Intro to NEA, Water Resources in Iceland, Master Plan for the Utilization of Energy Resources & Petroleum Exploration

The staff of
Orkustofnun, National Energy Authority, Iceland

Compiled and Presented by Kristinn Einarsson, November 2011
Overview

• History and Role of the National Energy Authority
• Hydropower Plants and Utilization of Electric Energy
• Master Plan for the Protection and Development of Hydropower and Geothermal Resources
• Groundwater Resources and Freshwater Consumption
• Petroleum Exploration on the Icelandic Continental Shelf
Orkustofnun – National Energy Authority

- Founded in 1946 as the State Electricity Authority
- 1967: Separation into the National Energy Authority and the State Electricity Company. Landsvirkjun – National Power Company founded at the same time
- 2003: Geothermal resources research services split-off, ÍSOR – Iceland GeoSurvey founded
- 2008: General water cycle monitoring & research split-off, moved to the Icelandic Meteorological Office
- Present: Licensor and supervisor of research and utilization permits for electric power, water resources, minerals, petroleum and mining on the continental shelf. Hosts the Geothermal Programme of the UN University
Scope and division of tasks

• Authorities
  – Administration of utilization and resources research & accounting. Strategic planning

• Utilities
  – Project planning, execution and operation. Site selection and planning of utilization

• Users
  – Energy use (electricity, house heating), domestic water consumption
Hydropower Plants and Utilization of Electric Energy
Development of Energy Utilization

• First phase - until the 1970s
  – Electrification of the country (mainly by hydropower)
  – Harnessing of most easily accessible geothermal fields

• Second phase - after 1965
  – Development of power-intensive industry

• Third phase - after 1973/74
  – Replacement of oil by renewable energy resources, especially for space heating

• Fourth phase - after 1995
  – Further expansion of power intensive industry

• Fifth phase - from 2012 ?
  – Parliamentary resolutions on energy policy & master plan
  – Replacement of oil in transport & fisheries sectors ?
Energy in Water Resources

Precipitation 285 TWh/a

Evaporation
- 33

Glacier flow
- 43

Flowing water 187 TWh/a

Groundwater
- 22

Dispersed and not harnessable energy 123 TWh/a

Harnessable energy 64 TWh/a

Stored energy in glaciers 7800 TWh

Groundwater 22 TWh
### Potential for Electricity Production (TWh/a)

<table>
<thead>
<tr>
<th></th>
<th>Hydro</th>
<th>Geothermal</th>
<th>Together</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resources considered by NEA as sustainable</td>
<td>30</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Production in year 2010</td>
<td>12.6</td>
<td>4.5</td>
<td>17.1</td>
</tr>
<tr>
<td>In relation to sustainable</td>
<td>42%</td>
<td>22%</td>
<td>34%</td>
</tr>
</tbody>
</table>

NB! Wind and tidal power has not been evaluated yet.
Hydropower Plants in Iceland 2010 (>10 MW)

[Map showing locations of hydropower plants in Iceland with markers for 100 MW, 200 MW, and 500 MW.]
### Installed On-Grid Capacity 2010

<table>
<thead>
<tr>
<th>Power Station Size</th>
<th>No.</th>
<th>MW</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power stations &lt;1 MW</td>
<td>24</td>
<td>6</td>
<td>0,3</td>
</tr>
<tr>
<td>1 MW &lt; Power stations &lt; 10 MW</td>
<td>17</td>
<td>66</td>
<td>3,5</td>
</tr>
<tr>
<td>Power stations &gt;10 MW</td>
<td>12</td>
<td>1811</td>
<td>96,2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>53</td>
<td>1883</td>
<td>100</td>
</tr>
</tbody>
</table>
Electrical Grid in 2010

Source: Landsnet – National Grid
Electricity production 1930-2010
Electricity Consumption by Sectors [GWh] in 2010

- Household: 879 GWh (5.31%)
- Aluminium: 12279 GWh (74.10%)
- Ferro-silicium: 930 GWh (5.61%)
- General Industry: 548 GWh (3.31%)
- Utilities: 670 GWh (4.04%)
- Services: 1008 GWh (6.08%)
- Agriculture: 218 GWh (1.32%)
- Fishery: 39 GWh (0.24%)
Electricity consumer prices 2010

[€/kWh]
# Electricity Production in some Industrialized Countries 2009

<table>
<thead>
<tr>
<th>Country</th>
<th>Electricity Production (TWh)</th>
<th>Fuel (TWh)</th>
<th>Nuclear (TWh)</th>
<th>Hydro (TWh)</th>
<th>Other Renewables (TWh)</th>
<th>Import of Electricity (TWh)</th>
<th>Export of Electricity (TWh)</th>
<th>Inhabitants 2010 (millions)</th>
<th>Electricity Production (MWh per capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>367.3</td>
<td>291.5</td>
<td>56.4</td>
<td>6.7</td>
<td>10.0</td>
<td>7.1</td>
<td>4.5</td>
<td>62.0</td>
<td>5.9</td>
</tr>
<tr>
<td>Denmark</td>
<td>35.5</td>
<td>28.8</td>
<td>0.0</td>
<td>0.0</td>
<td>7.8</td>
<td>10.6</td>
<td>11.7</td>
<td>5.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Germany</td>
<td>568.9</td>
<td>374.1</td>
<td>133.2</td>
<td>25.1</td>
<td>51.5</td>
<td>43.0</td>
<td>57.9</td>
<td>82.3</td>
<td>6.9</td>
</tr>
<tr>
<td>Japan</td>
<td>1038.2</td>
<td>672.8</td>
<td>274.3</td>
<td>82.1</td>
<td>9.0</td>
<td>0.0</td>
<td>0.0</td>
<td>126.5</td>
<td>8.2</td>
</tr>
<tr>
<td>USA</td>
<td>4183.9</td>
<td>2963.0</td>
<td>807.7</td>
<td>281.5</td>
<td>113.0</td>
<td>41.5</td>
<td>22.8</td>
<td>310.4</td>
<td>13.5</td>
</tr>
<tr>
<td>Sweden</td>
<td>151.4</td>
<td>19.6</td>
<td>55.2</td>
<td>70.9</td>
<td>3.5</td>
<td>14.9</td>
<td>12.9</td>
<td>9.4</td>
<td>16.1</td>
</tr>
<tr>
<td>Canada</td>
<td>553.3</td>
<td>140.2</td>
<td>85.2</td>
<td>348.1</td>
<td>5.9</td>
<td>18.6</td>
<td>44.8</td>
<td>34.0</td>
<td>16.3</td>
</tr>
<tr>
<td>Finland</td>
<td>87.5</td>
<td>41.8</td>
<td>21.9</td>
<td>12.7</td>
<td>0.6</td>
<td>15.7</td>
<td>5.2</td>
<td>5.4</td>
<td>16.3</td>
</tr>
<tr>
<td>Norway</td>
<td>131.3</td>
<td>5.4</td>
<td>0.0</td>
<td>117.3</td>
<td>1.1</td>
<td>14.7</td>
<td>7.1</td>
<td>4.9</td>
<td>26.9</td>
</tr>
<tr>
<td>Iceland</td>
<td>16.8</td>
<td>0.0</td>
<td>0.0</td>
<td>12.5</td>
<td>4.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.3</td>
<td>52.4</td>
</tr>
</tbody>
</table>

Source: IEA
Icelandic Electricity Production in OECD Perspective

- Electricity production of Iceland in 2010: 55 MWh/a per capita
- Average use in OECD countries 2009: 8 MWh/a per capita
- Electricity production of Iceland: Sufficient for 7 million average OECD citizens
Master Plan for the Protection and Development of Hydropower and Geothermal Resources
Opposition to Energy Development

- Energy development in Iceland did not meet much opposition up to the mid 1990’s. In 1995-2006 widespread protest came from some public sectors, because of three hydro projects in glacial rivers, mainly because of environmental issues.
- One was abandoned, one is on hold, but the third was commissioned in the autumn of 2007
- **Conclusion:** A need for a plan that ranks potential projects and not only from energy policy viewpoint
Other interests than energy needs

Energy development must not only consider energy needs. Other considerations include:

• Land use
• Regional development
• Employment
• Impact on society at large
• Impact on Nature and cultural heritage
• Sustainable development of society
Master Plan for Utilization of the Energy Resources

• The Icelandic Government decided in 1997 to develop a Master Plan for Hydro and Geothermal Energy Resources
• First phase initiated in 1999, final report in 2003
• The development of the MP should be based on scientific evaluation and be open for public debate
• It should give an overview of the energy projects and rank them with respect to selected criteria
• In total 19 hydropower projects (16.6 TWh/a) and 24 geothermal projects (18 TWh/a) were evaluated and ranked on environmental impact and feasibility
Master Plan for Utilization of the Energy Resources

- New Electricity Act in 2003 diminished the role of the State, as a free market was allowed to be developed for electrical energy production.
- Second phase of the MP was initiated in 2004 and the final report issued in 2011.
- Ranking of projects by the steering committee as in the 1st phase.
- In total 40 hydropower projects (16.6 TWh/a) and 41 geothermal projects (30.7 TWh/a) were evaluated and ranked on environmental impact and feasibility.
Master Plan for Utilization of the Energy Resources

Ministry of Industry responsible for the project, in co-operation with the Ministry for the Environment

Proposed power projects were evaluated and categorized on the basis of:

• Energy efficiency and economic interests
• Impact on the natural environment, cultural heritage sites, grazing, fishing, hunting and recreational activities
• Implications for regional development
Act on Master Plan for Protection and Development of Energy Resources

• Act passed in May 2011, transforming the Master Plan process into an established and permanent planning tool
• Regular re-evaluation phases every 4 years
• Approval by parliamentary resolution
• Results to be binding for municipal land use planning
• Takes river basin management plans into account
Proposal for a Parliamentary Resolution

• Proposal on the basis of the final report in 2011 for a parliamentary resolution, with classification of projects into 3 classes:
  1. projects appropriate for development,
  2. projects appropriate for protection, and
  3. projects awaiting further consideration

• Put forward for SEA by the Minister of Industry supported by the Minister for the Environment

• Public hearing of the proposal finished Nov 11, 2001

• About 200 responses received from the public

• Final proposal to be delivered to parliament before the end of 2011
# Electric Power Potential

<table>
<thead>
<tr>
<th>Category</th>
<th>Hydro GWh/a</th>
<th>Geothermal GWh/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Production (2010)</td>
<td>12,592</td>
<td>4,465</td>
</tr>
<tr>
<td>Appropriate for Development</td>
<td>3,326</td>
<td>9,908</td>
</tr>
<tr>
<td><strong>Existing &amp; To be developed</strong></td>
<td><strong>15,918</strong></td>
<td><strong>14,373</strong></td>
</tr>
<tr>
<td>Appropriate for Protection</td>
<td>7,745</td>
<td>17,765</td>
</tr>
<tr>
<td>Awaiting further Consideration</td>
<td>6,008</td>
<td>3,098</td>
</tr>
<tr>
<td><strong>Total – Existing &amp; Master Plan</strong></td>
<td><strong>29,671</strong></td>
<td><strong>35,236</strong></td>
</tr>
</tbody>
</table>
Phase II Geothermal (red) and Hydro (blue) Power Projects
Phase II Working Group I: Influence Areas of Geothermal (red) and Hydro (blue) Power Projects
Phase II Working Group II:
Travel Areas of Geothermal (red) and Hydro (black) Power Projects
Hydropower Plants in Iceland (>10 MW)
Existing & To be developed by Master Plan

National Energy Authority, Kristinn Einarsson, September 2011
Geothermal Electric Powerplants (>10 MW)
Existing & To be developed by Master Plan

National Energy Authority, Kristinn Einarsson, September 2011
Groundwater Resources and Freshwater Consumption
Runoff map of Iceland (mm/yr)

Mean runoff 1645 mm/year eq. to 5370 m$^3$/s discharge
Runoff classification

- Direct runoff rivers, ~ 60% of the runoff
- Glacial rivers, ~ 20% of the runoff
- Groundwater-fed rivers, ~ 20% of the runoff
Importance of Water Resources

- Water for hydro-power (surface flow, rivers)
- Domestic and drinking water (mainly sub-surface flow, 97% groundwater)
- Reservoirs (glaciers, lakes, aquifers) are important
- Besides, water forms the foundation for Life on Earth
Discharge of main spring areas

Q [m³/s]
1-5
5-15
15-40
>40
Natural sulphate in groundwater
Natural chloride in groundwater
Water Protection Areas
### Freshwater abstraction mio m³/yr

(under revision; excluding geothermal water)

<table>
<thead>
<tr>
<th></th>
<th>Surface water</th>
<th>Groundwater</th>
<th>Total freshwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public water supply</td>
<td>3</td>
<td>76</td>
<td>79</td>
</tr>
<tr>
<td>Agriculture, forestry, fishing</td>
<td>1</td>
<td>69</td>
<td>70</td>
</tr>
<tr>
<td>Industry (mainly cooling)</td>
<td>1</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Households</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total abstraction</strong></td>
<td><strong>5</strong></td>
<td><strong>160</strong></td>
<td><strong>165</strong></td>
</tr>
</tbody>
</table>
Petroleum Exploration on the Icelandic Continental Shelf
Areas on the Icelandic continental shelf with potential for commercial accumulations of oil and gas
Exploration for oil and gas in Iceland

• Exploration of offshore areas in beginning phase
• Legislative framework ready for exploration and production licenses of hydrocarbons – EU Directive 94/22/EC transposed into Icelandic law
• Special act on taxation of hydrocarbon extraction, revised in 2011 before 2\textsuperscript{nd} licensing round
• Strategic Environmental Assessment finalized for the northern part of the Dreki Area
• Arctic frontier area
• First licensing round completed, second round now open, closing on April 2, 2012
Legislative framework – Hydrocarbons Act

- Orkustofnun - National Energy Authority grants licenses for
  - Prospecting (non-exclusive license, up to 3 years, no drilling)
  - Exploration and Production (exclusive license, up to 12 years, max. 16 years for exploration, additionally up to 30 years for production)
- Exploration licenses normally granted by public notice inviting applications, at least 90 days deadline, no discrimination, public and objective criteria for selection
- Licenses may also be granted without public notice, e.g. by an open-door policy effective within specific time intervals
- Licensees are supervised by the National Energy Authority regarding exploration and utilization of the resource
- Hydrocarbons act & hydrocarbons taxation act revised in 2011
First Icelandic licensing round – northern Dreki Area

• Deadline for applications was 15 May, 2009
• Two applications received from
  ▪ Aker Exploration
  ▪ Sagex Petroleum and Lindir Exploration
• Both applications later withdrawn
• Norway (Petoro) may participate with up to 25% in any license granted within the treaty area

Jan Mayen Agreement Area

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Jan Mayen Agreement Area
Terms of second round

• Not a pre-defined limit on sizes of license areas
• Standard Joint Operation Agreement to be submitted as part of documentation – Similar to Norwegian JOA
• Company arrangement for licensees similar to Norwegian model
• ESA-complaint regarding registration of companies, handled in modification of Hydrocarbons Act
  ▪ Branch or agency of company registered in an EEA country sufficient for registration
• ESA-complaint regarding bases, handled similarly as in Norway
Financial terms of second round

• Fiscal regime revised – new hydrocarbon tax act 2011
  ▪ Extraction levy (royalty)
    • 5% of value of processed hydrocarbons
    • Operating expense for tax purposes => deductible
  ▪ Special hydrocarbon tax
    • Profit ratio * 0.45
  ▪ General corporate income tax: 20%
Location

- North of the Arctic circle
- Distance from shore: 200-400 km
- Water depths mostly range from 800 to 2000 m
- Area size: 42 700 sq. km
Climate and sea ice

- Cold oceanic climate
- Mean temp. < 10°C all year round – ca. 5 to 8 °C in summer, -2 to 0 °C in winter
- Mean wind speed ca. 10 m/s in winter, 6 m/s in summer. Over half of obs. < 12 m/s.
- Frequent fogs in summer, icing during winter
- Edge of sea ice north and west of the area since the cold period 1965–71; not considered to be a problem
- Further information on climate collected by a weather buoy (2007-2009), confirming model calculations
Currents

- Measurements conducted by taking ADCP profiles from a ship and by an anchored mooring
- Bottom current velocity in the area on the order of 5 cm/s

Dynamic surface elevation (Mortensen 2004)
Highest wave – 98%, 1 yr and 100 yr

Wave height in the Dreki Area is less than at the west-coast of Norway
Main conclusions of the SEA

- Water depths 1000 to 2000 m in 80% of the area
- Great variability in biomass and consequently in habitats
- The area is important feeding ground for pelagic fish, especially herring, and possibly for whales
- On-site current measurements needed (collected 2007-2008)
- Need for registration and mapping of delicate habitats of benthic species (started in 2008)
- No information on demersal fish in the area (investigated in 2009)
The Dreki Licensing Area

- The northern Dreki Area is part of the Jan Mayen Micro-Continent (JMMC) with indications of continental strata and suitable structures.

- Similarities to the middle East Greenland coast that is part of Greenland Licensing areas, the Møre- and Vøring Basins at the Norwegian coast, which are proven hydrocarbon provinces.
Iceland continental shelf portal

- GIS based web portal online (Orkustofnun, Iceland GeoSurvey)
- http://www.icsp.is
Key 2D seismic surveys over the Jan Mayen Area

**Commercial Surveys**
- WI-JMR-08 (2008)
- ICE-02 (2002)
- IS-JMR-01 (2001)

**NPD-NEA Surveys**
- J-79 (1979)
- JM-85 (1985)
- JM-88 (1988)

- CGG Veritas reprocessed part of IS-JMR-01 data in 2009
- Spectrum acquired dataset in 2011

- Spectrum reprocessed JM-85 & JM-88 data in 2009
Spectrum 2009 reprocessing of JM-85 data comparison

Original data set

Reprocessed data set

Spectrum 2009 reprocessing of JM-85 data comparison
Borehole & seafloor samples in the Jan Mayen area

Academic ODP & DSDP cruises
- 5 wells during Leg 38 in 1974
- 1 well during Leg 151 in 1993
- 2 wells during Leg 162 in 1995

USSR 1973 & NEA-NPD 2010
- 5 seafloor samples in 1973
- 25 samples on the North Dreki area, piston coring device, most samples >2m penetration, 2010
- Data available upon request
Multi-beam bottom mapping in 2008
Available upon request

(Source: Marine Research Institute of Iceland)
JAS-11: A collaboration project between NGU, NPD and Orkustofnun. The new aeromagnetic survey will provide a comprehensive and state of the art aeromagnetic dataset of the Norway Basin.
Tectonic History of the JMMC

Collage based on results of recent research publications and observations at the JMMC

(Courtesy of Anett Blischke, Iceland GeoSurvey)
Stratigraphy
Main Question: Potential Source Rocks
Jameson Land Basin
Mathiesen et al, 2000

• Upper Permian Ravnefjell Formation:
  ▪ Post-mature, except NW-Region
  ▪ HC-generation began Mid-Cretaceous
  ▪ Main phase, Late Cretaceous – Early Paleocene

• Lower Jurassic Kap Stewart Formation:
  ▪ Sufficient maturity for Oil exploration in central & southern area of the basin
  ▪ Regionally extensive
  ▪ HC-generation, Paleocene - during and shortly after extrusion of the volcanic rock sequences

• Upper Jurassic Hareelv Formation
Preliminary results from NPD ROV sampling summer 2011

- Rock samples collected in outcrop areas on steep parts of ridges with a remotely operated underwater vehicle (ROV)
- Preliminary results indicate that the sequences of strata in seismic sections include rocks of Palaeozoic, Mesozoic and Cenozoic age
- Results to be presented by NPD at the Nordic Geological Winter Meeting in Reykjavik, 9-12 January 2012
Jan Mayen Micro Continent cross section

Source: Anett Blischke, Iceland GeoSurvey
New 2D seismic quality data
= more possibilities for data interpretation

Jan Mayen Trough

Seabed
Late Oligocene - Miocene
Base Late Oligocene
Top Eocene
UC Middle Eocene
UC Top Paleocene
UC Late Paleocene poss.
Top Mesozoic poss.
Top Paleozoic poss.
(or actual Basement ???)
Top Basement poss.
(Crystalline ?? deep reflector)

Data by courtesy of Spectrum

ORKUSTOFNUN
National Energy Authority
Hydrocarbon potential for the Dreki Area

- Best analogue comparison with East Greenland exploration examples and Møre Basin for the Norwegian side
- Post Paleocene sedimentary rocks of sufficient thickness and age in the ridge flank areas
- Indications of pre-opening sedimentary strata of possibly Paleozoic, Triassic-Jurassic and maybe Cretaceous age - underneath the west flank areas, i.e. Jan Mayen Basin
  - Supported by this summer’s ROV sampling by NPD
- Potential reservoir rocks, e.g. locally shallow marine to generally marine deposits, especially submarine fans / turbidite deposits for post Paleocene deposits, and limestone platform to continental deposits for pre-opening formations
- Potential traps present, both structural and stratigraphic
Present situation

• First licensing round application period completed with no exploration and production licenses issued
• Possible reasons for the outcome:
  • Economic crisis during licensing round
  • Low oil prices
  • Frontier area – high risk, potential high reward
  • Fiscal framework
• Decision by Norway to resume governmental exploration and initiate the opening process for licensing on the Norwegian part of the Jan Mayen ridge
• Second licensing round open until April 2, 2012
Thanks for your attention

Orkustofnun – National Energy Authority serves the government and the public in the fields of energy administration as well as energy & mineral resources administration and research

Our website in English http://www.nea.is