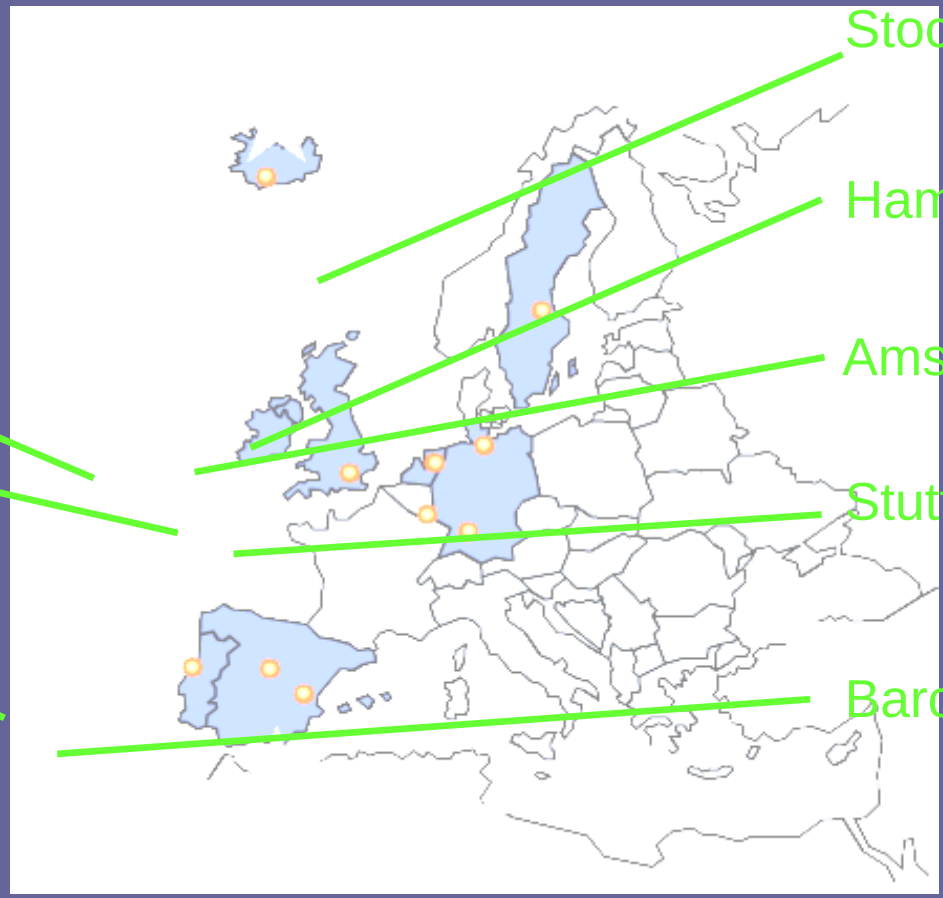
London

Luxemburg

Madrid

Porto



Stockholm

Hamburg

Amsterdam

Stuttgart

Barcelona

ECTOS-project,

Infrastructure

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- Creating and integrating hydrogen infrastructure into the existing urban setting in Reykjavik (2002-2003)
- Production; On site electrolyser (using renewable electricity to split water into hydrogen and oxygen). Only supply: WATER and ELECTRICITY
- Storing; 1 compressor units delivering hydrogen at 440 bar
- Distribution on site of gaseous hydrogen directly on to vehicles.

The ECTOS-project,

Infrastructure (cont.)

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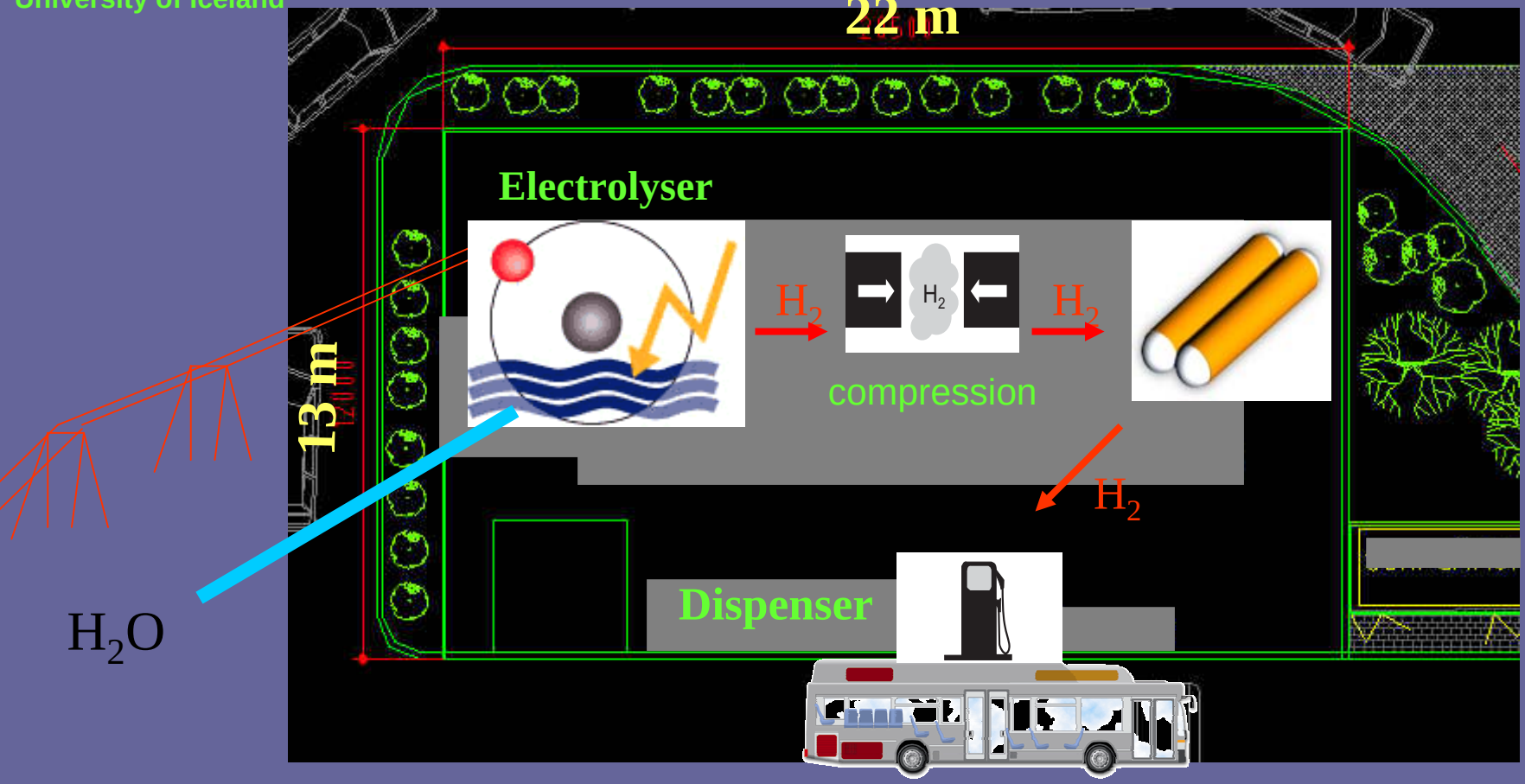

Fueling infrastructure for the future

Inauguration Ceremony Planned April 24th 2003

Hydrogen Station cont.

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Infrastructure analysis

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- Choosing 5 example locations
- Investigate impact of trasforming to hydrogen at each location.
- Extrapolating findings to rest of Iceland

The non-technical face of ECTOS

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- Drivers, Carriers and Barriers for a hydrogen society in Iceland .Socio-environmental -and economic issues.
- Survey: 93% of the responders claimed to have a positive attitude towards hydrogen as a future fuel
- Summer Course for graduate students on the H-Infrastructure: www.verk.hi.is/energy
- Information dissemination: www.newenergy.is www.ectos.is)

Demonstration vessel

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Estimate a 500 kw engine for a 100 ton fishing vessel; using a fuel cell

The problem is to store sufficient amount of hydrogen for a 4-5 day trip

The first estimates for the amount of hydrogen needed to be stored for such a fishing vessel could be: 1000 kg H

Alt.storage possibility could be Sodium BoroHydrides (Millennium Cell)or Metalhydrides (JSW – Varmaraf)

Large Scale Hydrogen Implementation Barriers in Iceland

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- Production
- Storage
- Infrastructure
- Utilization

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PRODUCTION:

- Not likely to be a serious implementation barrier in Iceland
- Electrolysis - ample supply of primary renewable energy to provide for transportation hydrogen needs
- Fossil - no indigenous sources of fossil fuels in Iceland
- Geothermal –Steam Turbine Electricity and Hydrogen separation from geothermal gases
- In addition to Thermo-electric production and storage from waste heat of thermal power plants

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STORAGE

- Potentially large world wide implementation barrier and research opportunity
- Established expertise in liquid and compressed gas storage in other countries/private industry
- Hydride storage remains a relatively nascent field
- University of Iceland/Icelandic New Energy/Varmaraf plan to focus research on hydride storage

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Making Hydrogen by using the heat content of geothermal water

- One of the novelties of research in Iceland presently is the development of a new concept of using the heat content of geothermal water for making hydrogen and managing hydrogen storage

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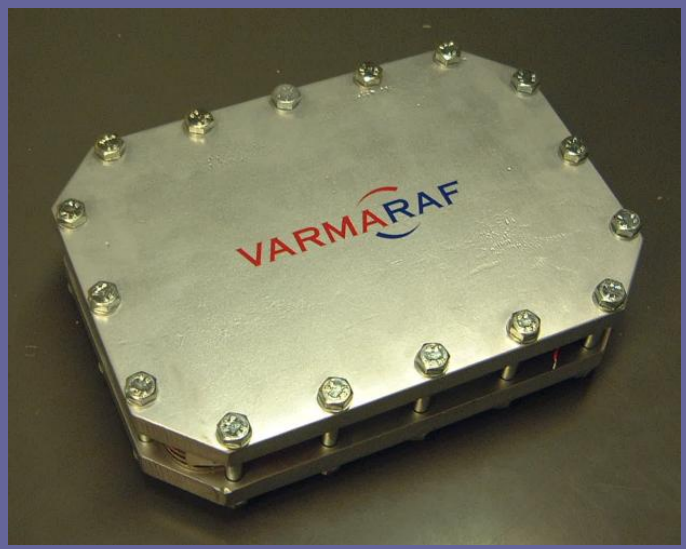
A technology for solid state electricity generation from heat has been developed in Iceland and an interesting merger of this technology and hydrides is emerging



Japan Steel Works, one of the world´s foremost producers of metal hydrides is becoming a close partner in this field

Projects under preparation

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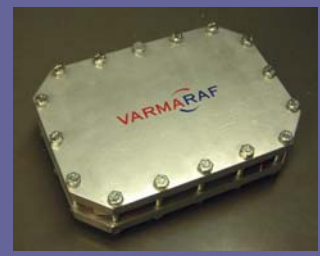
- HYPEC: Hydrogen and Proton Energetics Consortium
- involving the development of thermally managed hydrides for storing and compressing Hydrogen



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HYPEC main goal

- To develop and demonstrate a residential hydrogen and fuel cell system based on hydrides/gas and a completely CO_2 free energy chain
- To develop a benchmark for efficiency, safety, costcutting and general sustainability approach

Demonstrating stationary applications

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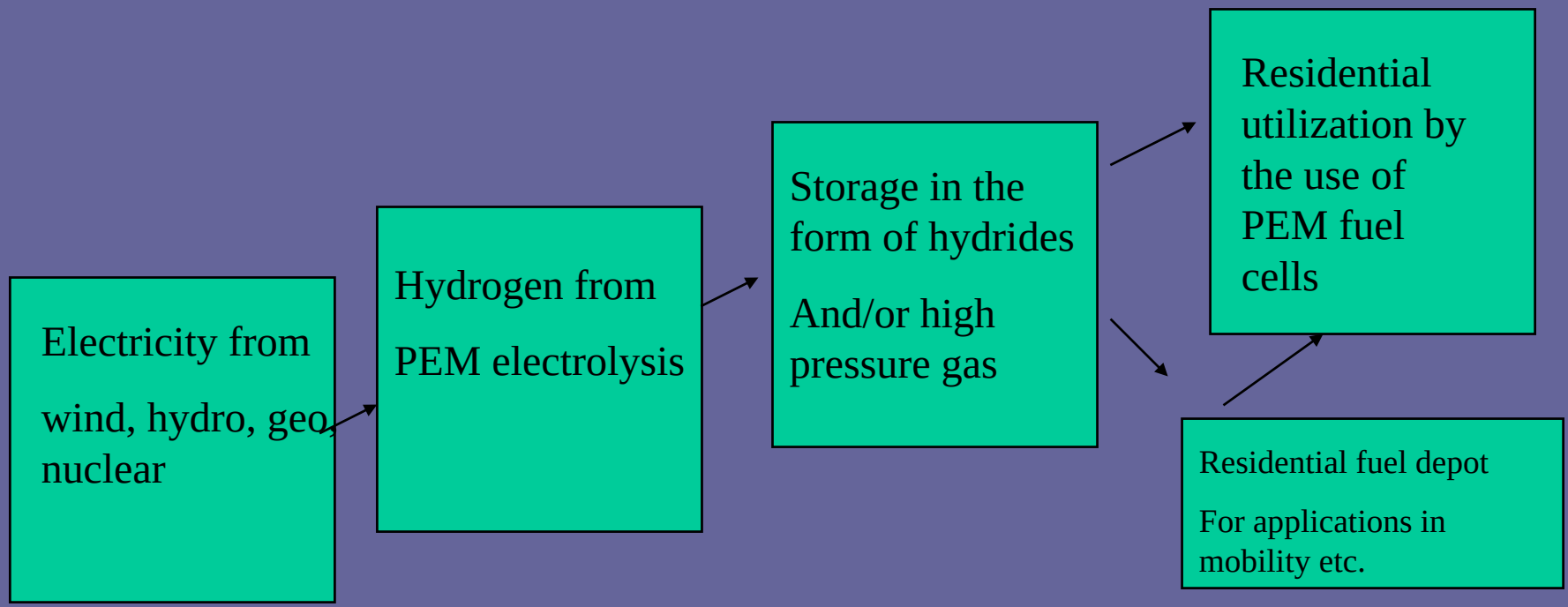

Fundamental H-storage research at U.I.

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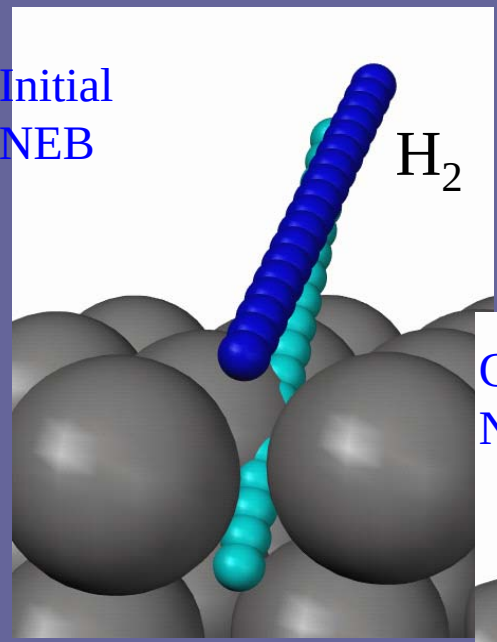
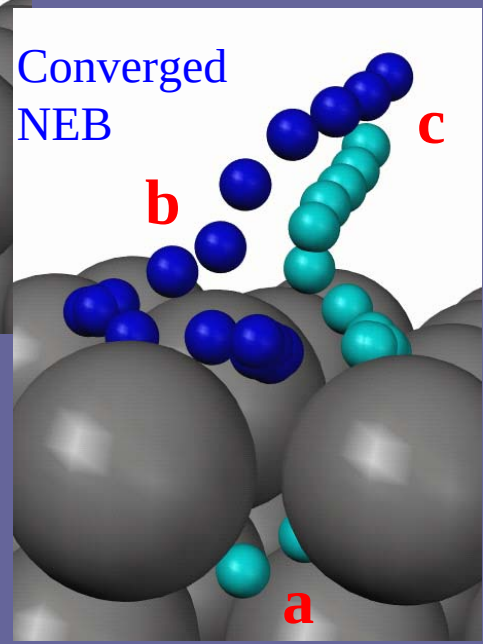
- **Dr. Hannes Jonsson**

Thoretical calculations using density functional theory
H_2 dissociation/recombination on Ni(111)

Dr. Sveinn Olafsson
Nanotechnology





INFRASTRUCTURE

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- Inherently linked to methods of production and storage
- May not be a major implementation barrier in Iceland due to:
  - Potential for on-site production and storage
  - High population density in Iceland (Reykjavik) and most of the remaining population lives in coastal areas
  - Minimum level of “station conversion” is required to make hydrogen widely available to the public

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UTILIZATION

- Will the switch to hydrogen occur in a market economy?
- Cost of hydrogen may be competitive in Iceland due to inexpensive electricity, projected further reductions in the cost of electrolyzers, and high petroleum taxes
- Cost of Fuel Cell Technology needs to go down
- The three major groups of H-users in Iceland:
  - Will a complete conversion to FC buses occur after 2005 if the cost of FCs remains high?
  - Fishing fleet - positive interest among the Federation of Fishing Vessel Owners for a fuel cell fishing boat
  - Passenger Cars - currently no import duties on hydrogen vehicles
    - this is a significant incentive in Iceland, but no vehicles are currently available for consumers to purchase

Conclusion

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- Being independent of fossil fuel imports is a beautiful vision, which could be partly realised in Iceland during the next decades and finished around mid century
- Major barriers do exist and need appropriate policy and research attention
- Working together in dedicated groups we hope to bring about

"A HYDROGEN SOCIETY"

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Thank you for your attention!