UTILIZATION OF GEOTHERMAL ENERGY IN ICELAND – UNITED NATIONS UNIVERSITY GEOTHERMAL TRAINING PROGRAMME

Krafla power plant, N-Iceland

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Match Making Conference
Athens, Greece, 11 September 2014

UNITED NATIONS UNIVERSITY
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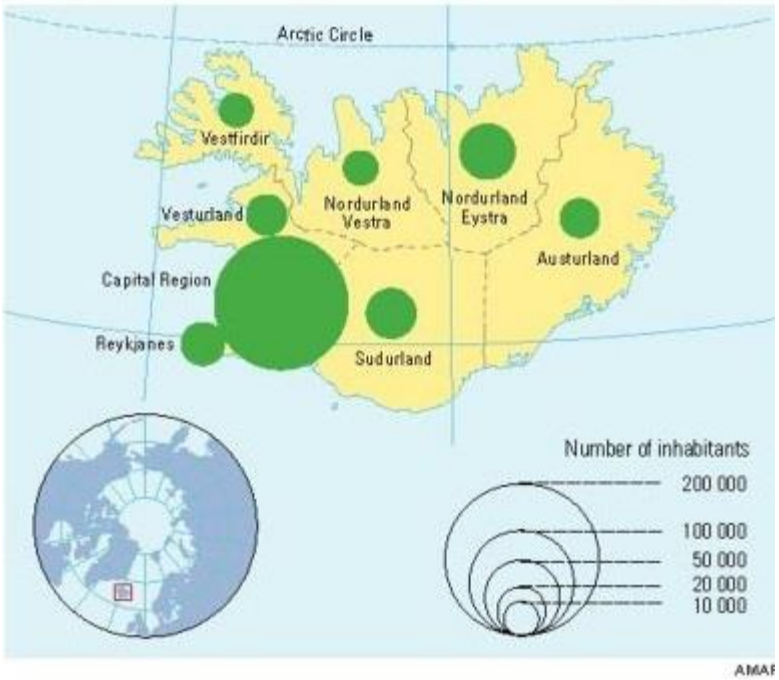
SOME BASIC FACTS

- Iceland has an area of 103,000 km^2 and a population of 327,050
- Iceland has considerable hydro and geothermal resources and has utilized them to become the country with the highest electric power consumption per capita



Electric power consumption (kWh per capita)

DATABANK | DOWNLOAD DATA | SHARE

Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants.

International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp), Energy Statistics and Balances of Non-OECD Countries and Energy Statistics of OECD Countries.

Catalog Sources World Development Indicators

View in WDI Tables

TABLE | MAP | GRAPH | METADATA

Search all indicators

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Featured indicators

Climate Change

Access to electricity (% of

1980-1983 | 1984-1988 | 1989-1993 | 1994-1998 | 1999-2003 | 2004-2008 | **2009-2013**

Country name	2009	2010	2011
Iceland	51,259	51,440	52,374
Norway	23,860	24,891	23,174
Canada	15,164	16,211	16,473
Kuwait	16,351	16,759	16,122

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GENERATION OF ELECTRICITY IN ICELAND 2013 AND 2012

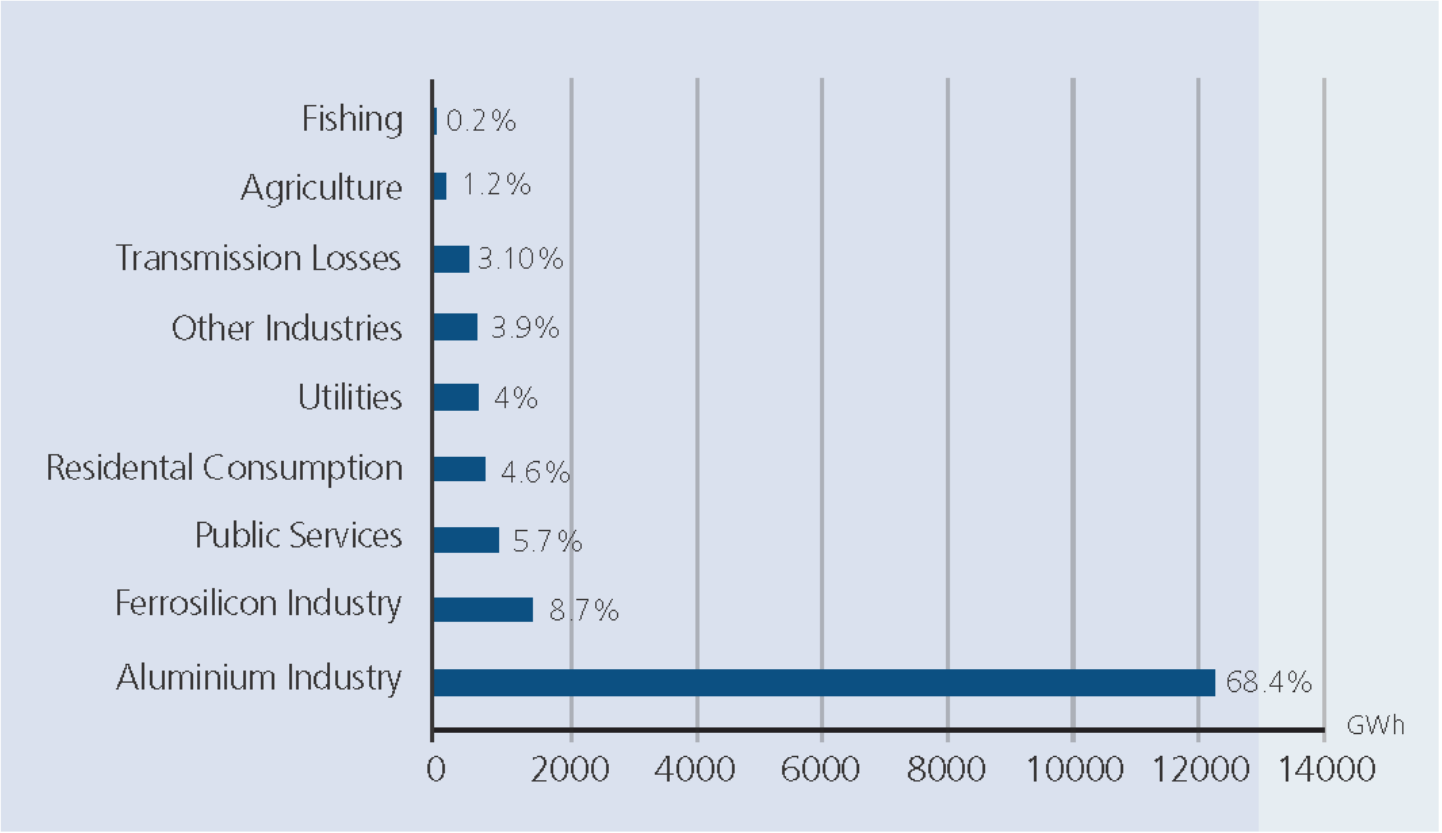
Installed capacity in power plants

	2013		2012	
	MW	%	MW	%
Hydro	1.986	71,8	1.885	70,7
Geothermal	665	24	665	25
Fuel	114	4,1	115	4,3
Wind	2	0,1	0	0
Total	2.767	100	2.665	100

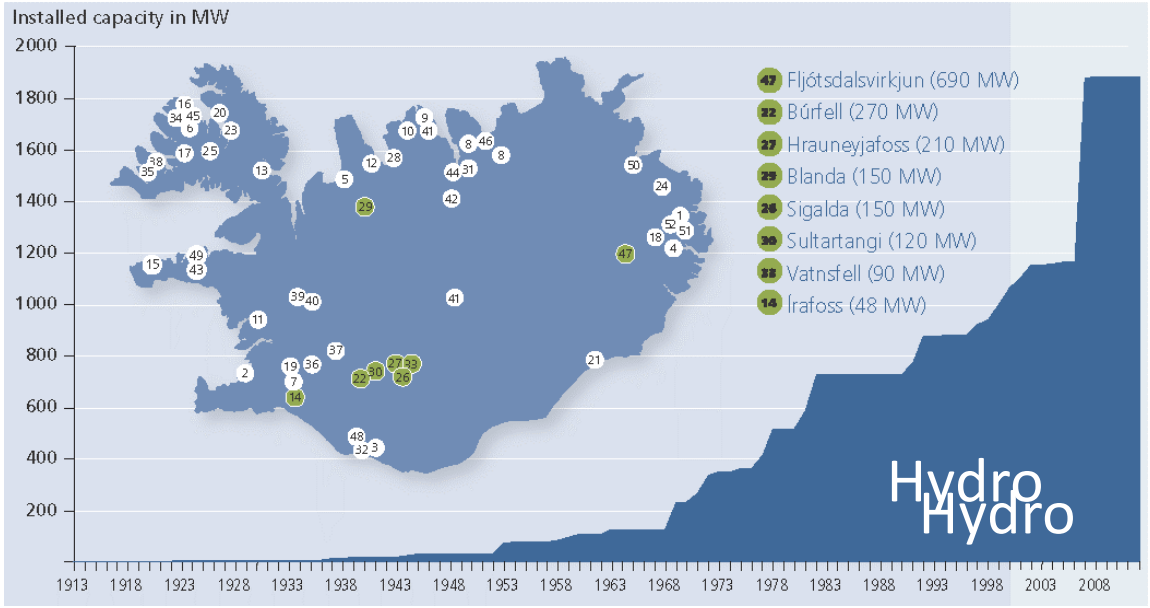
Electricity production

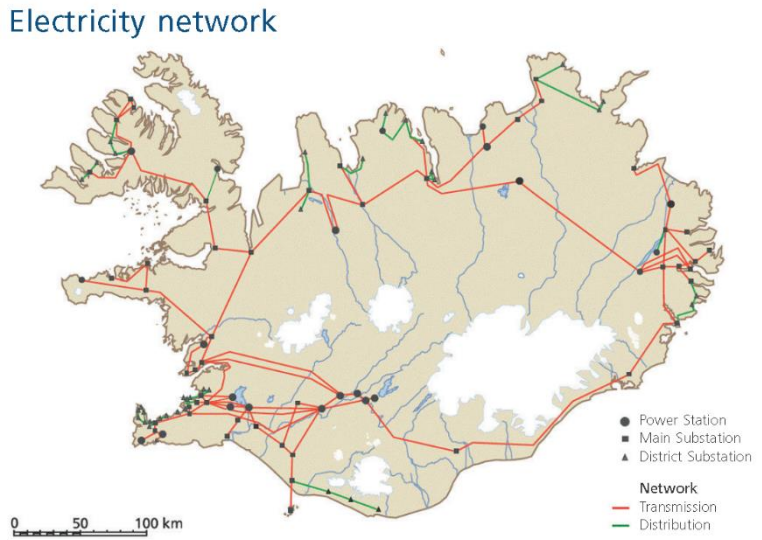
	2013		2012	
	GWh	%	GWh	%
Hydro	12.863	71	12.337	70,3
Geothermal	5.245	29	5.210	29,7
Fuel	3	0	3	0
Wind	5	0	0	0
Total	18.116	100	17.550	100

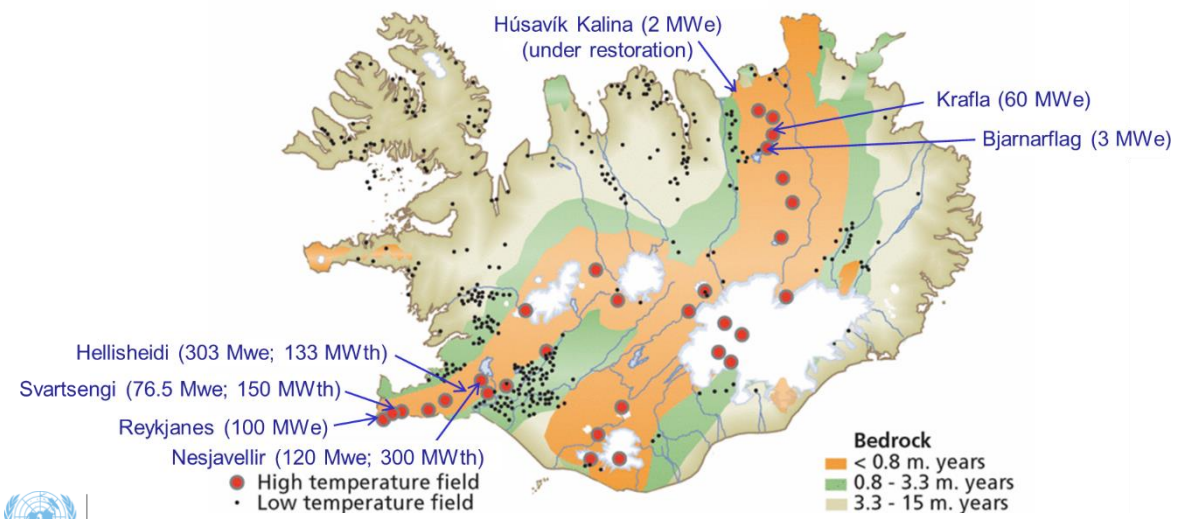
ELECTRICITY CONSUMPTION 2013



ICELANDIC POWER PLANTS – ELECTRICITY GRID







Geothermal

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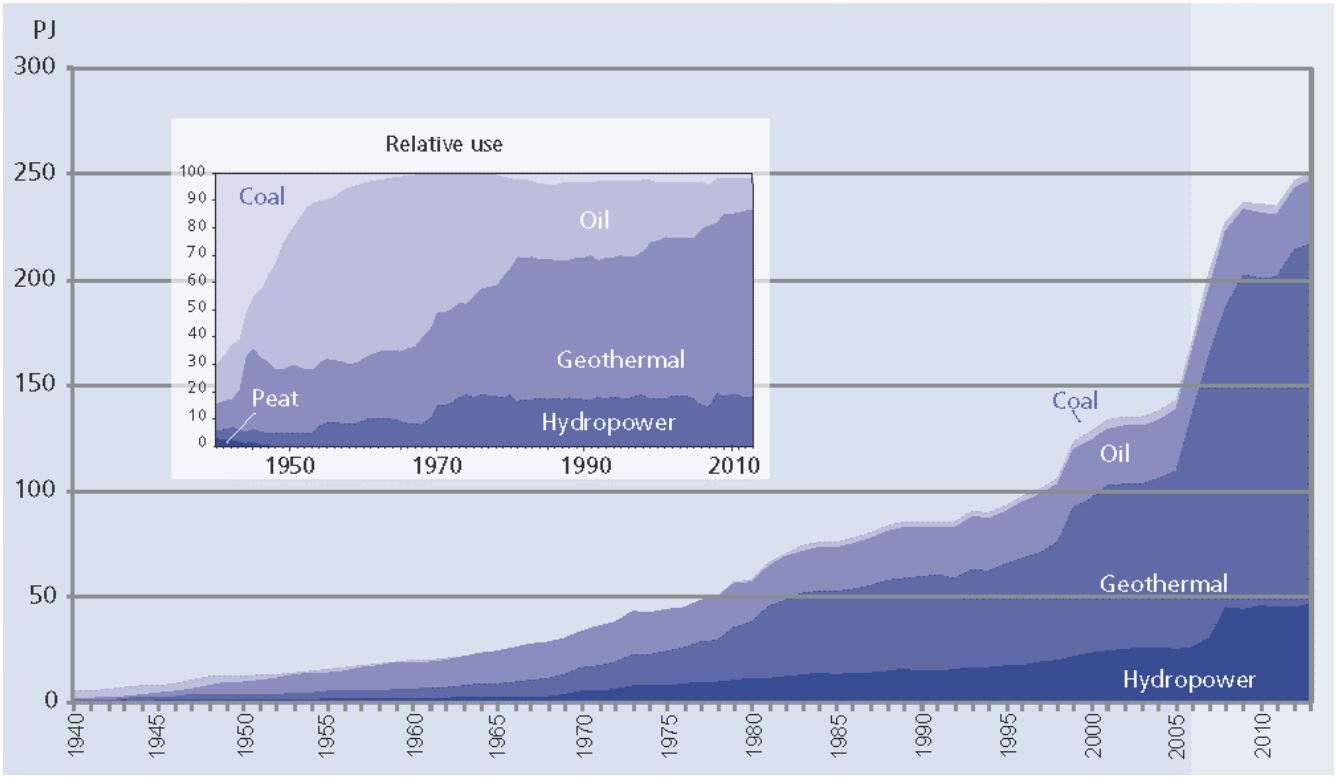
PRIMARY ENERGY

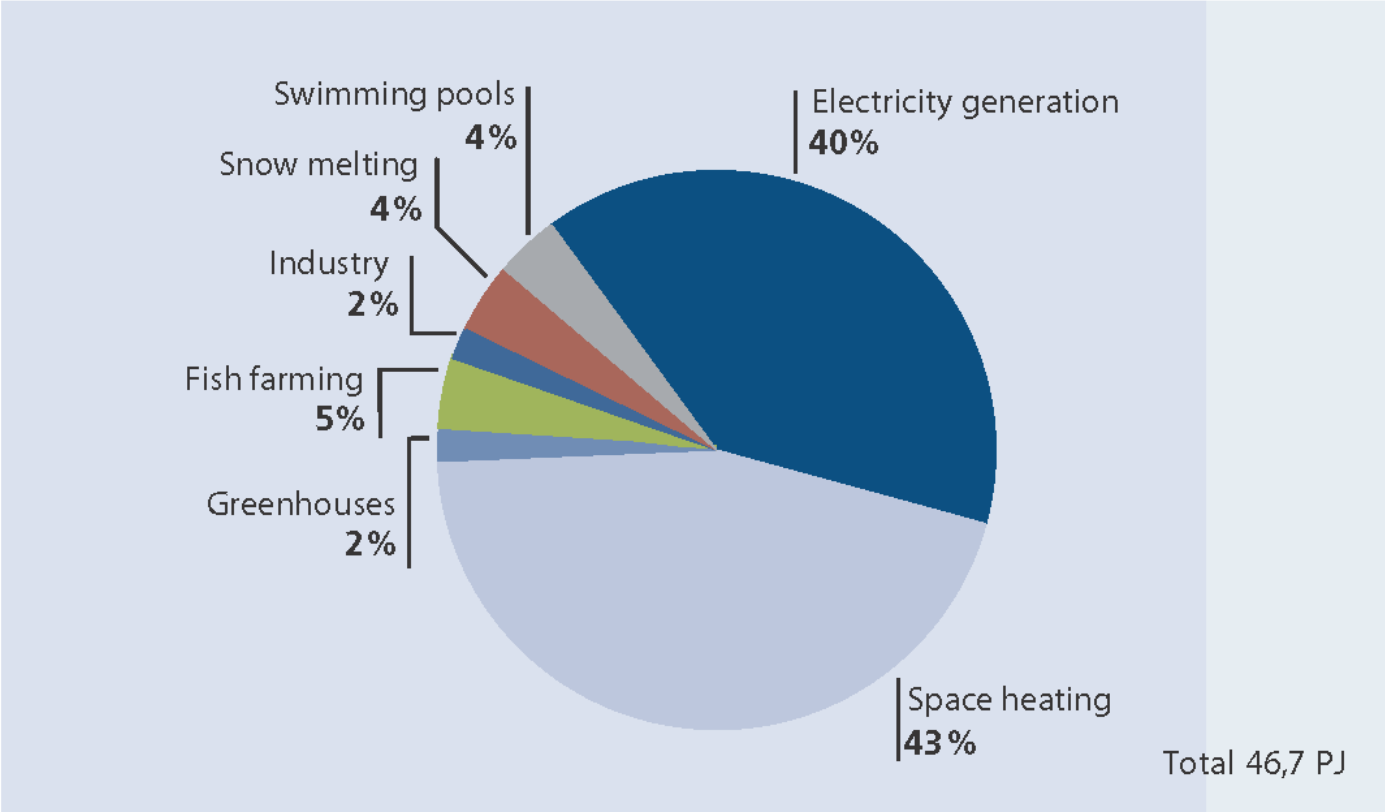
- About 85% of the primary energy used in Iceland is renewable domestically produced energy (hydro and geothermal)
- The remainder is imported fossil fuels, mainly used for transportation



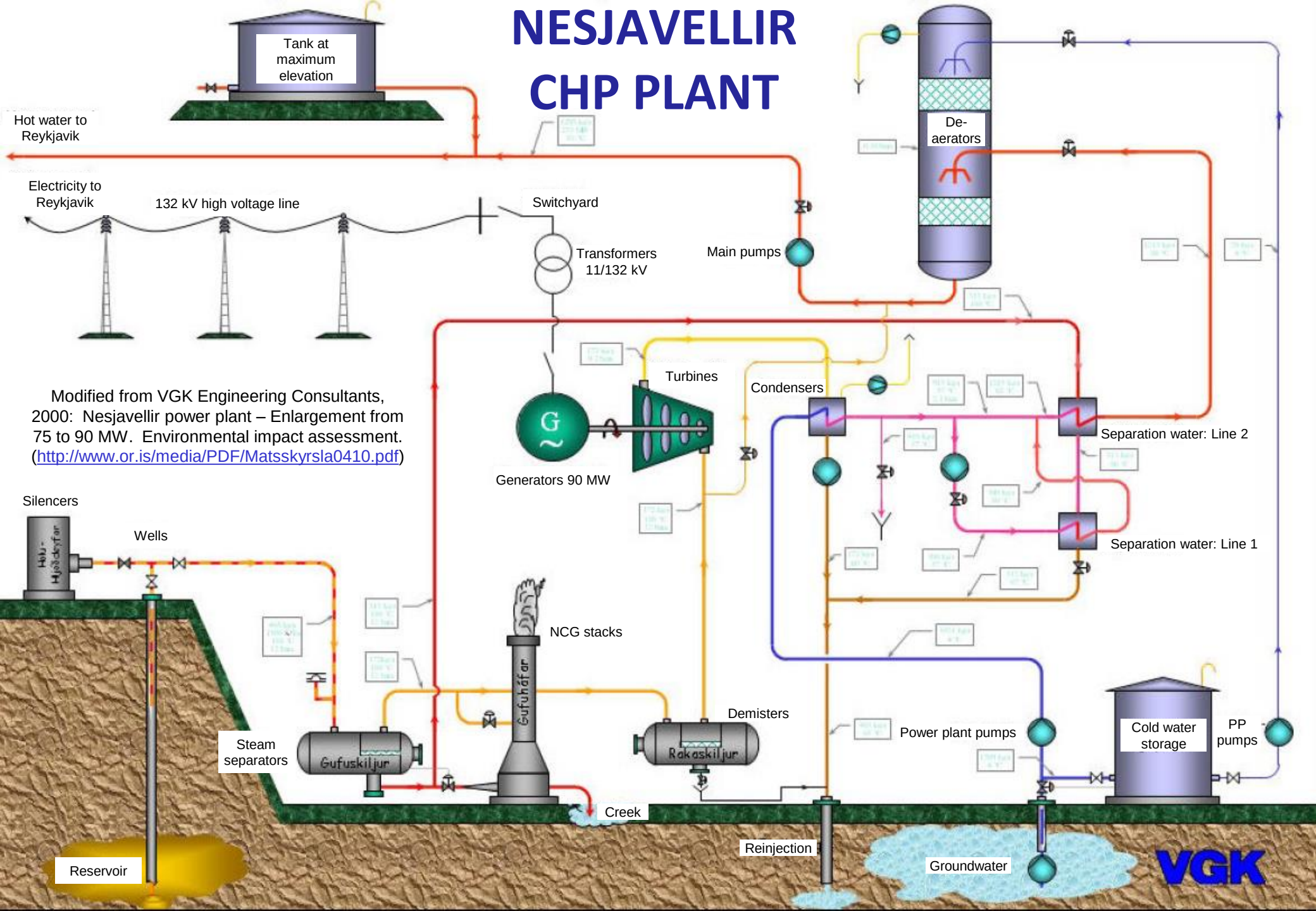
GEOTHERMAL ENERGY

- While hydropower is used for electricity generation, the use of geothermal energy is much more diverse

Utilisation of geothermal energy 2013



NESJAVELLIR CHP PLANT

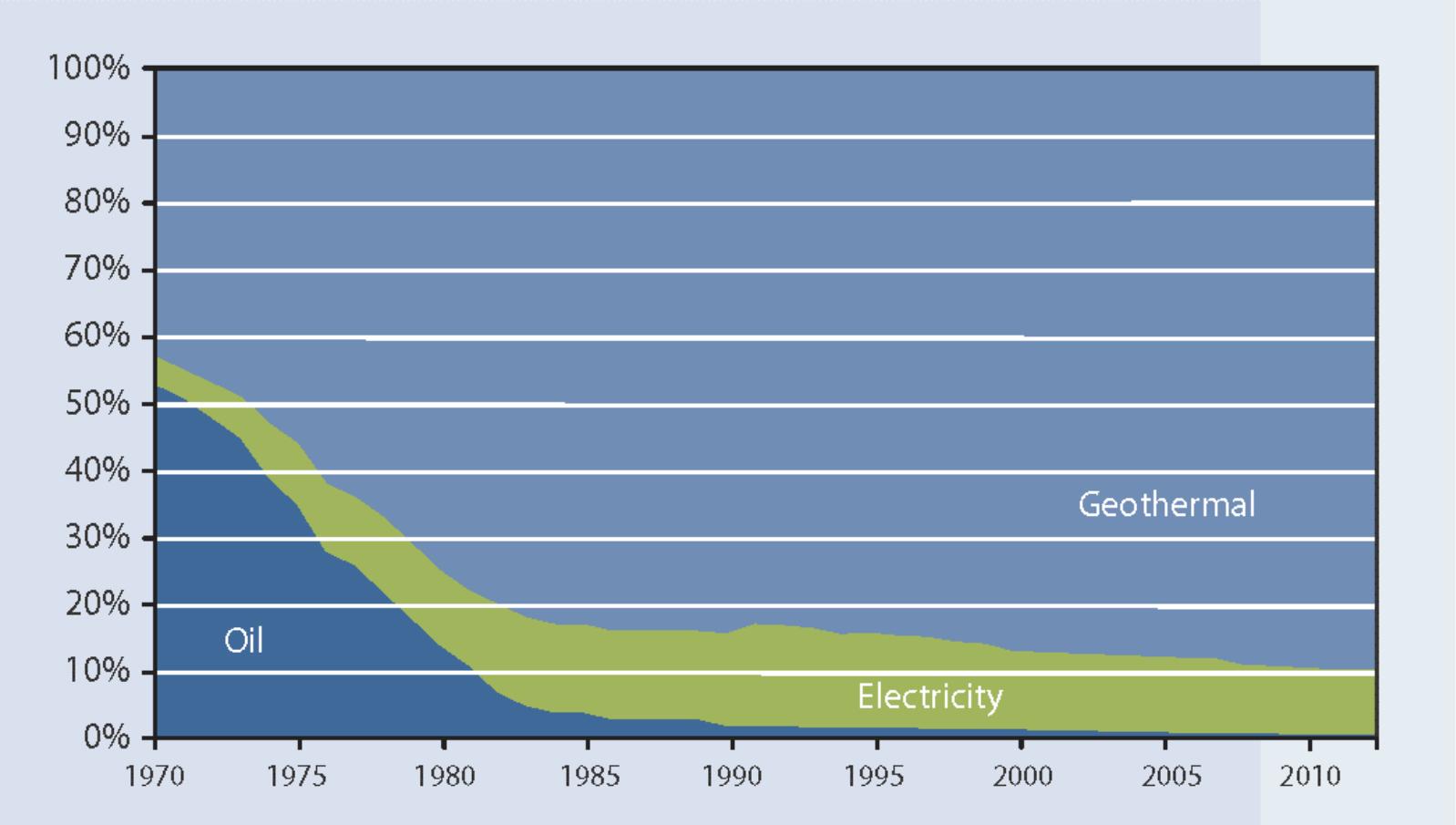


Modified from VGK Engineering Consultants, 2000: Nesjavellir power plant – Enlargement from 75 to 90 MW. Environmental impact assessment. (http://www.or.is/media/PDF/Matsskyrsla0410.pdf)

SPACE HEATING

Geothermal accounts for 89% of Iceland‘s space heating needs

National Energy Authority of Iceland: Energy Statistics in Iceland 2013
(http://www.os.is/gogn/os-onnur-rit/orkutolur_2013-enska.pdf)



SPACE HEATING AND CONSUMPTION

Typical radiator arrangement in an apartment

Radiators come in various shapes

Radiator thermostats

A warm living room on a cold winter day

Showering

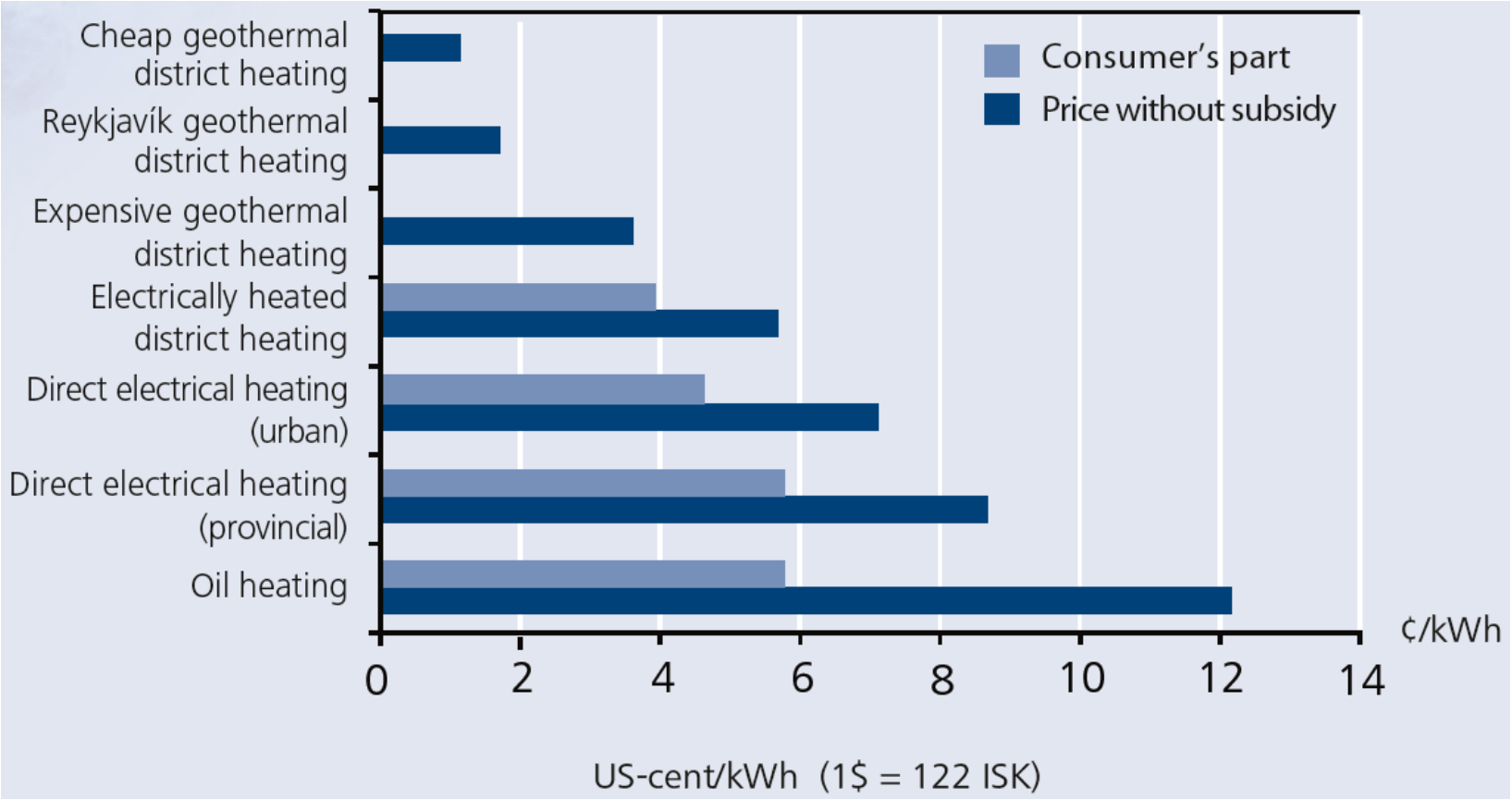
Bathing

Washing hands

Washing dishes

Cooking

COMPARISON OF ENERGY PRICES FOR RESIDENTIAL HEATING IN 2010



National Energy Authority of Iceland: Energy Statistics in Iceland 2011
(http://www.os.is/gogn/os-onnur-rit/orkutolur_2011-enska.pdf)

COMPARISON OF DH PRICES IN EUROPE

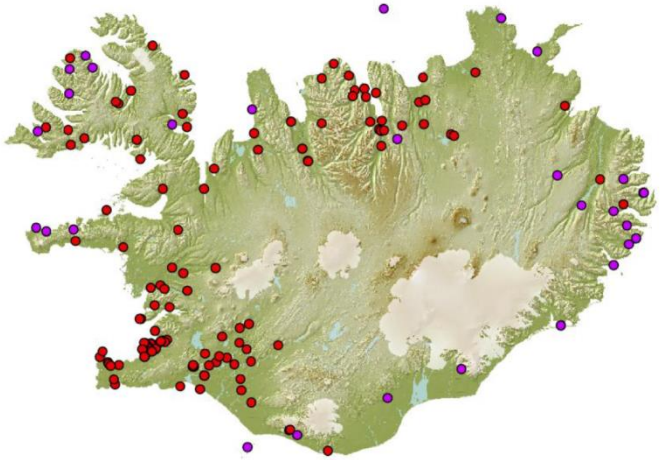
- In this context, it is enlightening to compare average district heating prices in different European countries in 2009, based on a survey conducted by Euroheat & Power

Region	Country	Price (EUR/GJ)	Price (EUR¢/kWh)
Europe	Iceland	2.58	0.93
	Russia	4.48	1.61
	Croatia	8.95	3.22
	Poland	10.4	3.7
	Estonia	12.25	4.41
	Slovenia	12.44	4.48
	Finland	12.8	4.6
	Latvia	13.89	5.00
	Romania	14.04	5.05
	Austria	15.96	5.75
	Sweden	16.55	5.96
	France	16.61	5.98
	Czech Republic	17.1	6.2
	Lithuania	17.6	6.3
	Slovakia	18.08	6.51
	Germany	19.55	7.04
	Norway	20.8	7.5
	Denmark	25.03	9.01
America	United States	8.64	3.11
Asia	Korea	12.14	4.37

http://www.euroheat.org/

SWIMMING POOLS

- There are about **163** recreational swimming centers in Iceland
- **134** of those use geothermal heat
- Based on surface area **90%** of pools are heated by geothermal
- About **220 m^3** of district heating water (40 GJ) is needed annually for each m^2 of pool surface area
- A new medium sized swimming pool uses as much water as is needed to heat **80-100** single family dwellings



Swimming pools in Iceland in 2008. Red: geothermally heated pools. Purple: pools heated by electricity, oil or waste

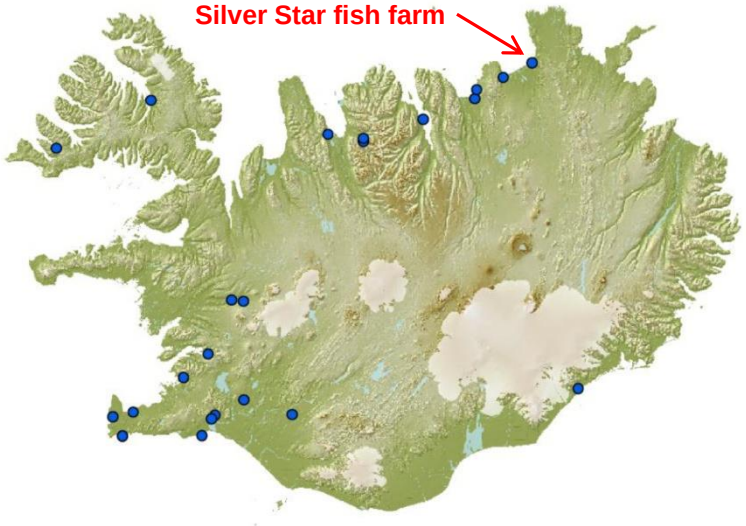
The Álftanes swimming pool (www.visitreykjavik.is)

The Árbaer swimming pool (www.isisport.is)

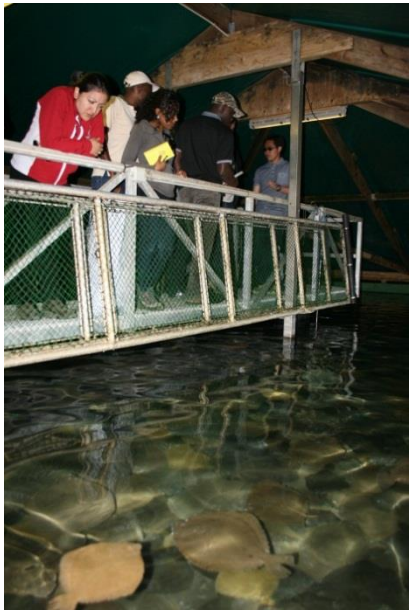
The Laugardalur swimming pool: the largest swimming pool in Iceland (www.reykjavik.is)

FISH FARMING - AQUACULTURE

- Growth rate of fish is affected by water temperature (increasing water temperature from 5°C to 8°C can increase growth rate by 30%)
- To increase farming efficiency, water temperature is elevated by using geothermal water, either directly or through heat exchangers
- Used for various stages of development, depending on species: hatching eggs, smolt production and for grown fish
- Species: Arctic char (8-14°C), Rainbow trout, Salmon (10°C for eggs and smolt), Halibut (10-14°C), Turbot (14-20°C), Cod
- Production of warm water species has been suggested: Tilapia (27°C), Barramundi, African catfish, Senegalese sole
- Density of fish, parasites, oxygenation and recirculation of water need to be taken into account



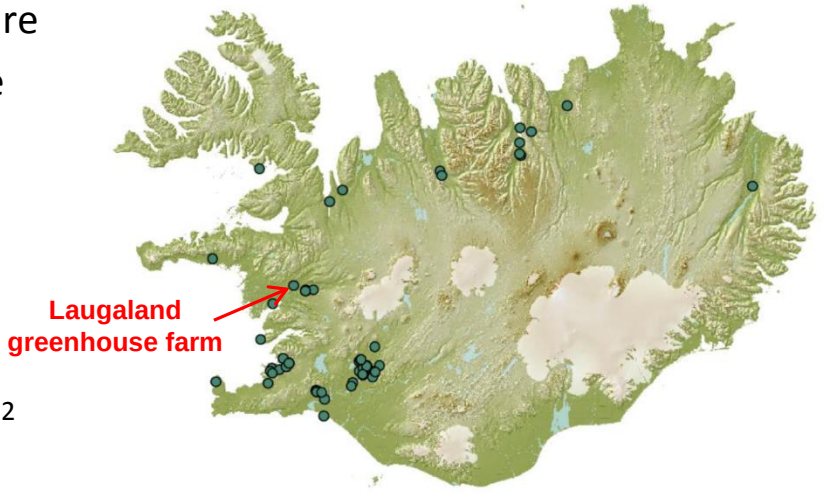
Fish farms in Iceland using geothermal water in 2008



Photos from UNU-GTP excursion to Silver Star fish farm. The farm grows arctic char, halibut, salmon and turbot.

GREENHOUSES - HORTICULTURE

- As with fish, the growth rate of plants is affected by temperature
- Experiments with heating soil for potato growing started in the late 19th century
- In the first half of the 20th century, geothermal heating was installed in many greenhouses
- Many vegetables and flowers could be grown economically, which would not be possible without geothermal heating
- In 2008, geothermally heated greenhouses covered 192,000 m^2 using 700 TJ/year
- Geothermally assisted horticulture has been influential in the establishments of some towns



Greenhouses in Iceland utilizing geothermal in 2008

Young cucumber plants

Fully grown cucumber plants

Cucumbers

Cucumbers ready for the market

Photos from UNU-GTP excursion to the Laugaland greehnouse farm which specializes in cucumber production

SNOWMELTING

- The estimated coverage of snow melting systems in 2010 was 1,208,000 m2
- Utilizes mostly effluent water from space heating systems (at ~35°C): 1080 TJ (64%)
- But also water from the DH system (at 80°C): 610 TJ (36%)
- Used by: municipalities for public areas (streets, plazas, walkways, soccer fields), power plants and airports, individuals
- Large increase in past years (many new houses/apartment complexes utilize snowmelting systems)
- Increases the efficiency of geothermal water use, contributes to better living standards and increases safety

Snow melting systems are common in new parking lots (http://www.nea.is/geothermal/direct-utilization/snow-melting/)

*Before ...

... and after.*

*Public space – downtown Reykjavik

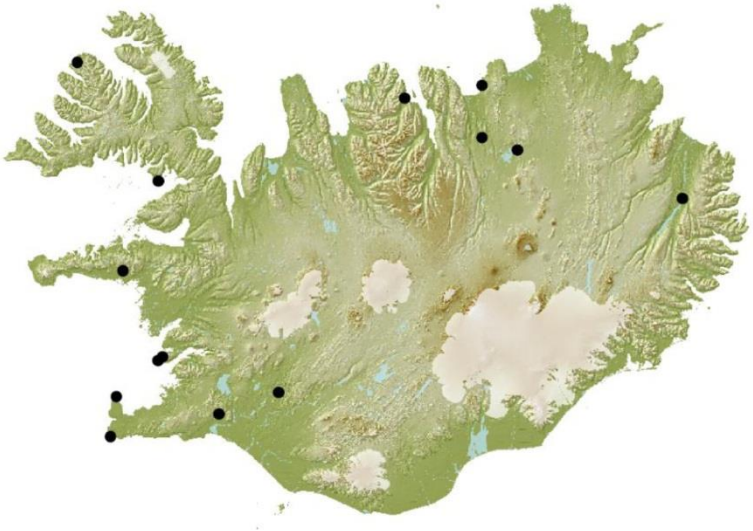
Snow melting system by a private house

*Photos by Thorleikur Jóhannesson

INDUSTRIAL USE

- Seaweed processing (drying)
- Drying of fish for export
- Salt production (by evaporating sea water)
- Curing of pre-cast concrete units
- Drying timber
- Washing wool
- Cooking

Geothermal can be used to regulate temperature during the curing process of pre-cast concrete units (www.ev.is)



Industrial geothermal utilization in Iceland in 2008

Seweed can be used as fodder and fertilizer – or to extract alginates for use in pharmaceutical or cosmetic products (http://www.thorverk.is)

Geothermal water or steam is used to dry various fish parts for export (http://www.nea.is/geothermal/direct-utilization/industrial-uses/)

Geothermal steam can be used for cooking (http://www.gonomad.com/features/1006/iceland-energy.html)

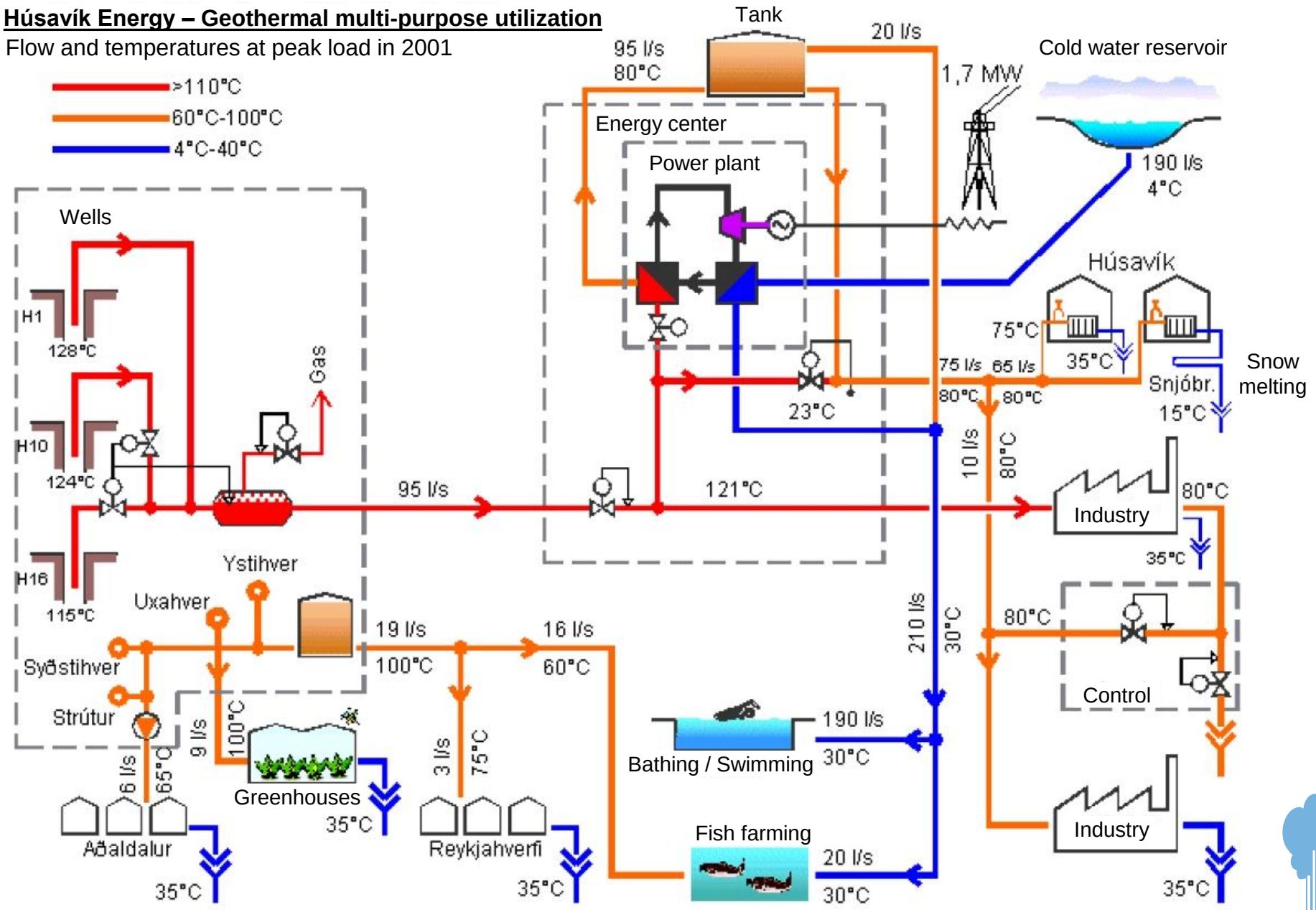
NON-ENERGY PRODUCTS FROM GEOTHERMAL WATER

- Carbon dioxide: greenhouses, beverages, food industry, dry ice
- Cosmetic products (Blue Lagoon)

Algae and minerals from the Blue Lagoon are used as ingredients for various skin treatment products and cosmetic products (www.bluelagoon.com)

Geothermal CO2 for the beer

DOING IT ALL AT ONCE – MULTI PURPOSE UTILIZATION



http://www.oh.is/skrar/File/Framleidsla/Kerfismynd_OH.pdf

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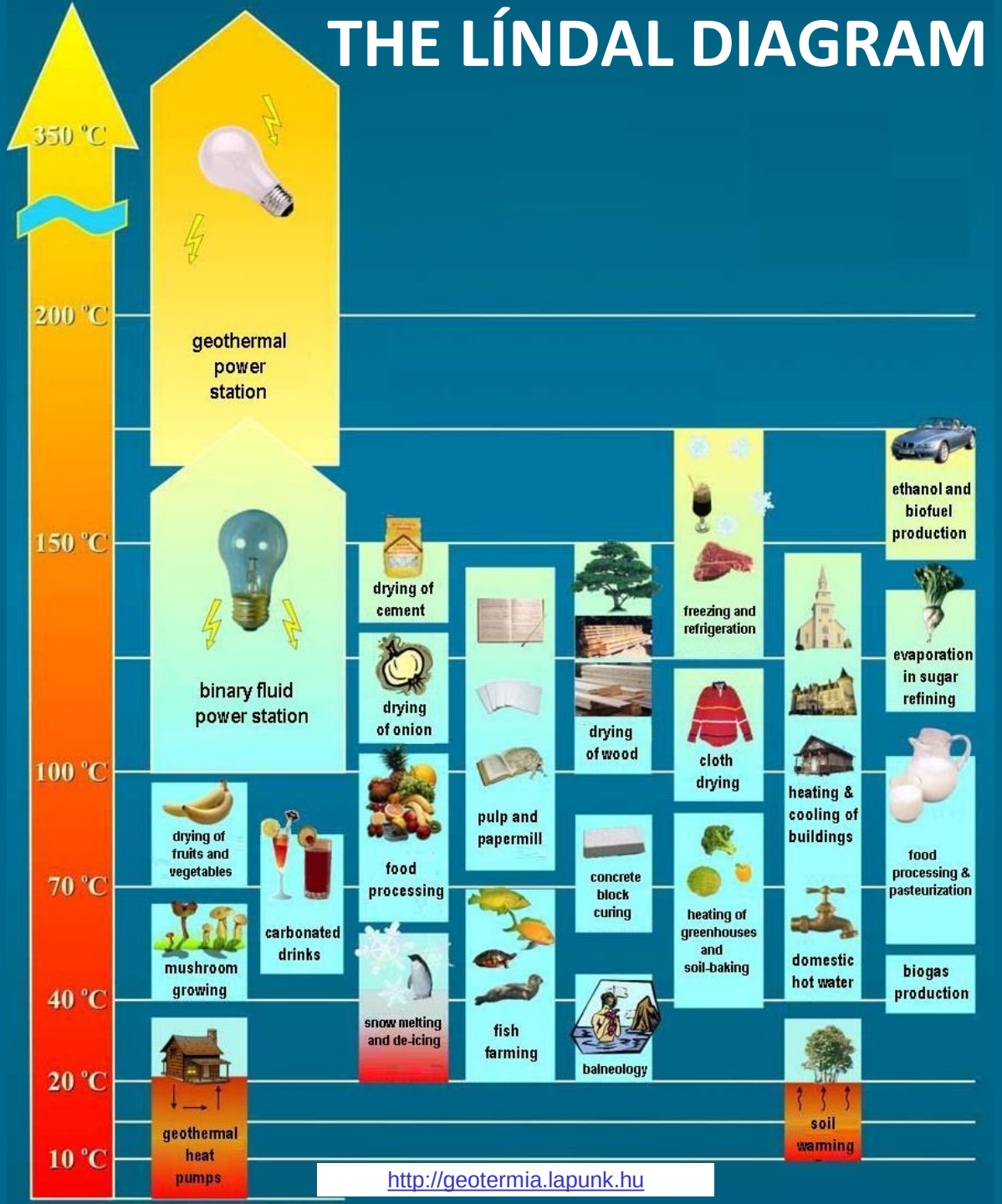
THE LÍNDAL DIAGRAM



http://geotermia.lapunk.hu

THE KNOWLEDGE BASE IN ICELAND

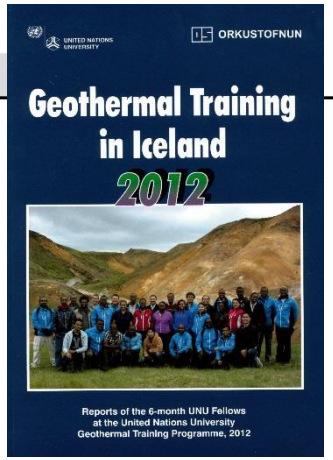
- The extensive use of geothermal resources in Iceland for direct use and electricity generation over the past century and decades has resulted in the accumulation of a great deal of expertise
- Iceland GeoSurvey, engineering firms, research institutions and universities all harbor experts who have devoted their careers to geothermal
- This knowledge can be shared across borders

UNITED NATIONS UNIVERSITY
GEOTHERMAL TRAINING PROGRAMME

- The United Nations University is the academic and research arm of the United Nations
- UNU-GTP has operated in Iceland since 1979
- Aims at assisting developing countries with significant geothermal potential to build up or strengthen groups of specialists that cover most aspects of geothermal exploration and development
- Is hosted at Orkustofnun – National Energy Authority of Iceland
- Our core activity is annual six months specialised courses for professionals in geothermal work through UNU Fellowships
- Offers Fellowships to former UNU Fellows to do MSc and PhD studies in Iceland
- Gives annual short courses in the developing countries, and has now added services such as customer-designed courses

LINES OF TRAINING AND TIME SCHEDULE

WEEK	Geological Exploration	Borehole Geology	Geophysical Exploration	Borehole Geophysics	Reservoir Engineering	Chemistry of Thermal Fluids	Environmental Science	Geothermal Utilization	Drilling Technology
1	Introductory Lecture Course Main aspects of geothermal energy exploration and utilization Practicals and short field excursions								
2									
3									
4									
5									
6									
7	Field geology Lithological, tectonic & hydrothermal mapping Temperature surveying	Sample preparation Cutting analysis Petrography Lithological & alteration logs	Thermal methods Magnetics - Gravity Seismic methods Resistivity of rocks Resistivity methods: DC, TEM & MT	Well logging & testing - theory & practises Logging and testing demonstrations Reservoir physics & well/reservoir modelling Monitoring response to exploitation		Sampling of fluid & gas Wet steam wells Analytical methods Thermodynamics Data processing and interpretation	EIA project planning Chemistry - Physics Biology - Monitoring Revegetation - Safety	Thermal design of power plants & source systems - Direct use of geothermal heat Scientific modelling of utilization systems	Drilling equipment & procedures Well design Rig operations - Safety Management Cementing
8									
9									
10									
11	Excursion to some of the main geothermal fields of Iceland, geothermal power plants and direct use facilities								
12									
13	Gradient wells Remote sensing - GIS	XRD - Fluid inclusions Logging software	Processing & modelling resistivity data - GPS	Resource management & reinjection Data processing & software applications		Water-rock interaction Corrosion & scaling	Gas dispersion & abatement Corrosion & scaling	Power plant components Control systems Corrosion & scaling	Completion - Testing Problems Drilling software
14									
15	Project and report writing								
26									



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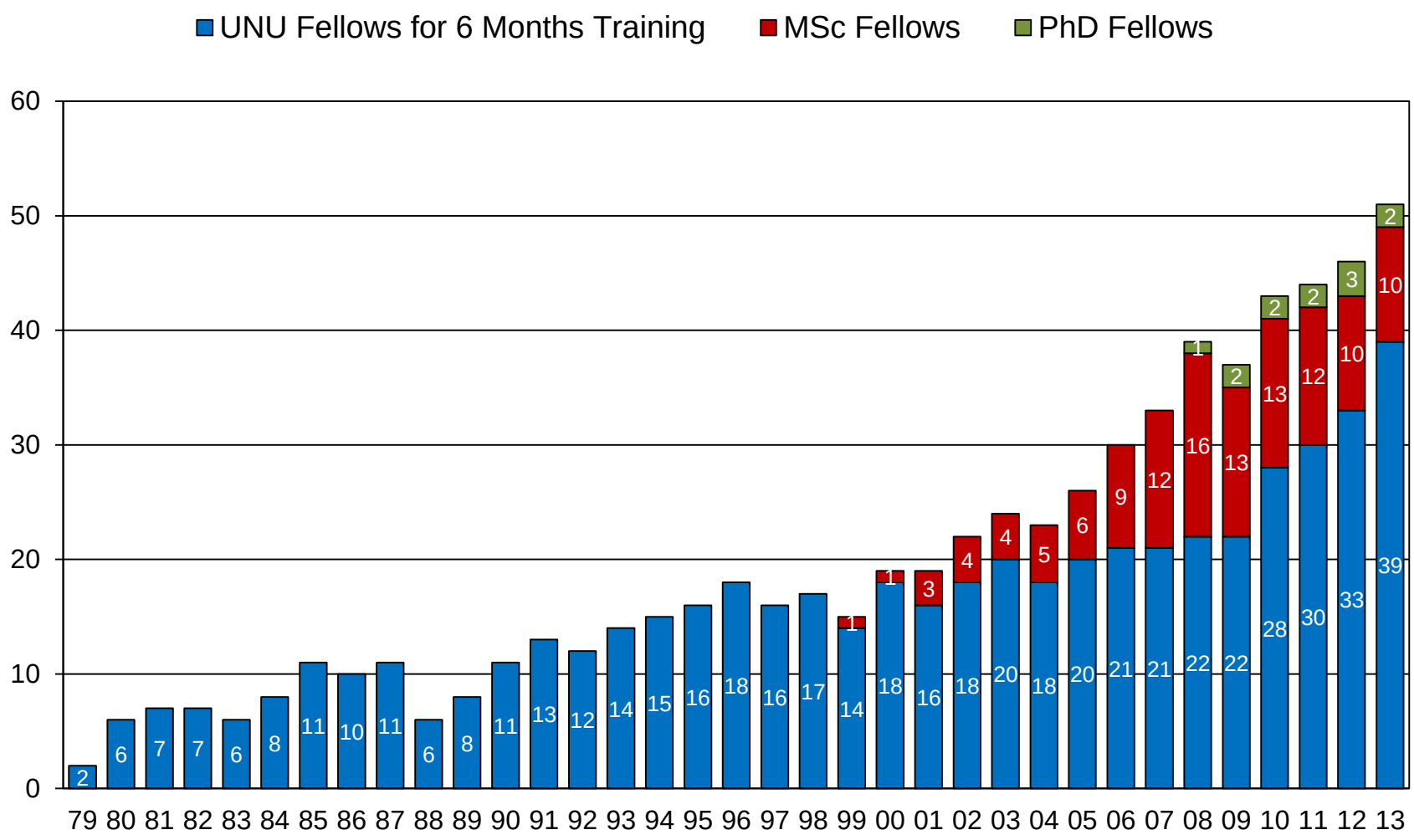
THE 6 MONTHS TRAINING

- Fellows arrive in late April and depart in late October
- Each Fellow conducts a research project and is assigned supervisors from Iceland GeoSurvey, the universities, engineering firms or research institutions as need calls for
- The trademark of the research is flexibility
- Selected Fellows from the developing countries receive Fellowships financed by the Icelandic government
- Paying Fellows are also accepted from public institutions in countries with geothermal potential
  - Usually paid for directly by the employer
  - Several European Fellows have been / will be supported by EEA grants

GREEK FELLOWS IN ICELAND

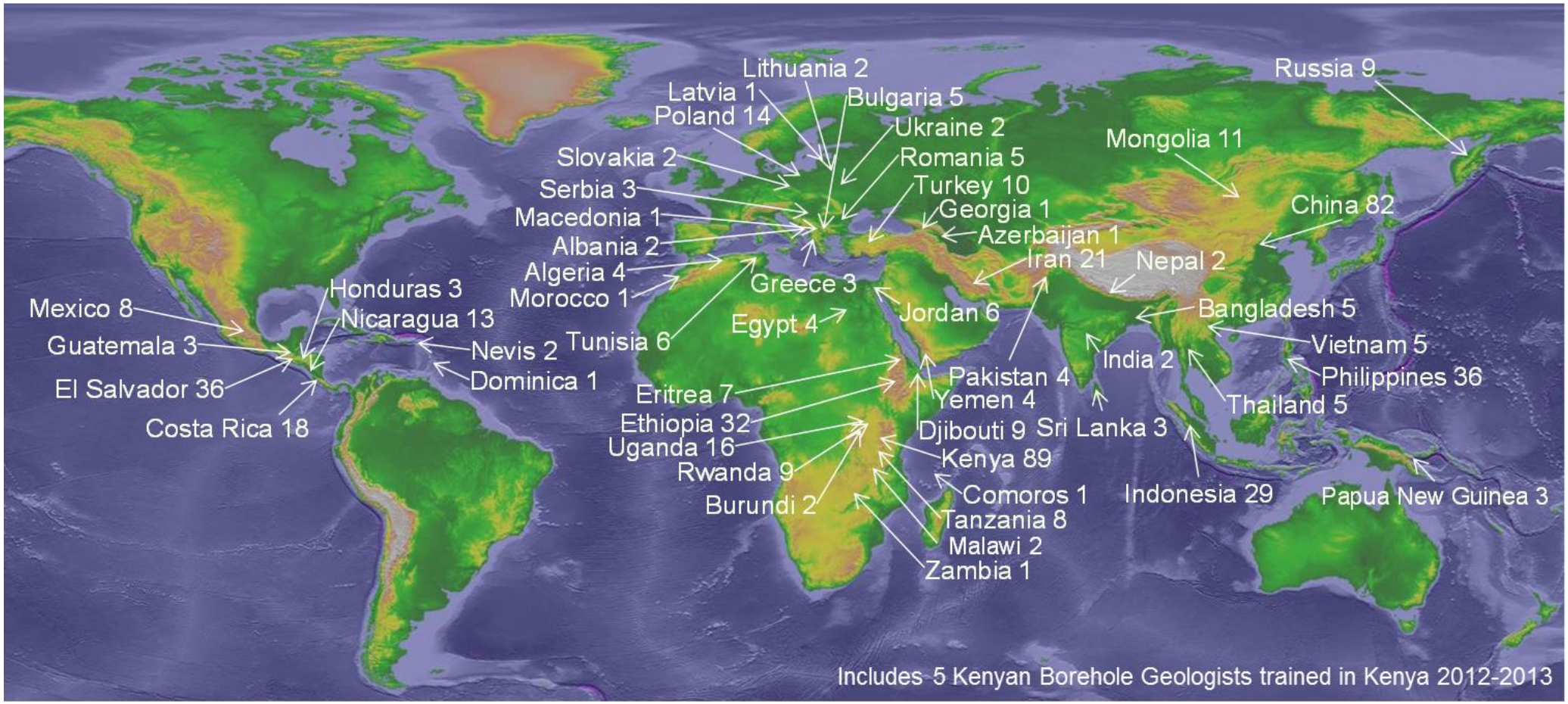
Name	Emmanouil Karras	Constandinia Panagiotou	Konstantinos Velegrinos
Year	1996	1996	1996
Institution	Central Union of Local Authorities of Greece	Central Union of Local Authorities of Greece	Central Union of Local Authorities of Greece
Field of study	Geothermal Utilization	Geothermal Utilization	Geophysical Exploration
Project title	Prospectives for exploiting the geothermal resources of Ikaria, Greece	Geothermal greenhouse design	Geophysical exploration of Helgavatn low-temperature field, W-Iceland and the Árskógsströnd area N-Iceland
Link to paper	http://www.os.is/gogn/unu-gtp-report/UNU-GTP-1996-06.pdf	http://www.os.is/gogn/unu-gtp-report/UNU-GTP-1996-11.pdf	http://www.os.is/gogn/unu-gtp-report/UNU-GTP-1996-19.pdf

NUMBER OF FELLOWS 1979 - 2013



In 2013 five Fellows were trained in Kenya

UNU-GTP FELLOWS IN ICELAND
1979-2013



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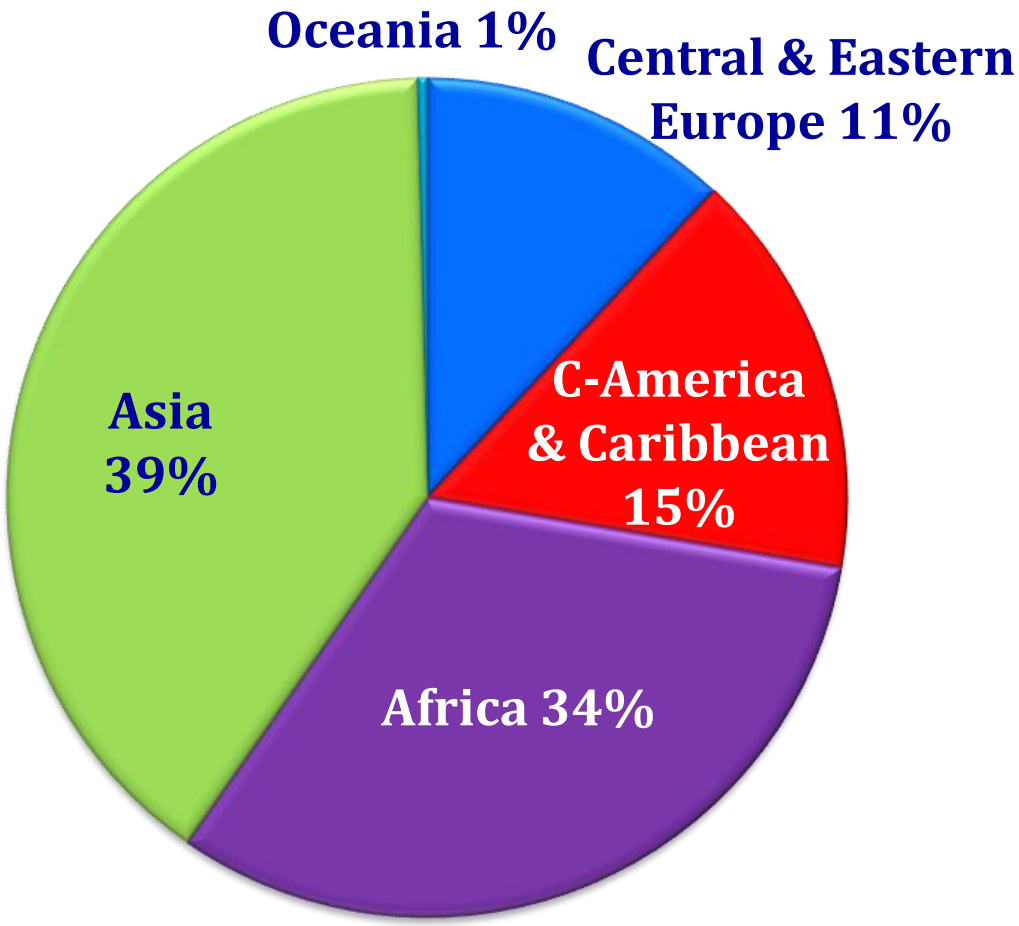
PARTICIPATION IN UNU-GTP



1979 - 2013

- 554 scientists and engineers from 53 countries have completed the 6 month specialized course
- Thereof 109 women (20%)
- MSc programme offered with University of Iceland since 2000 - 35 graduates
- PhD programme offered with UI from 2008

SHORT COURSES IN DEVELOPING COUNTRIES

- Since 2005, the UNU-GTP has conducted short courses in the developing countries
- Millennium development short courses are financed by the UNU-GTP and are held every year in Kenya for African countries and in El Salvador for Latin American countries
- Since 2010, the UNU-GTP has offered custom designed short courses or in-depth training in accordance to the needs of a paying customer – these have been financed directly from the customer‘s budget or through development funds available to the customer
- To date 17 such activities have taken place for several customers in 4 continents, ranging from 2 day short courses to 6 months hands-on training

THANK YOU !

Contact information:

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