VGK HÖNNUN

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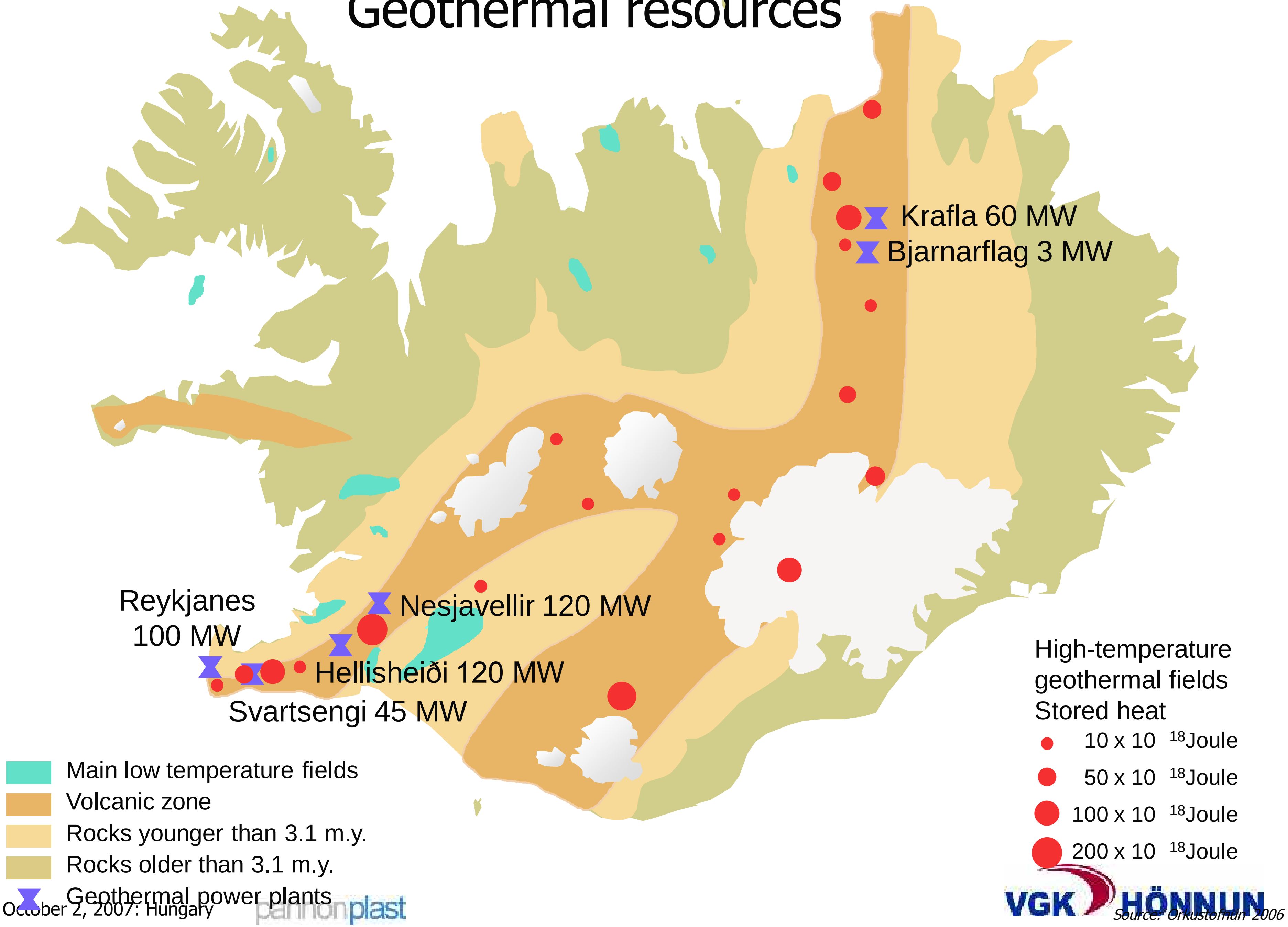
VGK-Hönnun
-General Introduction-

Sigurður St. Arnalds, COB

VGK HÖNNUN
CONSULTING ENGINEERS

Geothermal resources



Key facts and purpose

- We supply engineering consulting services in the areas of energy, environment, infrastructure and industry
- Founded in 1963
- 270 employees
- Headquarters at Grensásvegur 1 in Reykjavík, Iceland
- Turnover in 2006: 32 MEUR
- Expansion into international markets
- Take on ever larger and increasingly complex projects

Focus

Energy

- Geothermal power plants
- Hydro power plants
- Power lines
- Drilling Engineering
- Geothermal Research

Infrastructure

- Roads
- Airports
- Residences
- Heating systems
- Commercial buildings
- Industrial sites

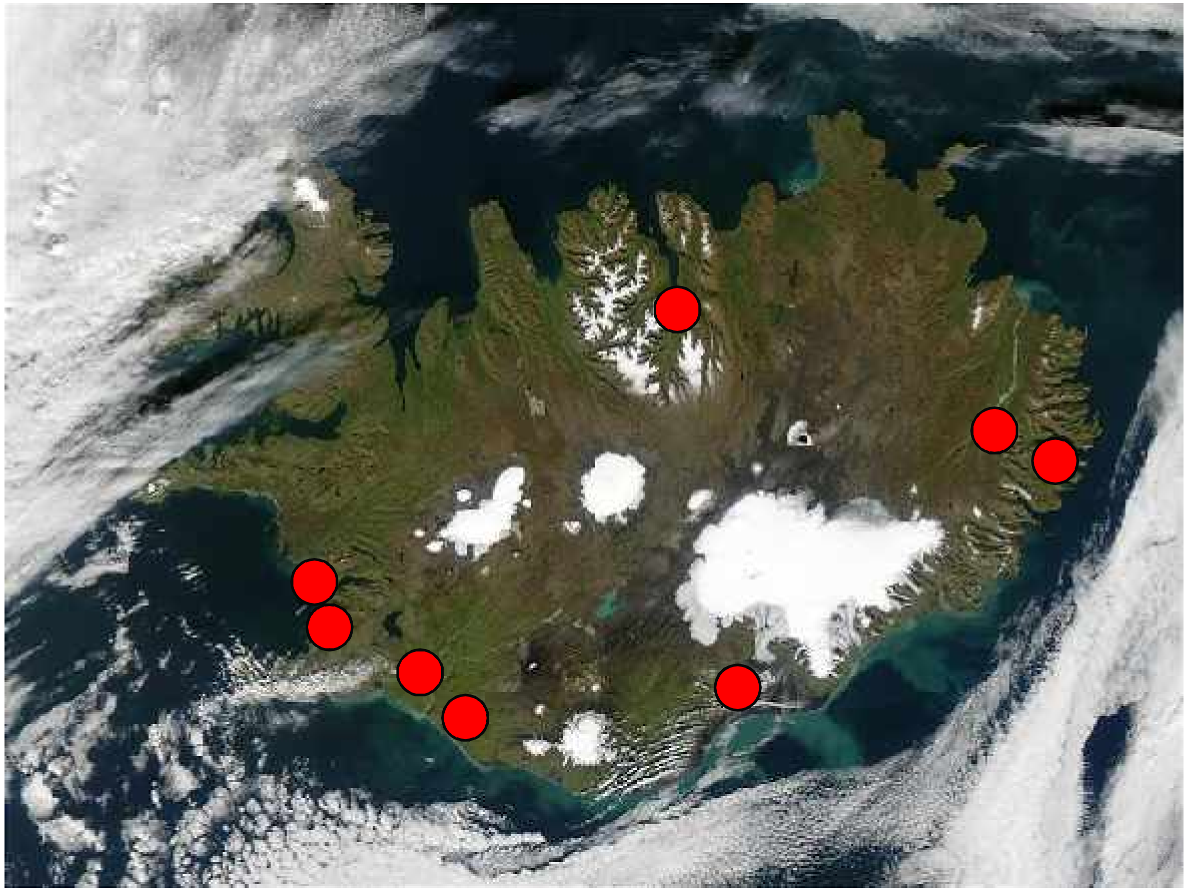
Industry

- Aluminum plants
- Fisheries
- Oil and gas
- Methane gas production
- Heating systems

Environment

- EIA
- Management
- Consulting

Domestic offices



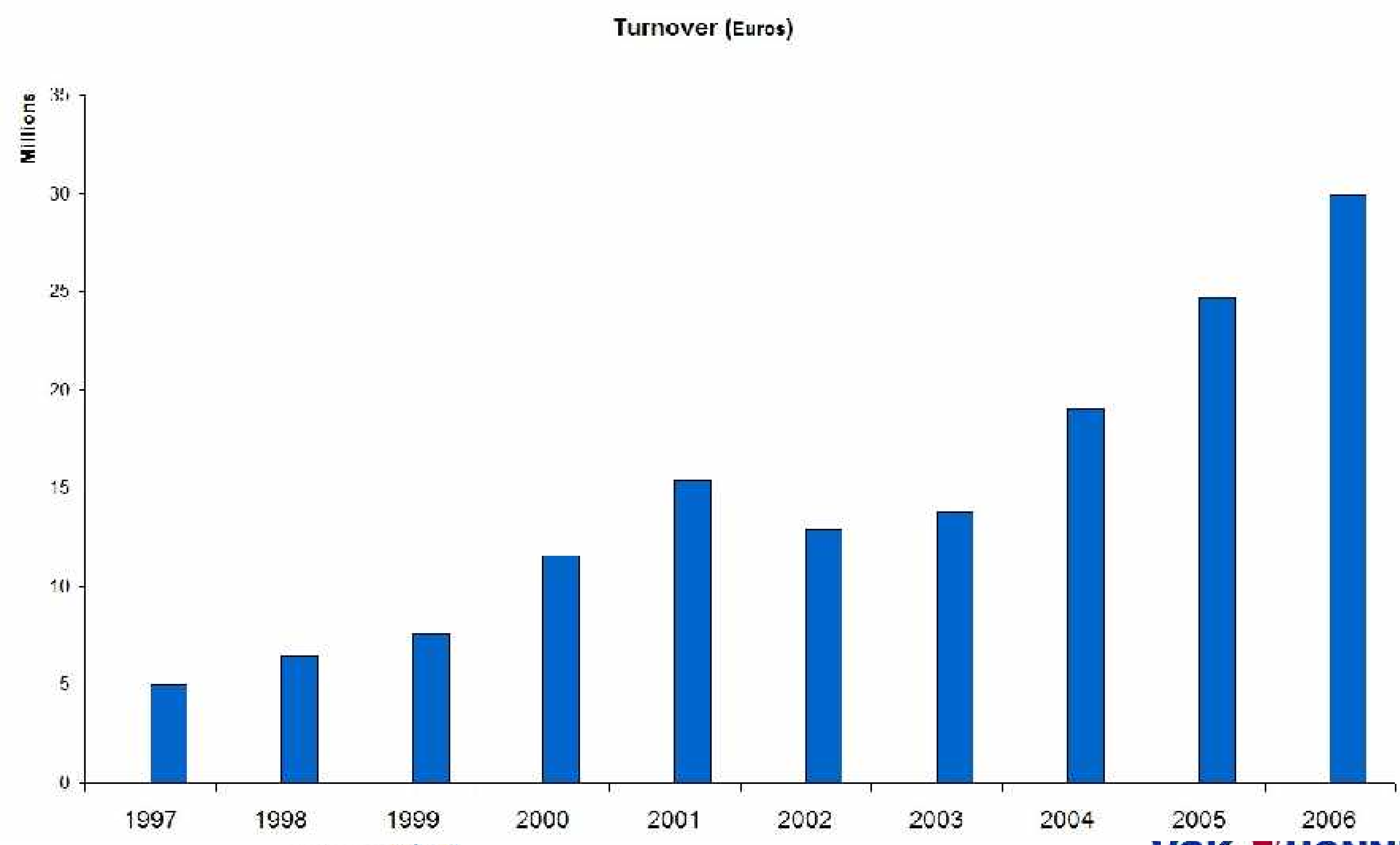
Reykjavík – Akranes – Akureyri – Húsavík – Egilsstaðir – Reyðarfjörður – Kirkjubæjarklaustur – Hvolsvöllur - Selfoss

Key financial figures

	2006 €M	2005 €M	2004 €M
Turnover	*31,6*	*26,2*	*20,2*
Current Assets	*10,5*	*8,4*	*6,2*
Current Liabilities	*4,3*	*5,1*	*4,5*
Current Ratio	*1,89*	*1,65*	*1,37*
Total Assets	*21,8*	*18,1*	*16,1*
Equity	*10,6*	*7,0*	*3,9*
Equity Ratio	*0,42*	*0,39*	*0,24*
Profit (Loss) Before Taxes	***4,7***	***4,2***	***2,2***

ISK to EURO ratio is 1 to 86.6 May 3rd, 2007

Annual turnover (M€)



Pure and simple

- Clean energy sources
- Pure environment
- "Green" technology
- Innovation and research are keys to the future

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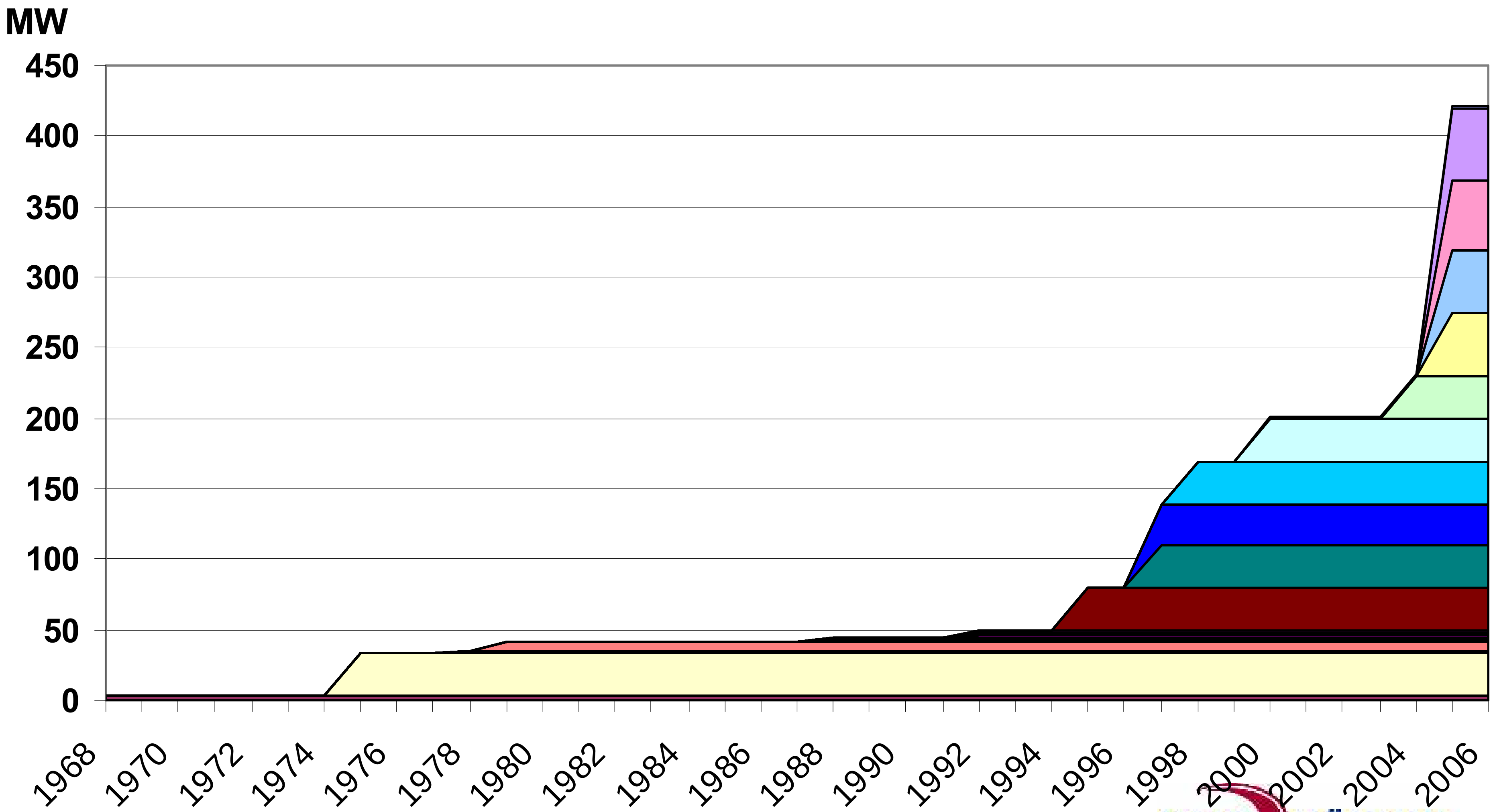
VGK-Hönnun
-Geothermal Experience-

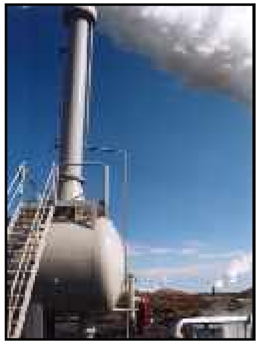
Runólfur Maack, CEO

VGK HÖNNUN CONSULTING ENGINEERS

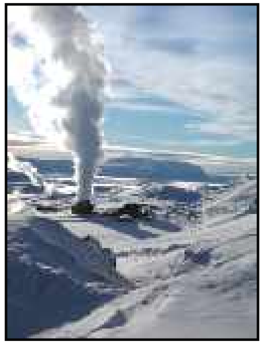
Geothermal Electrical Power in Iceland



Geothermal in Iceland



Reykjanes



Krafla

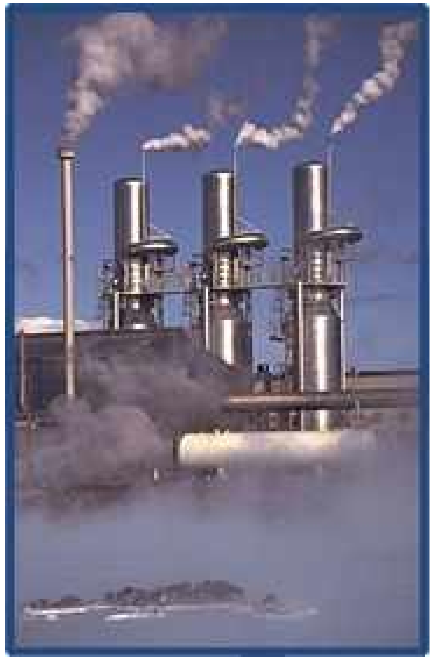
- Reykjavik Energy
  - In operation - 230 MW_{el} (+160 MW_{el}) + 300 MW_{th}
  - In preparation - 225 MW_{el} + 400 MW_{th}
- Landsvirkjun
  - In operation - 63 MW_{el}
  - In preparation - 400 MW_{el}
- Hitaveita Suðurnesja
  - In operation - 120 MW_{el} + 150 MW_{th}
- Húsavík Energy
  - First geothermal power plant using the Kalina technology - 2 MW_{el}

Hellisheiði

Nesjavellir

Engineering masterpieces

- 1971 – 1980 Svartsengi Energy Plant
- 1981 – 1990 Nesjavellir Geothermal Plant



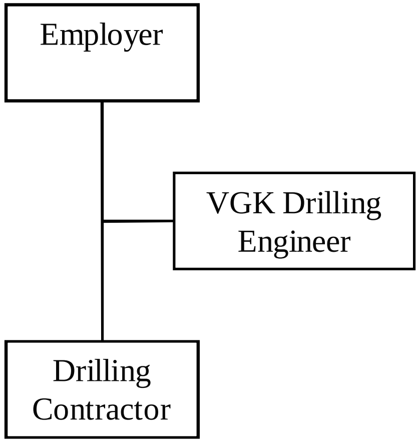
Geothermal project risk

- Drilling
- Success rate
- Temperature
- Fluid Chemistry
- Permeability

- Market
- Energy prices HUF/kWh
- Population
- Power transmission grid

Geothermal pre-drilling service

- Well design and location (Production & Re-Injection wells)
- Well pad and cellars design
- Cost estimates
- Tender documentation and bid evaluation
- Selection of contractor, contract negotiation and risk allocation
- Material procurement (Casing, wellhead, etc.)
- Drilling Rig Inspection

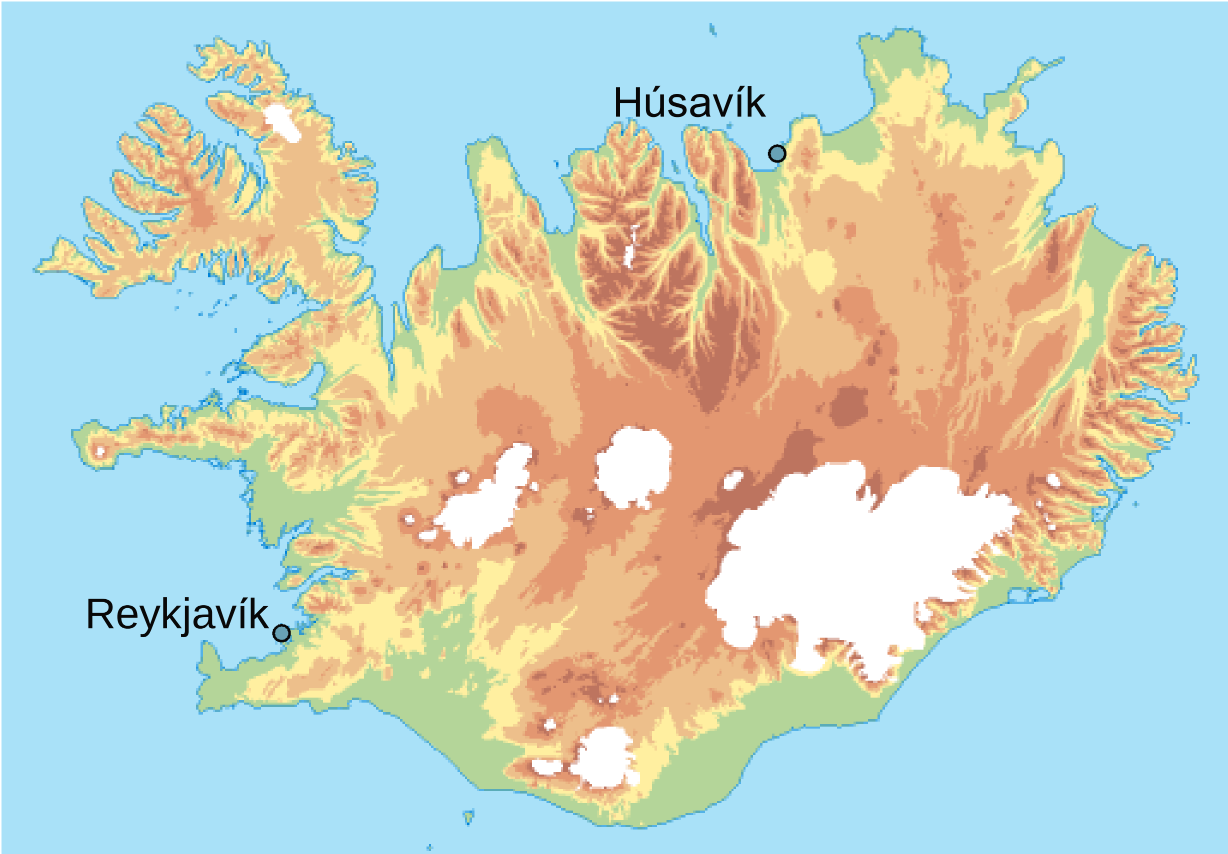


Drilling Engineer

- Drilling supervision (24 h, 7 days)
- Supervision of cement work
- Mud selection
- Well integrity assessment
- Drilling geologist
- Risk assessment

Húsavík town

Iceland



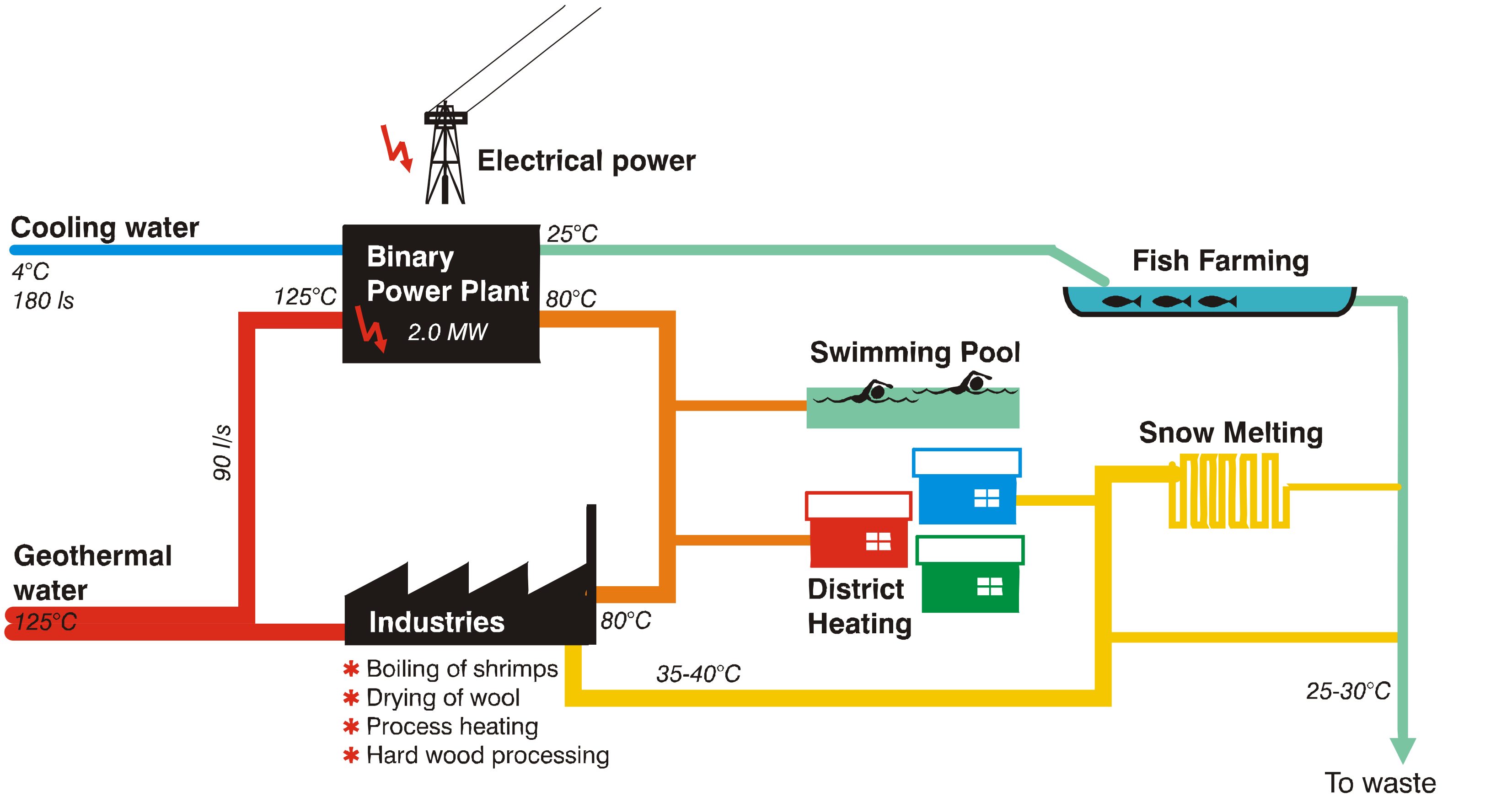
Húsavík project

- Geothermal resource, 120-125°C
- Geothermal district heating since 1970
- Asbestos pipeline, 18 km, renewed
- District heating temperature 80°C
- New steel pipeline, 1-2°C temp. drop
- Fluid to be cooled app.. 40°C
- Leading to multi use of the geothermal resources

Húsavík power plant

Turbine, tank, pump, separator, ...

Húsavík multi use



Exorka ehf

- Established in April 2001
- Mission: To design, market and sell turn-key Kalina power plants
- Market rights for Europe and S-America (Exergy Inc. holds the patents rigths)
- Owns all technical information on the Husavik plant
- Kalina technology is applicable for geothermal and waste heat recovery resources

Exorka International Ltd.

- Established in July 2007
  - As result of merger between GPS (Geodynamic Power System) and Exorka ehf.
- Shareholders:
  - Geysir Green Energy – Iceland
  - Geodynamics – Australia
  - Private investors - Germany
- Mission:
  - To develop and operate own Kalina power plants
  - Design, market and sell turn-key Kalina power plants

Exorka International Ltd.

- Holds worldwide marketing rights for the Kalina Cycle (exclusive rights in Australia/N. Zealand)
- Owns 4 geothermal claims in Bayern via its subsidiaries
- Preparing project in Nigaragua – bottoming plant
- Starting project in Cooper Basin – Geothermal plant
- More to come

Role of VGK-Hönnun

- VGK-Hönnun originally founded Exorka ehf.
- Studied the Kalina cycle in the Húsavík project
- Co-operated with the University of Iceland
- Provides full technical support for Kalina plants

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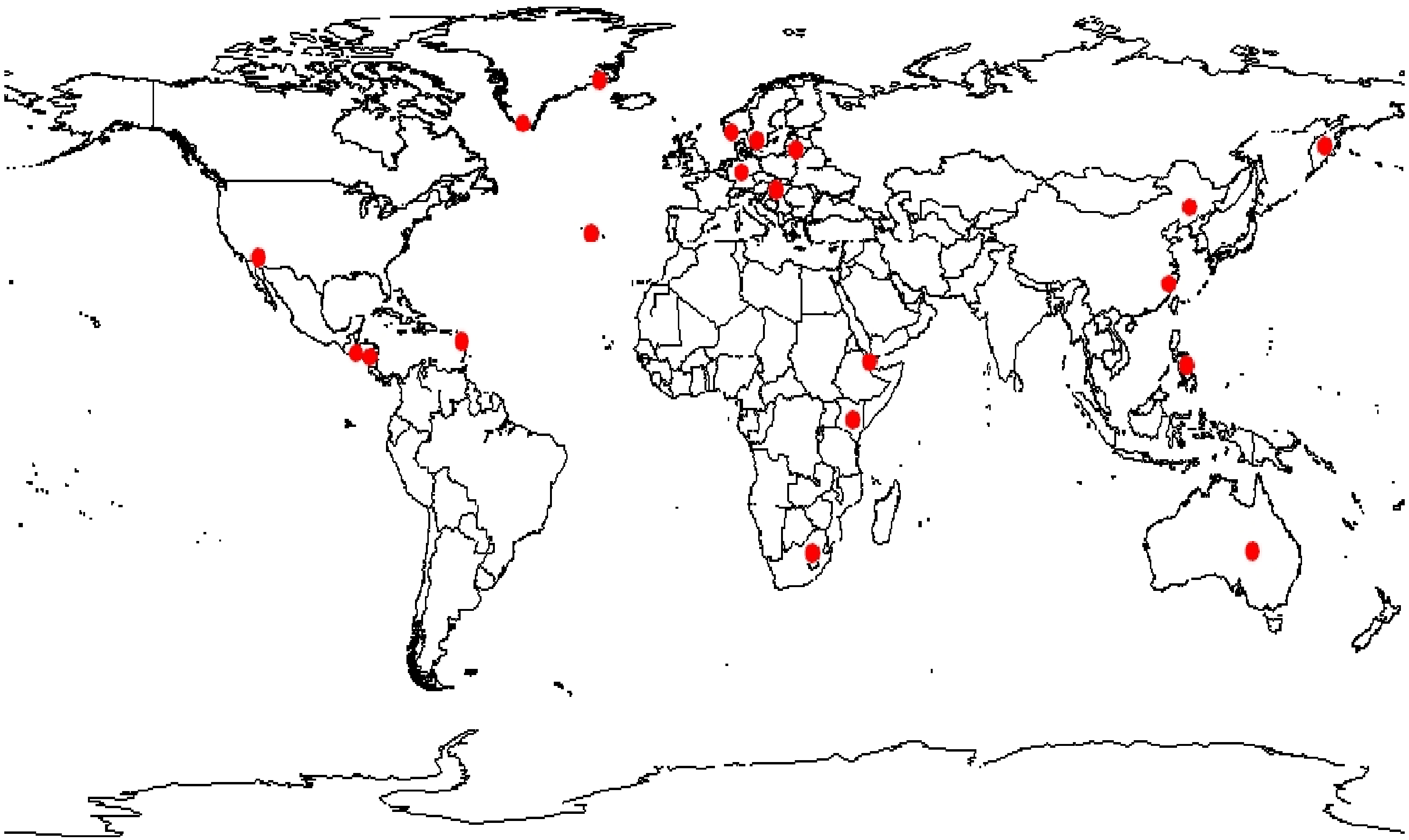
VGK-Hönnun
-International Experience-

Runólfur Maack, CEO

VGK HÖNNUN
CONSULTING ENGINEERS

Worldwide projects

- Sweden
- Russia
- Lithuania
- Azores
- Norway
- Guadeloupe
- Greenland
- China
- South-Africa
- Kenya
- Hungary
- Germany
- USA
- Nigaragua
- Australia



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El Salvador – Binary plant (ORC)

- Geothermal source
- 9 MW
- Commissioned 2007
- Owner, La Geo

Enex EPC contractor,
Engineering VGK-Hönnun

Germany – Binary plants (Kalina)

exorka

- Mauerstetten, construction started
- Hochoberdorf, in preparation phase
- Bidingen, in preparation phase
- Weilheim, in preparation phase

- Temperature range 120-130°C hot water

All 4 – 5 MW Kalina Plants, owner Exorka International

Engineering: VGK-Hönnun

Nigaragua – Binary plant (Kalina)

exorka

- Bottoming plant
- 18 MW
- Owner, Polaris / Exorka International
- Temperature range 160-170 °C separated water

Engineering: VGK-Hönnun and exorka International

Australia, Cooper Basin Binary plant (Kalina)

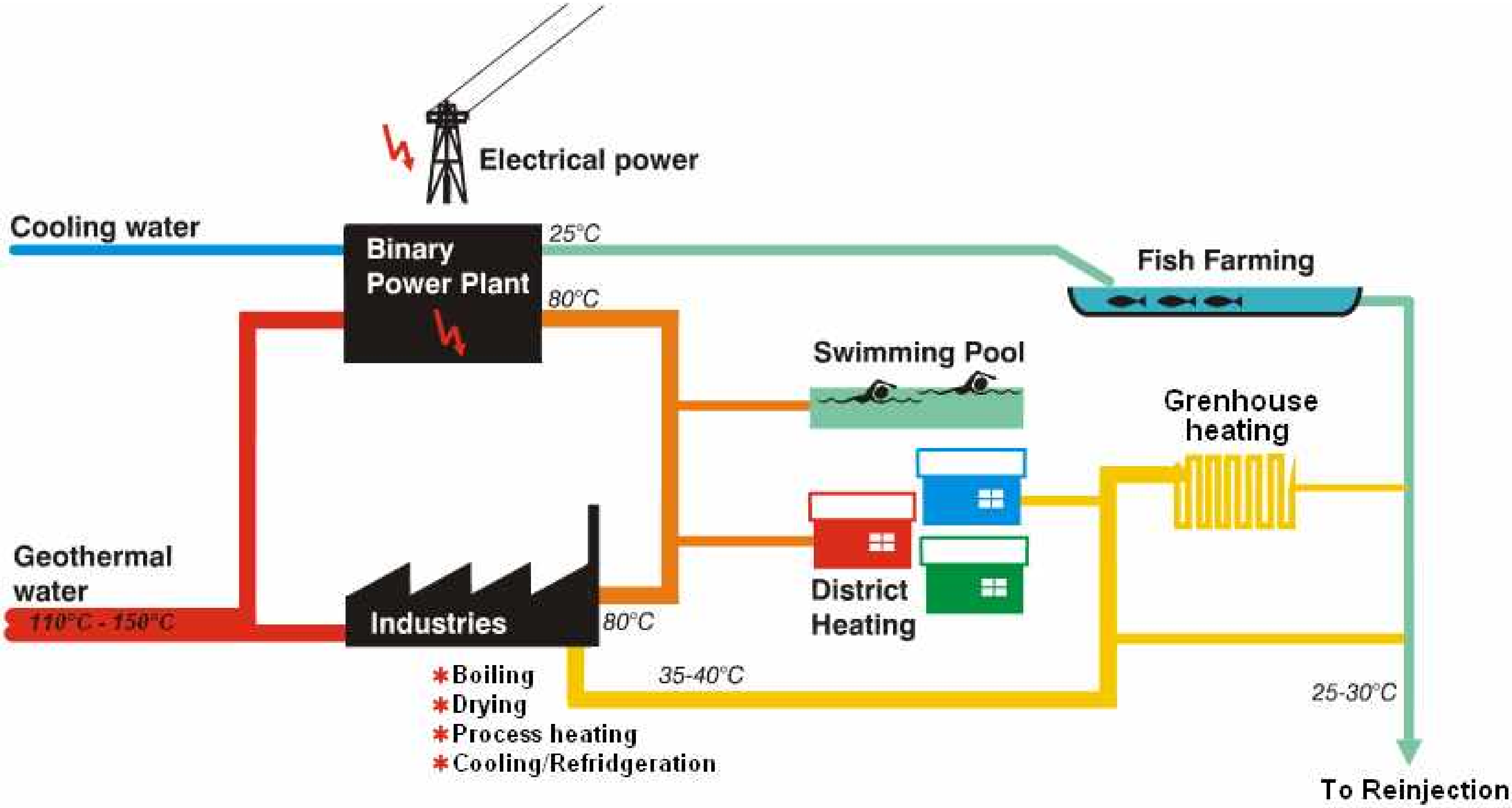
exorka

- First phase test plant
- 1 MW
- Owner, Geodynamics

Engineering: Exorka International

VGK-Hönnun technical back-up and assistance

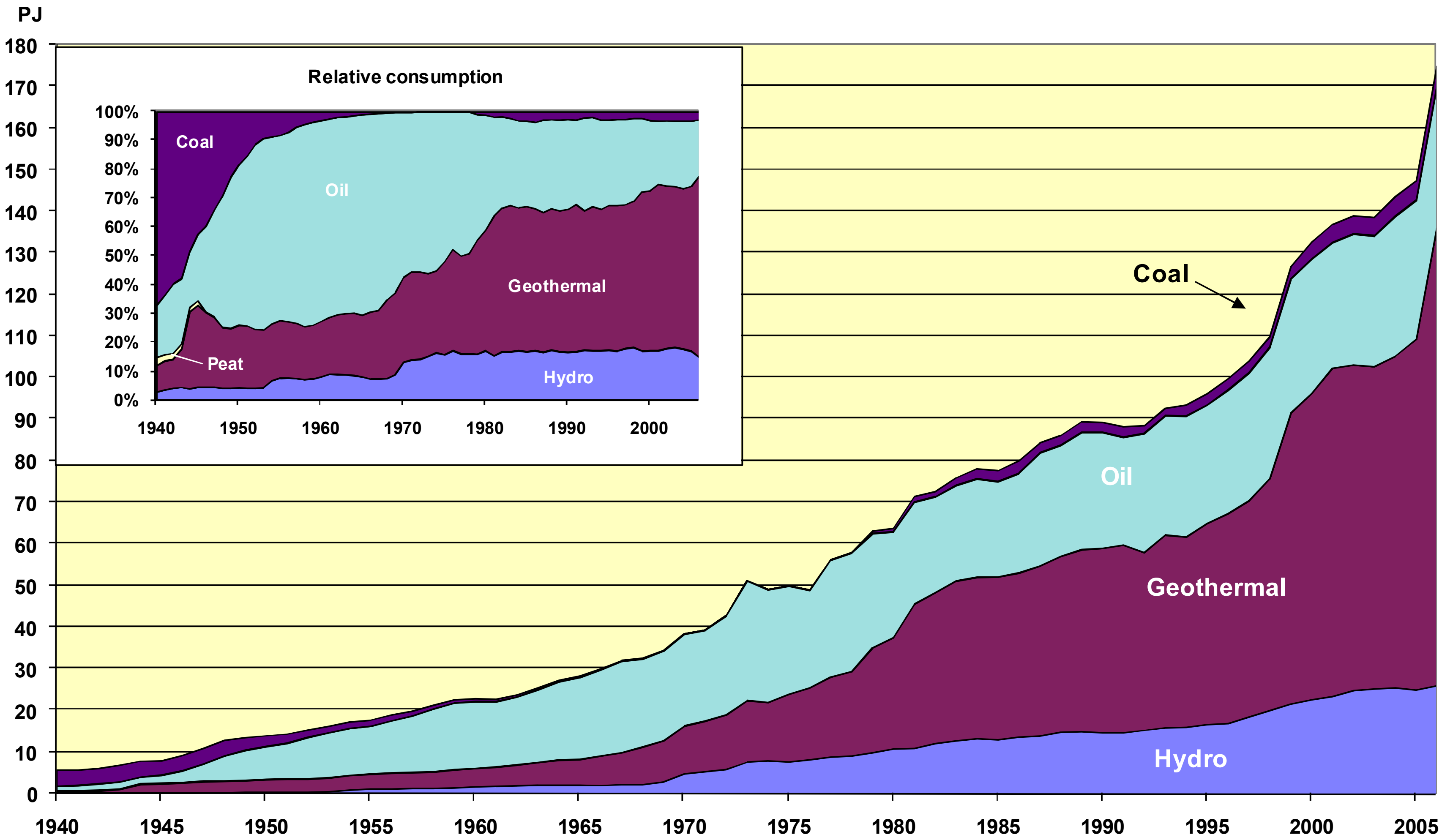
Hungary multi use?



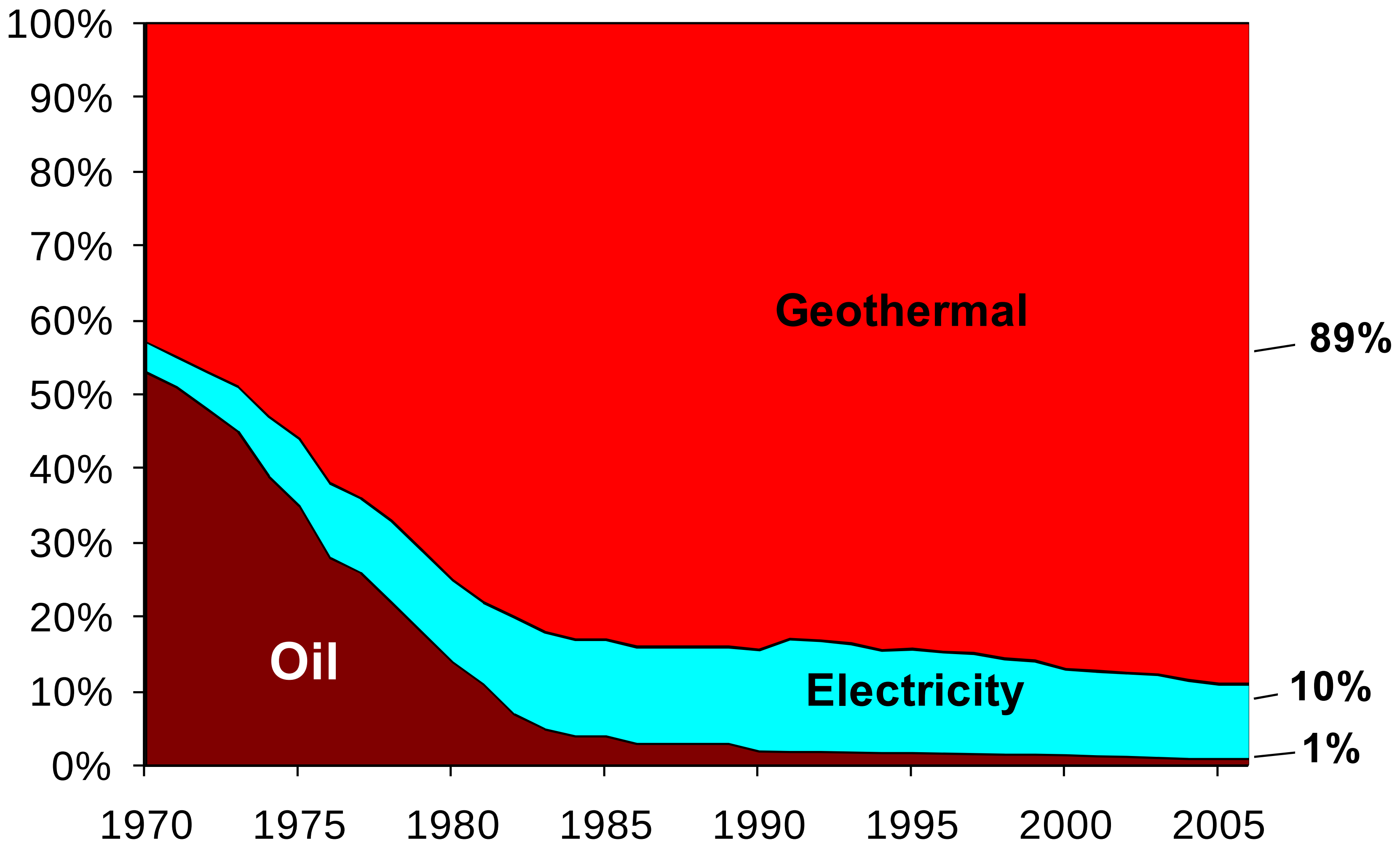
Geothermal Potential of Hungary

Helga Tulinius, Geophysicist, PM

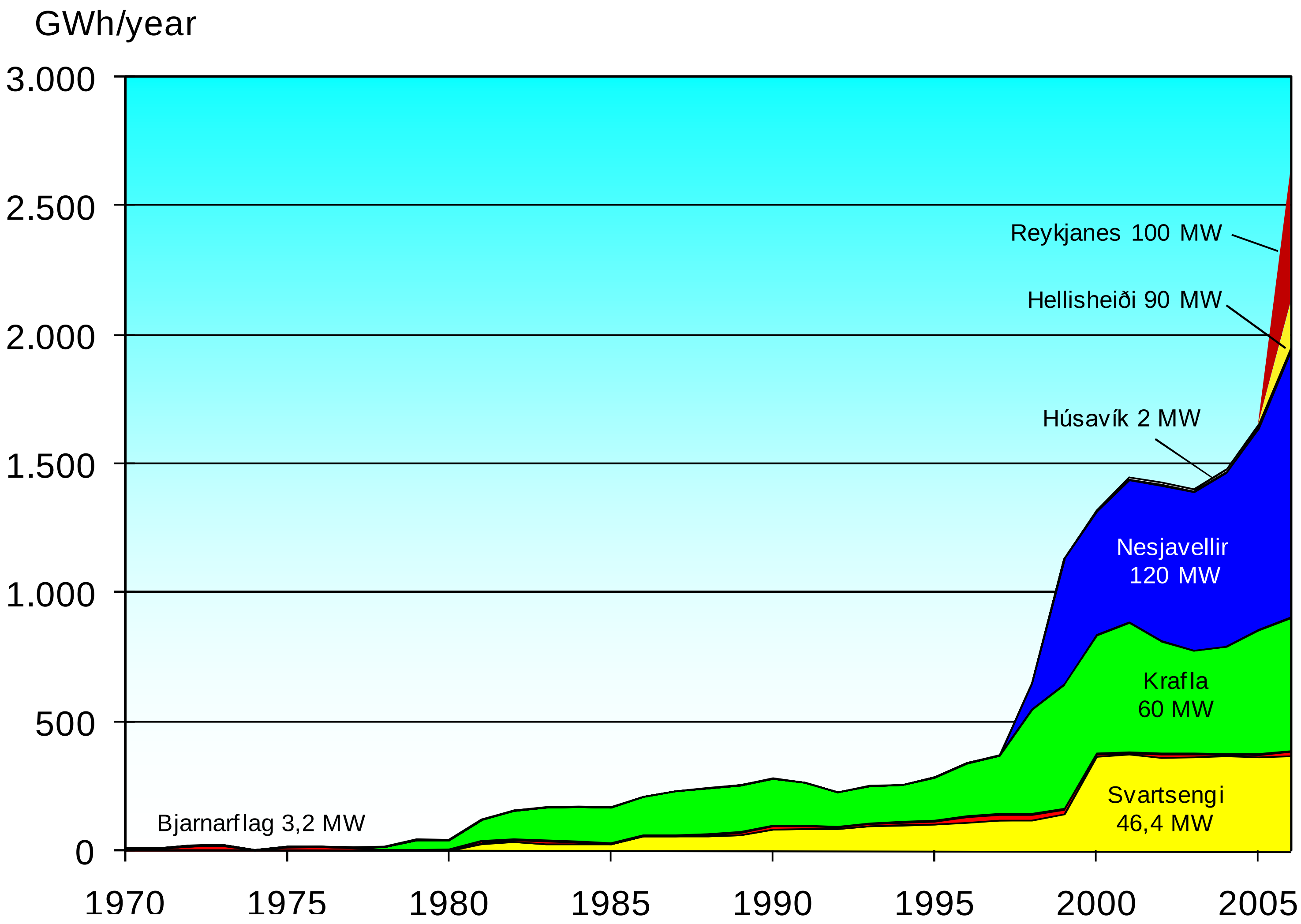
Primary energy consumption in Iceland 1940-2006



Energy sources used for space heating

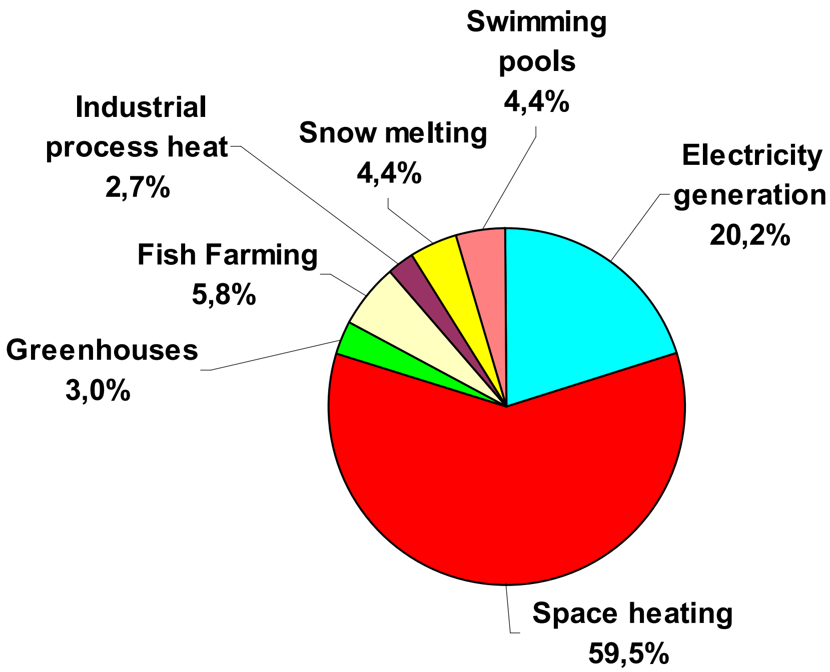


Geothermal electricity generation 1970-2006



Data for 2006 is estimated

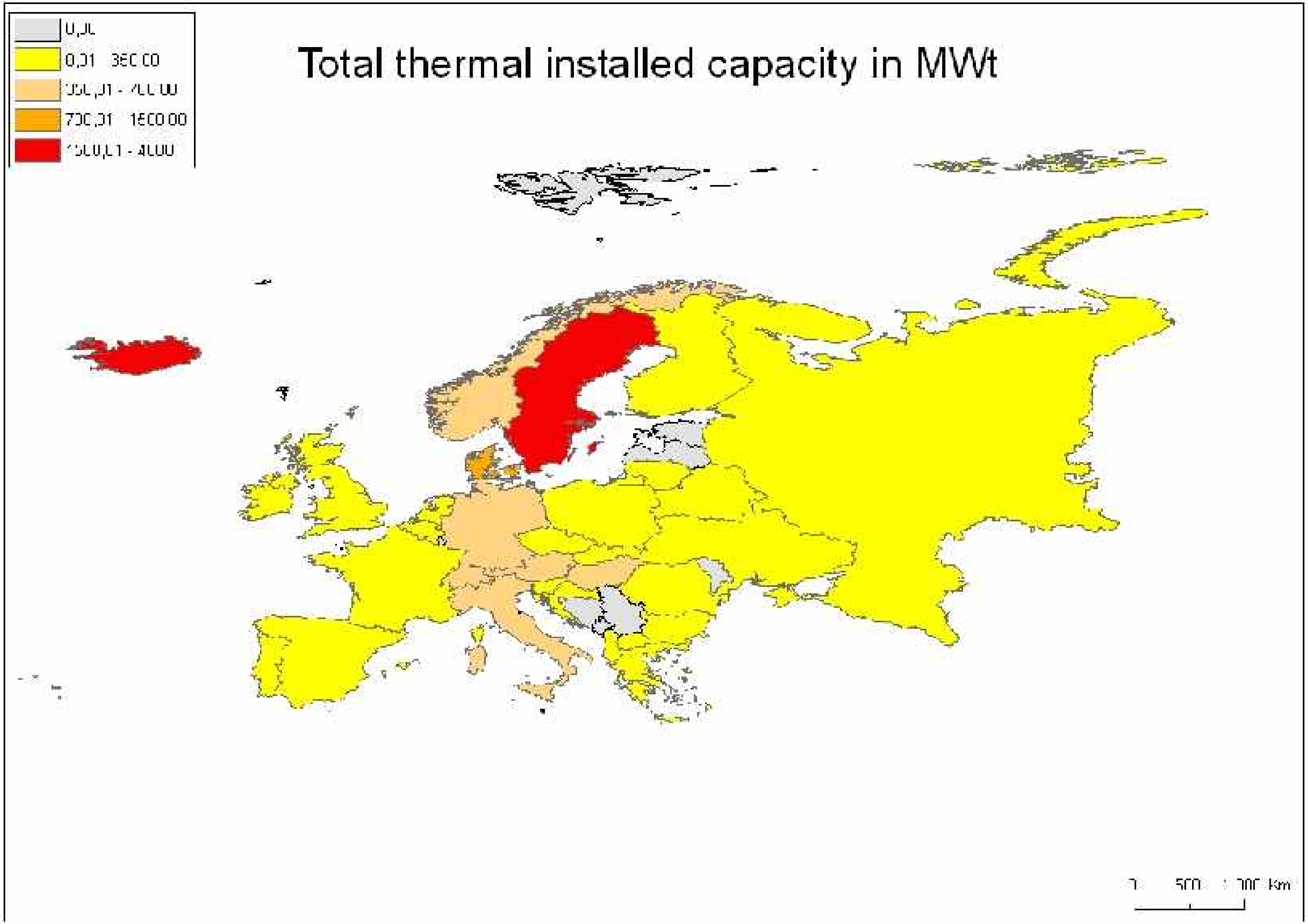
Geothermal uses in Iceland

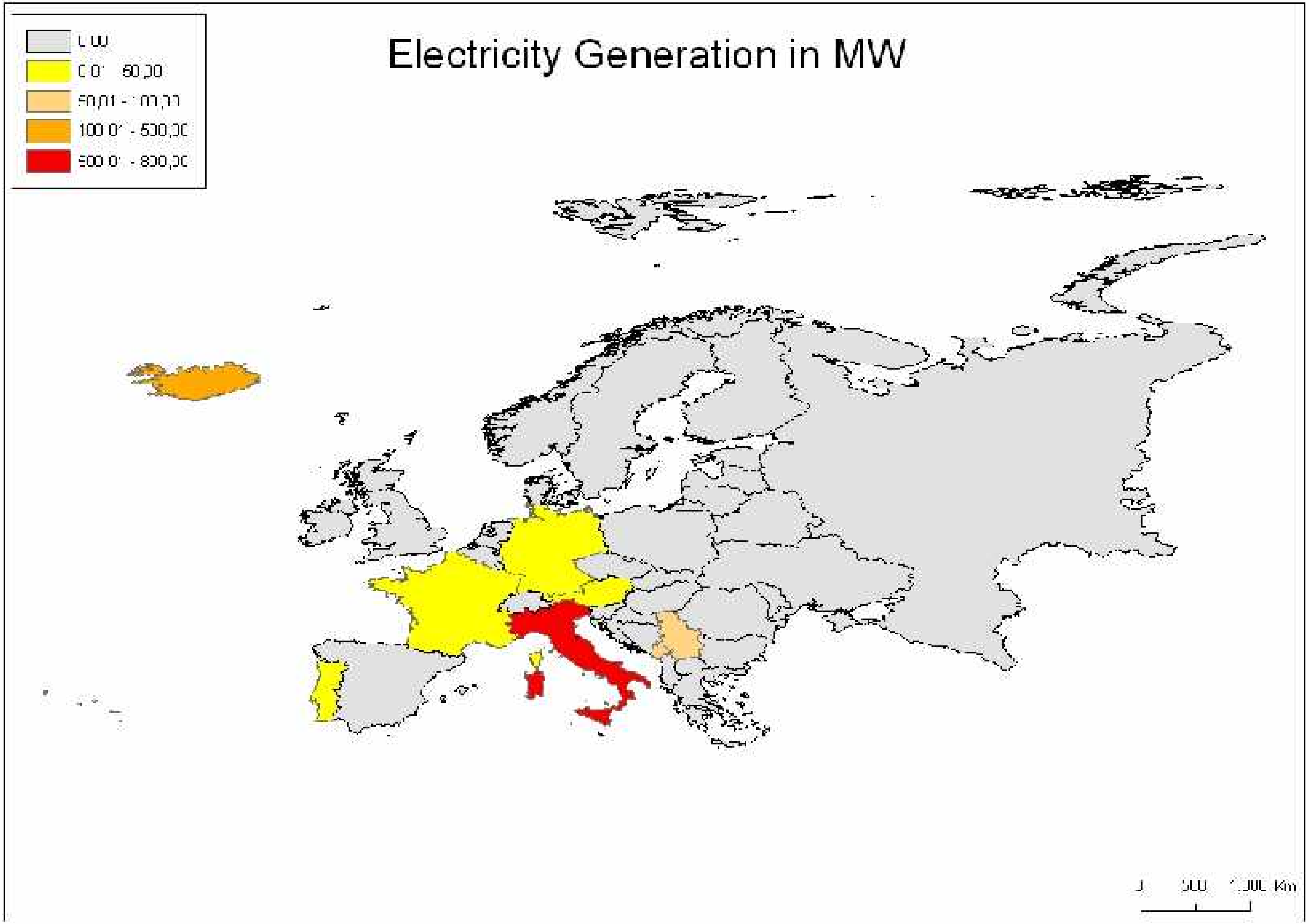


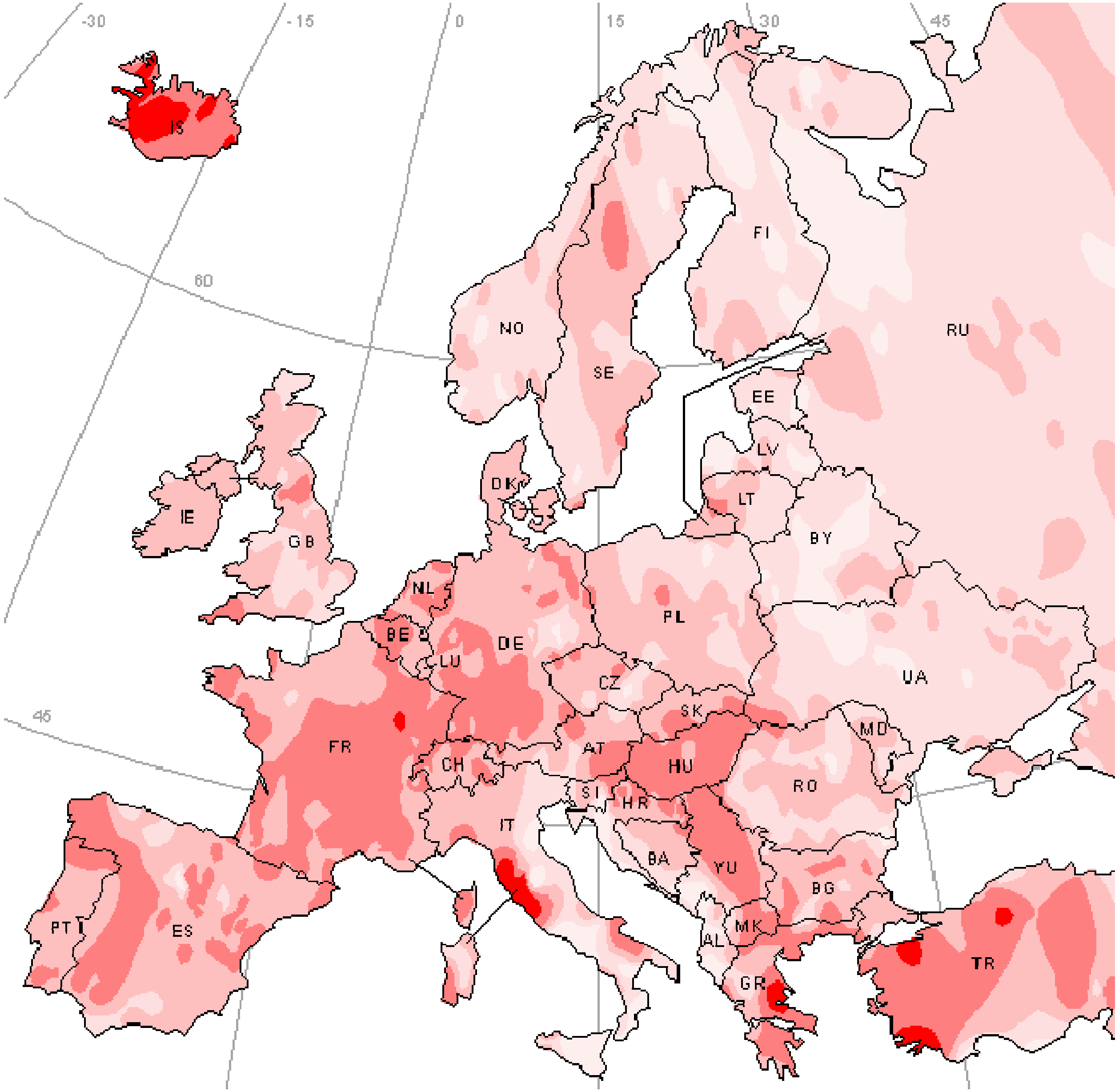
	Annual energy use TJ	%
Electricity generation	5,969	20.2
Space heating	17,587	59.5
Industrial process heat	800	2.7
Swimming pools	1,300	4.4
Greenhouses	900	3.0
Fish Farming	1,700	5.8
Snow melting	1,360	4.4
Total	29,556	100

Geo-Research Department

- Geologists
  - Surface geology
  - Borehole geology
- Geophysicists
  - Surveying
  - Analyzing
  - Interpretation
- Geochemists
  - Sampling
  - Analyzing
  - Interpretation
- Geographers
  - GIS software


Total thermal installed capacity in MWt


Electricity Generation in MW
0 MW
0,01 - 50,00
50,01 - 100,00
100,01 - 500,00
500,01 - 800,00



Geothermal Heat-Flow Density

- > 150 mW/m²
- 80 - 150
- 50 - 80
- 30 - 50
- < 30

Original map:
Atlas of Geothermal Resources in Europe
Plate 1
Heat-flow density
© 2002
European Communities
Publ. Nr. EUR 17811

Redesign and generalisation:
© 2005
Energie-Atlas GmbH
CH-4142 Münchenstein

Geothermal use in Hungary today

ELECTRICITY PRODUCTION

There is no geothermal power plant in operation as of September 2007.

DIRECT USE

- Total thermal installed capacity 694.2 MWt
- Direct use 7,939.8 TJ/year or 2,205.7 GWh/year

Direct use

The capacity and annual use for other direct-use applications include:

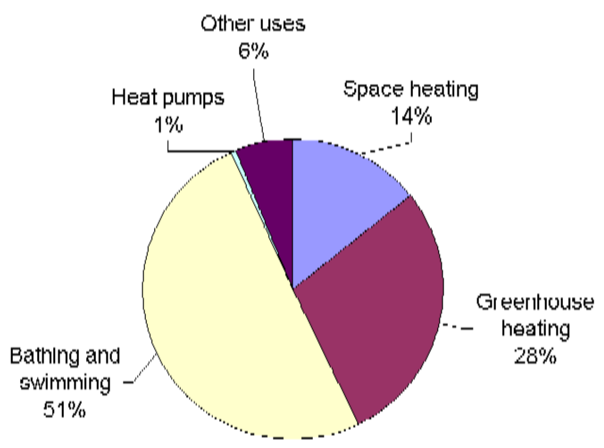
- Space heating (100.6 MWt and 1,016.7 TJ/yr)
- Greenhouse heating (196.7 MWt and 1,502.5 TJ/yr);
- Bathing and swimming (350 MWt and an estimated 5,040 TJ/yr)
- Other uses (not specified) (42.9 MWt and 358 TJ/yr),

John W. Lund, Derek H. Freeston, and Tonya L. Boyd: "World-Wide Direct Uses of Geothermal Energy 2005", published in Proceedings of the World Geothermal Congress 2005*, Antalya, Turkey, 24-29 April 2005.*

Direct use in Hungary

	(MW_t)	(%)	(TJ/yr)
Space heating	100,6	14,5	1016,7
Greenhouse heating	196,7	28,3	1502,5
Bathing and swimmin	350	50,4	5040
Heat pumps	4	0,6	22,6
Other uses	42,9	6,2	358
Total	**694,2**		**7939,8**

John W. Lund, Derek H. Freeston, and Tonya L. Boyd: "World-Wide Direct Uses of Geothermal Energy 2005", published in Proceedings of the World Geothermal Congress 2005*, Antalya, Turkey, 24-29 April 2005.*



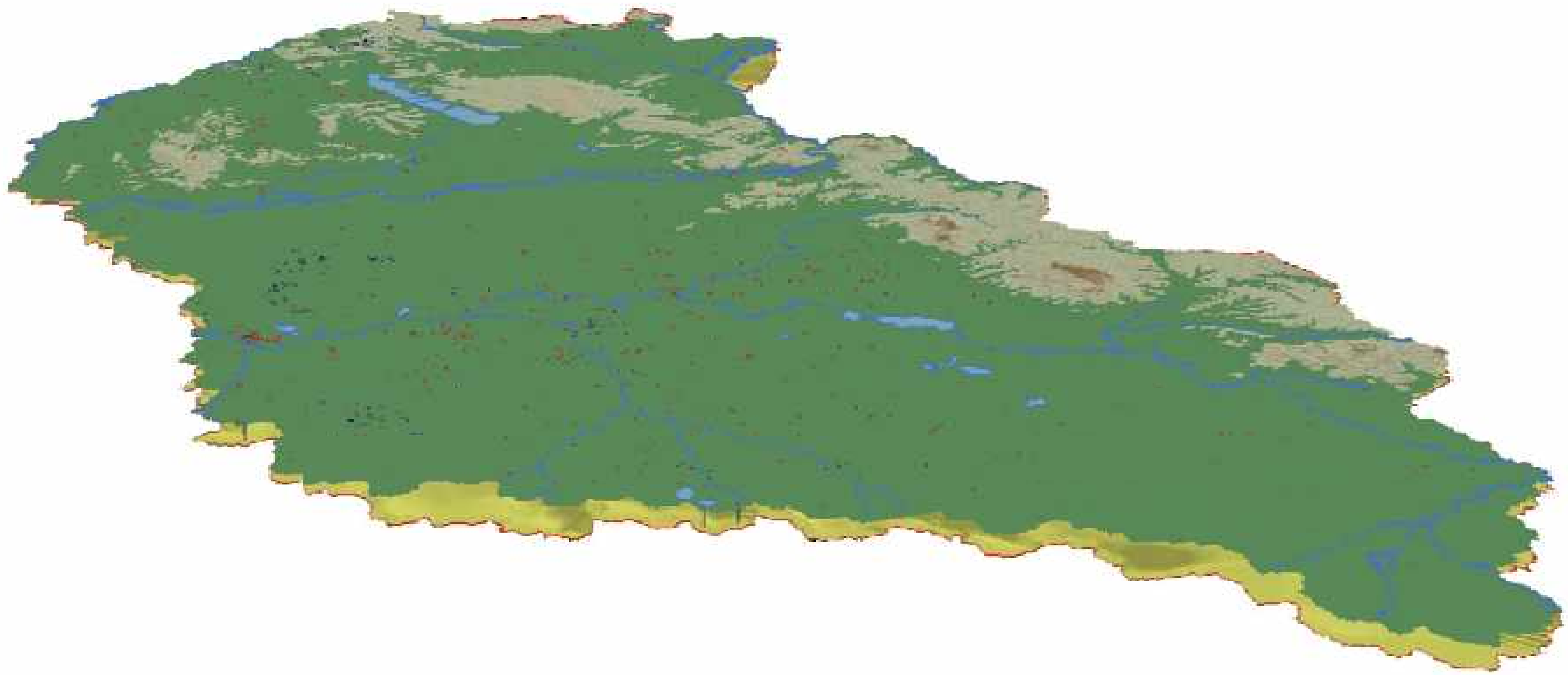
Geology of Hungary

- Geographically Hungary is located in the Pannonian Basin
- The Pannonian basin, is filled primarily by sediments during the upper Miocene (Pannonian age)
- Its crust is relatively thin, or only 25 to 35 km in thickness

Geological Conditions of Hungary

- The sediments filling the basin are multilayered
- Close to the surface, the upper Pannonian and Quaternary formations contain vast porous, permeable sand and sandstone beds, formed the upper Pannonian aquifer
- The deeper sediments are impermeable with low thermal conductivity (lower Pannonian layers), these insulate the basement relatively well
- The permeable part of the insulated basement are the potential geothermal sources

Geothermal in Hungary



Geological conditions

As a result of the earth's thin crust, Hungary's geothermal gradient is higher than the world average, 50°C/km versus 30°C for the world

The temperature of the rock (and the contained fluid) often exceeds 100°C at a depth of 2,000 meters.

Geothermal study of Hungary

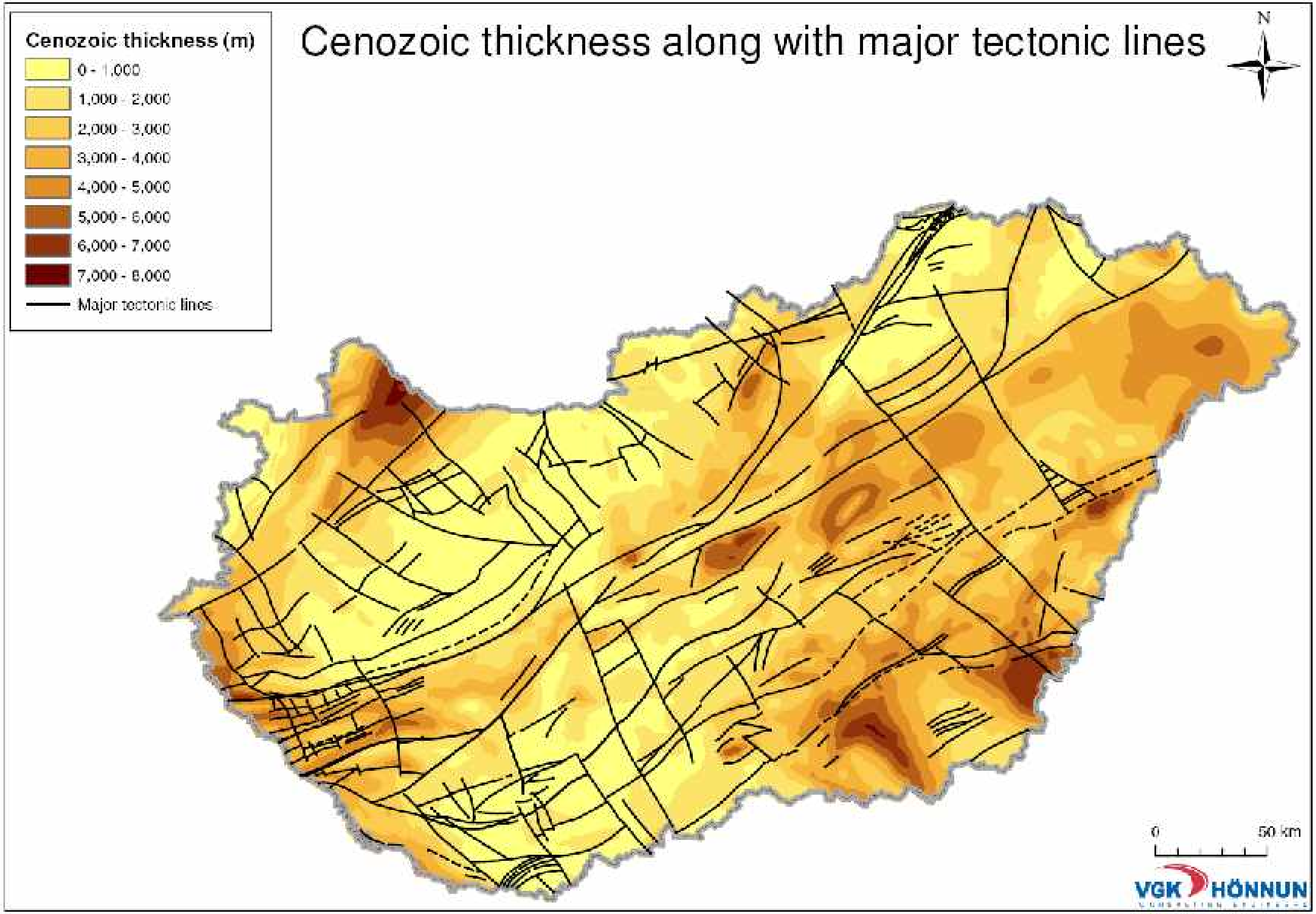
VGK-Hönnun started working on the geothermal resources of Hungary in the fall of 2006

Assumptions:

- Hot enough for electrical production T > 110°C
- Shallower than 3000 m
- Outlined 23 areas

Resources

- All data available – Internet
- Local sources
- Former ALTENER study
- Using GIS software to outline potential area
- MT and Gravity survey



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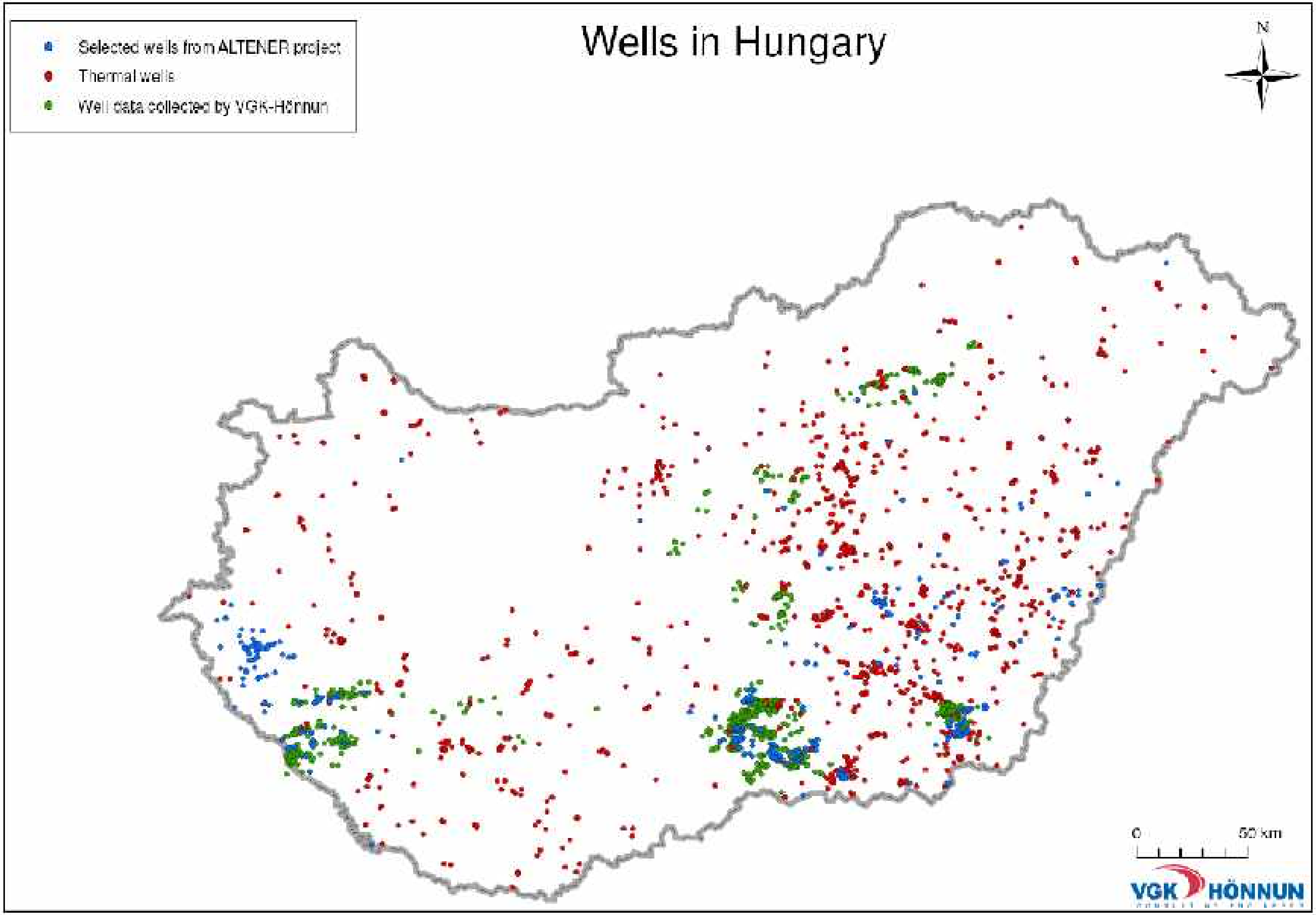
Wells in Hungary
Selected wells from ALTENER project
Thermal wells
Well data collected by VGK-Hönnun
N
0
50 km
VGK HÖNNUN

EU – Renewable Energy Targets

- Increase the share of the renewable energy to 20% of the total energy consumption on average in the EU countries before 2020

- For Hungary to meet this target, 164 MW electricity (about 20 PJ) needs to be installed and 9 PJ for space heating.

Capacity

- To produce Hungary's pledge (draft) for 2020 of 164 MW_e netto using 120°C water
  - about 8000 l/s is needed
- Conservative estimation – efficiency of heat conversion only 5% versus Kalina 12-13%
- Estimating 2 MW/well a total of 82 production wells and 41 injection wells are needed
  - ~10 wells/year drilled until 2020

Capacity continued

- Total surface area of Hungary is about 93,000 km^2
- Total surface area of research is 13,000 km^2

Assuming:

- Reservoir thickness 500 m
- Porosity 10%
- 8300 hr/year
- Only 2-3% of the research areas is needed

Space Heating

- To add 9 PJ/year to the current use (Hungary's pledge (draft) for 2020)
- Only 84 wells with the average of 20 l/s are needed
- Assuming 80°C hot water or affluent water from electrical production

Forecasts by Other Sources

- GM Energetika Központ, 1999: aiming the 10,5 PJ/year by 2002,
- VITUKI, 2004: the use of the geothermal sources can reach 9 PJ by 2010 (heatpumps included, 2,1 PJ)
- VITUKI, 2004: approximately 264 PJ/year heat coming from the crust on the area of Hungary
- GKM, 2007: Strategy of increasing renewable energy consumpiton in Hungary 2007-2020 (draft)

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The Kalina Technology and Hungary

Helgi Gunnar Vignisson, M.Sc. Chem. Eng.

VGK HÖNNUN CONSULTING ENGINEERS

Power production in Hungary

- Geothermal fluid available
- Temperature range is below 150°C
- There is need for electricity and thermal heat

- Binary Cycles optional solutions
  - Organic Rankine Cycle (ORC)
  - Kalina Cycle

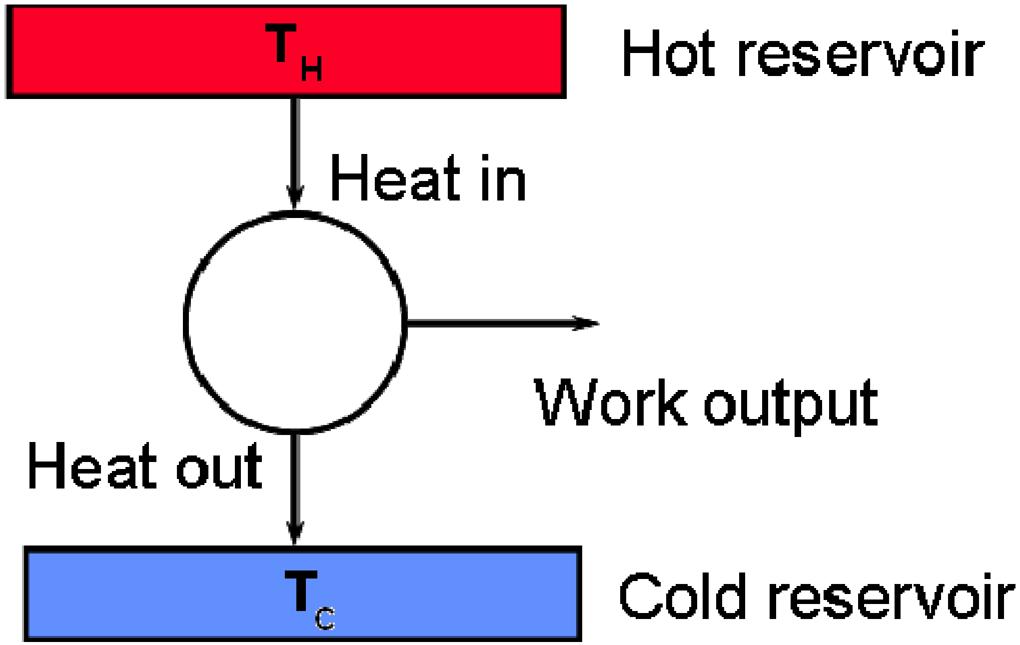
Kalina and ORC Difference

- Both
  - Closed Circuits
  - Utilise known and tested technology
- Organic Rankine Cycle (ORC)
  - Working fluid is organic chemical with low bp
  - Feasible for low temperatures ~150+°C
- Kalina Cycle
  - Working fluid is mix of Ammonia and Water
  - Feasible for very low temperatures ~110+°C

- Kalina Cycle better choice for Hungary's situation

Thermal efficiency (Carnot)

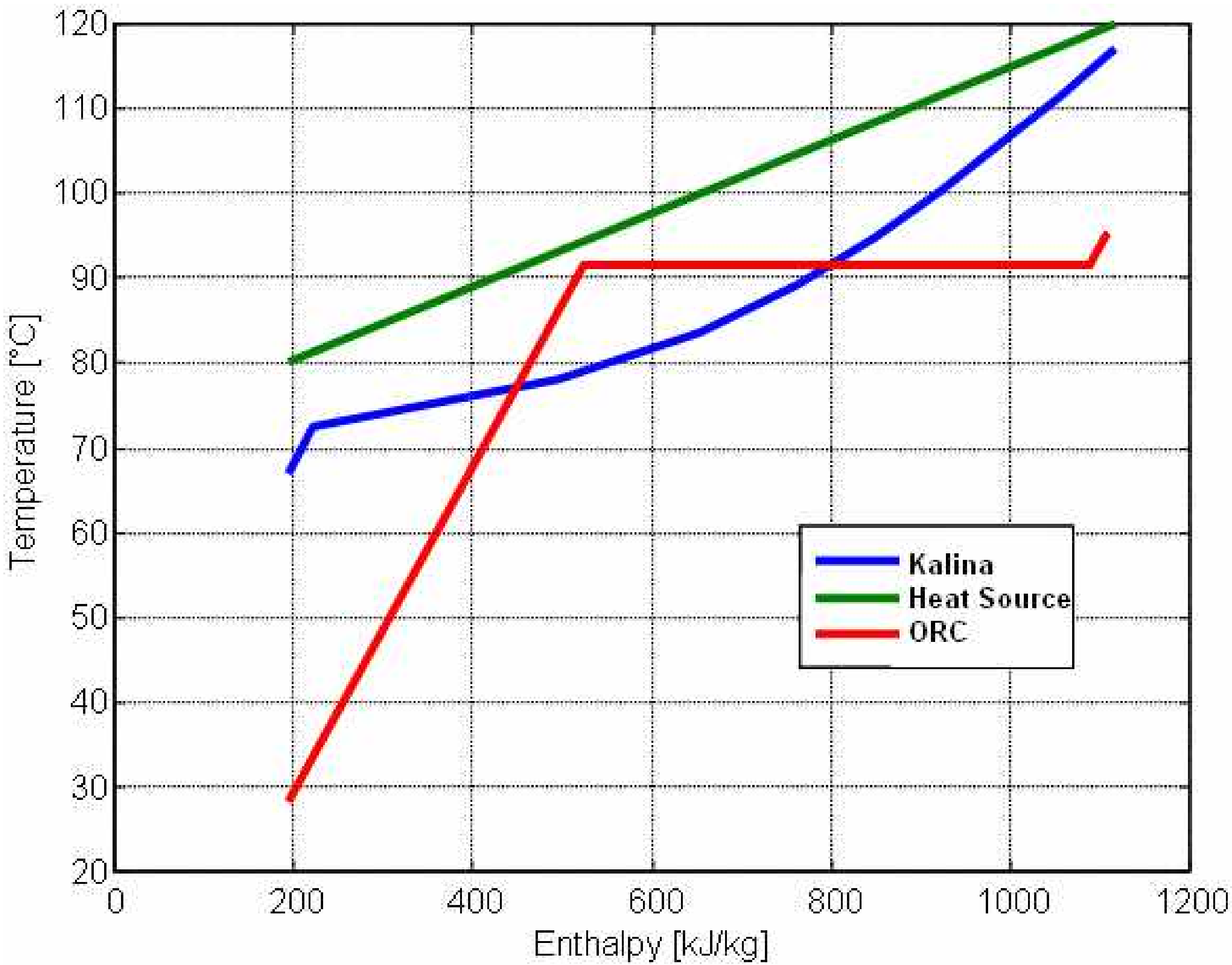
- "No engine operating between two heat reservoirs can be more efficient than a Carnot engine operating between the same reservoirs"



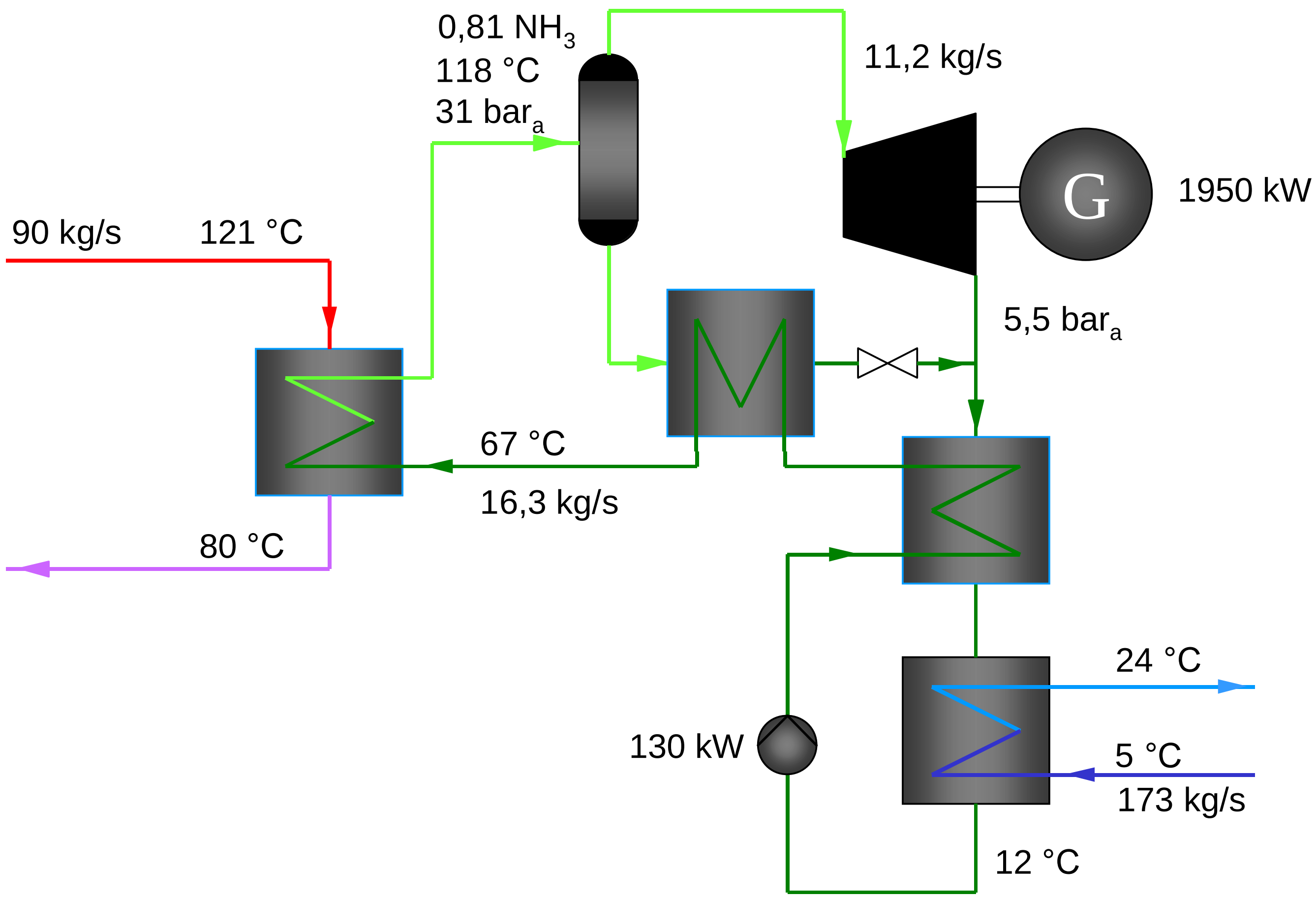
$$\eta_{Carnot} = 1 - \frac{T_C}{T_H}$$

$$\eta_{Callen,endoversible} = 1 - \sqrt{\frac{T_C}{T_H}}$$

Boiling curve comparison for Kalina and ORC



Kalina Cycle Process Diagram



Kalina references

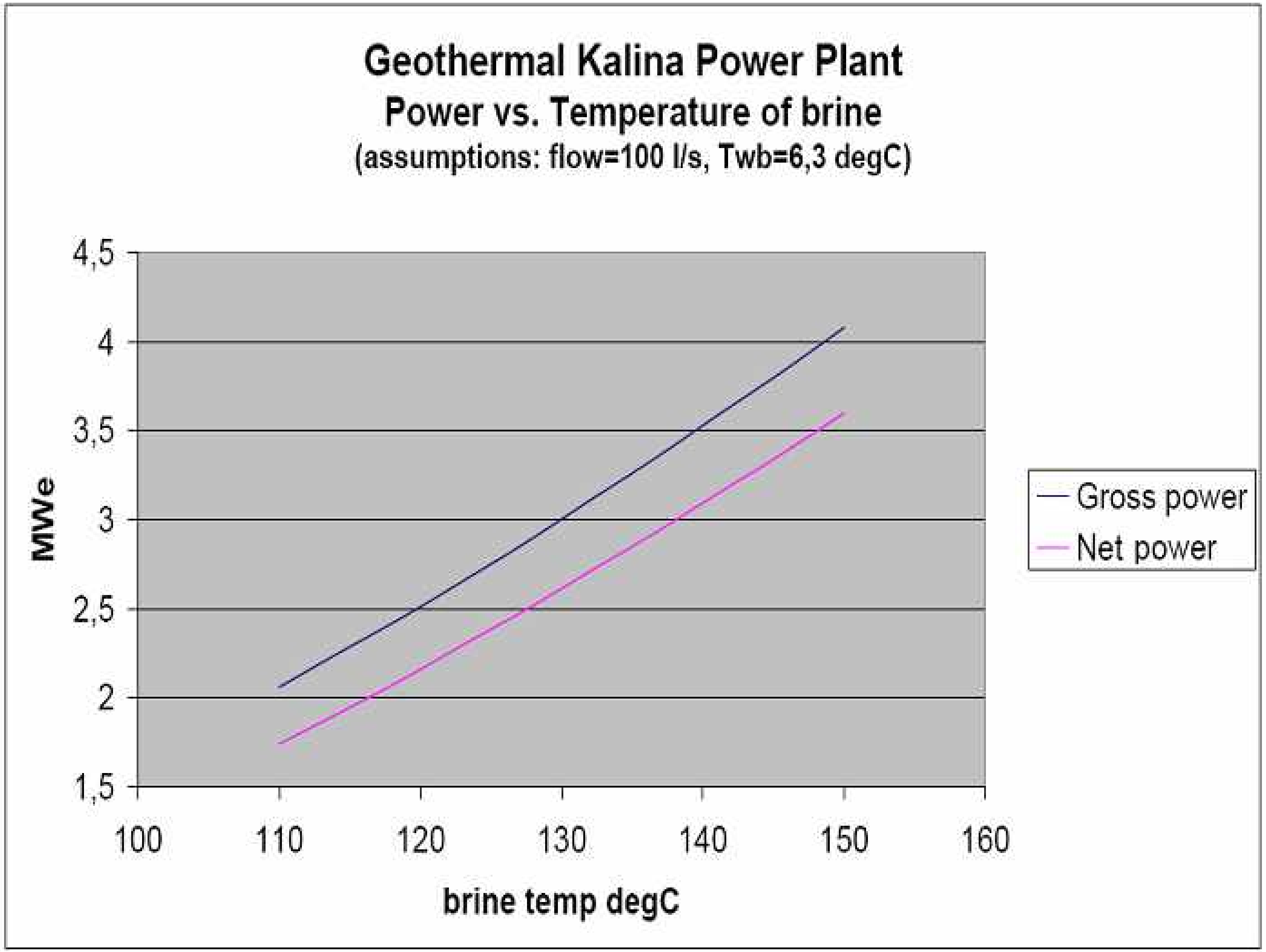
- Canoga Park, USA, demonstration plant
  - ***3 – 6 MW, 1991-1997***
- Fukuoka, Japan, incineration plant
  - ***4,5 MW, 1999***
- Sumitomo, Japan, waste heat from steel plant
  - ***3,1 MW, 2000***
- Husavik, Iceland, geothermal plant
  - ***2,0 MW, 2000***

Market

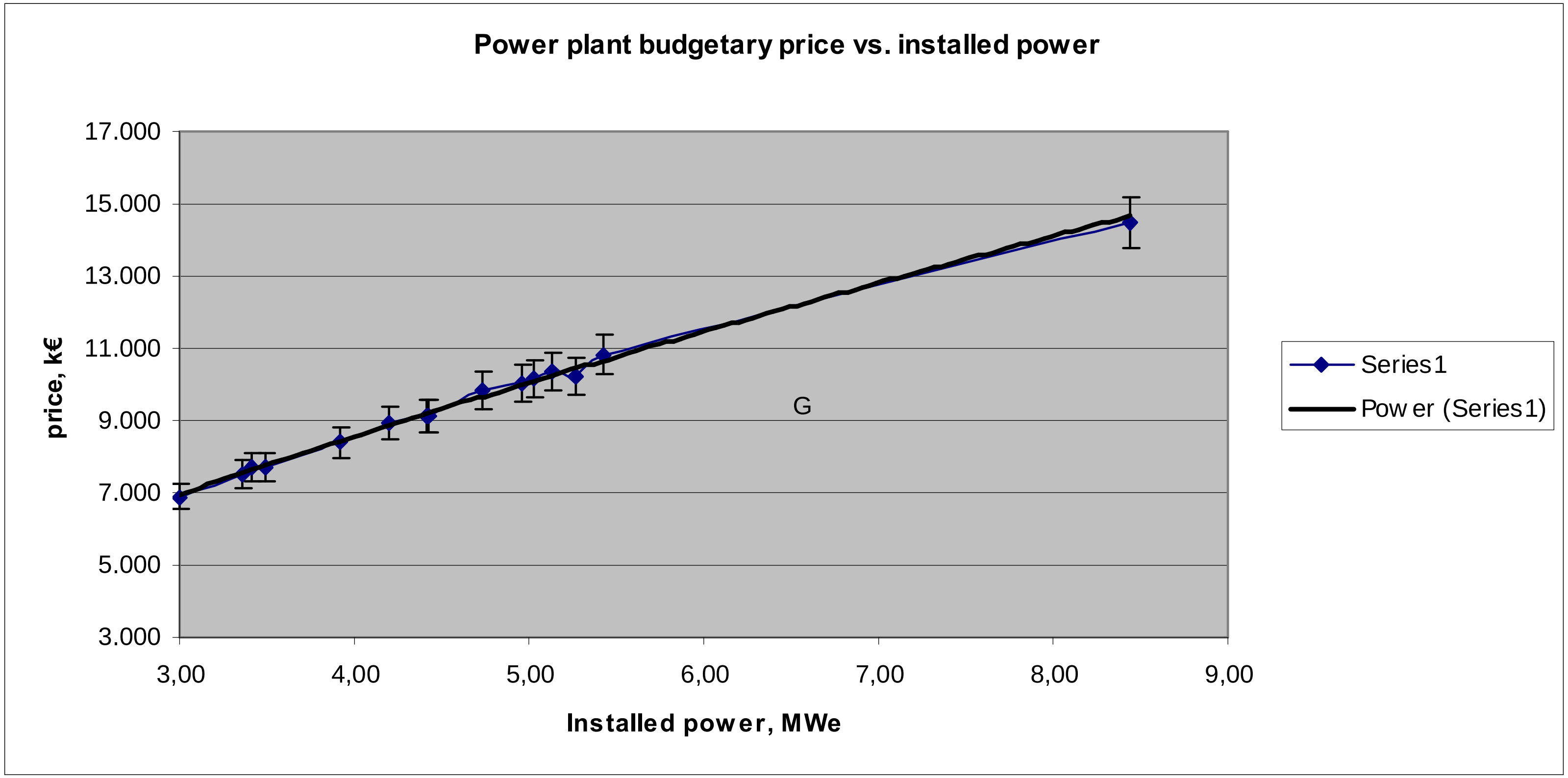
Wherever there is access to heat at relatively low temperatures (110 to 200 ^{o}C)

- Geothermal
- Metallurgical processes
- Gas and Diesel exhaust
- Waste incineration
- Biomass combustion

Power Production Potential
The importance of brine temperature

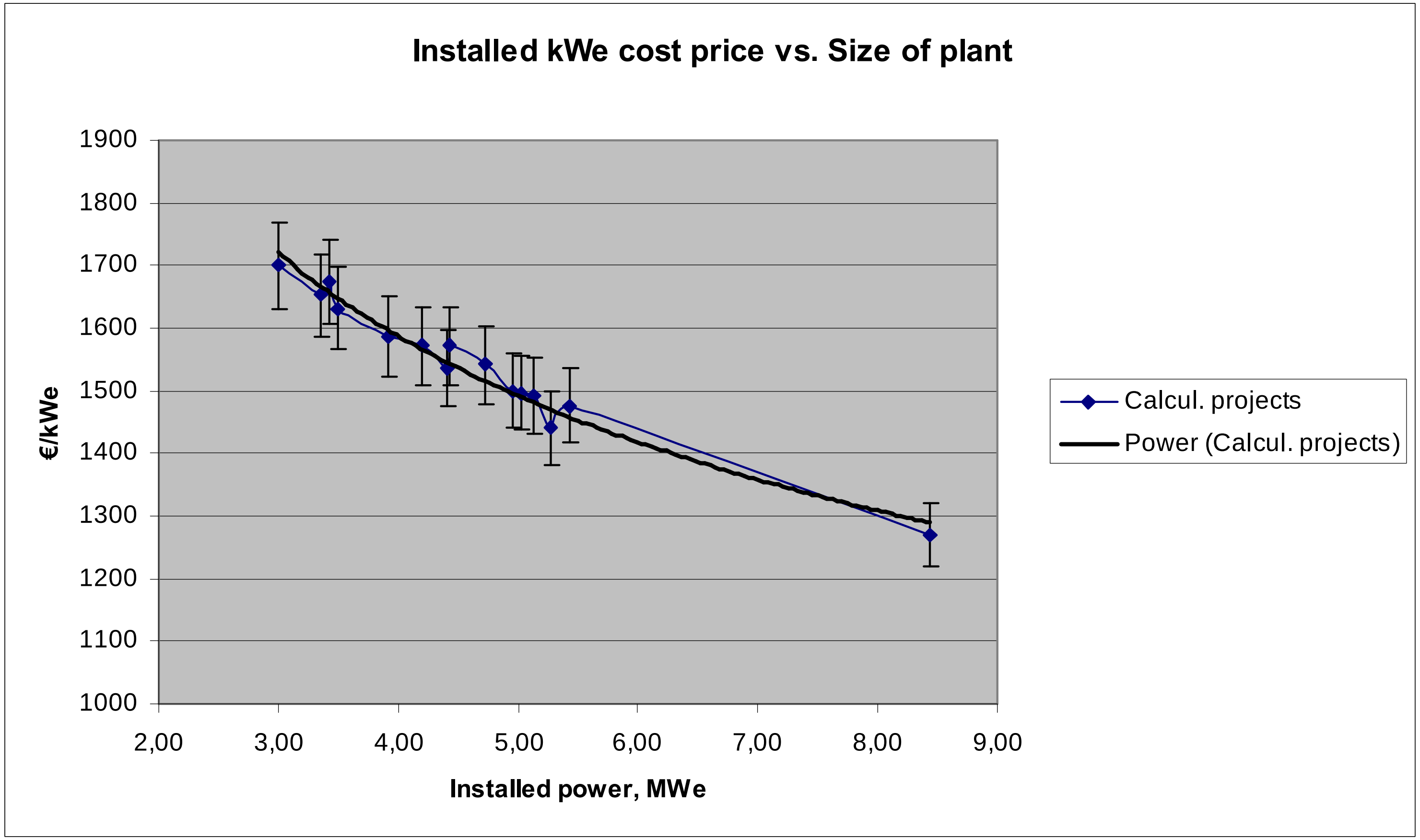


Kalina Power Plant budgetary pricing
(PP incl. Wet cooling tower)



Kalina Power Plant budgetary pricing

(PP incl. Wet cooling tower)



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The Bottom Line

- There is no CO_2 emissions from plants
- There is no additional strain on the environment
- The environmental impact is limited
- New, but well known technology
- Offers multiple use for nearby area
- Is safe and controllable

VGK-Hönnun hf.
Grensásvegur 1, 108 Reykjavik, Tel: (+354) 422 3000
Web: www.vgkhonnun.is / E-mail: vgkhonnun@vgkhonnun.is