Science, Industrial Projects and Life / Work Balance

Perceptive from Landsvirkjun, the national energy company in Iceland¶

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Director Geothermal Development

IMPROVE 4th Network School

Landsvirkjun

Outline

Landsvirkjun, the national power company

- Special purpose vehicle
- To improve quality of life in Iceland

Geothermal Projects

- Bjarnarflag – the oldest but smallest
- Theistareykir – the newest and the flagship
- Krafla – the really tricky one
- The others…

Geothermal Project Development

- Geothermal exploration is a continuous learning process – we are constantly learning more about how little we know!
- Every production well is an exploration (research) well

The Life and Work/Life Balance

- Background:
  - Home, education, family, interests
- Keep connection between practice and academia
  - Always try to make power plants better!
  - Participate in world class R&D projects like Improve and Krafla Magma Testbed and Iceland Deep Drilling Project
  - Maintain extensive knowledge network
- Personal motivation
  - Teaching GRÓ-Geothermal Training Program (UNESCO), Reykjavik University and papers and presentations

Landsvirkjun

Landsvirkjun

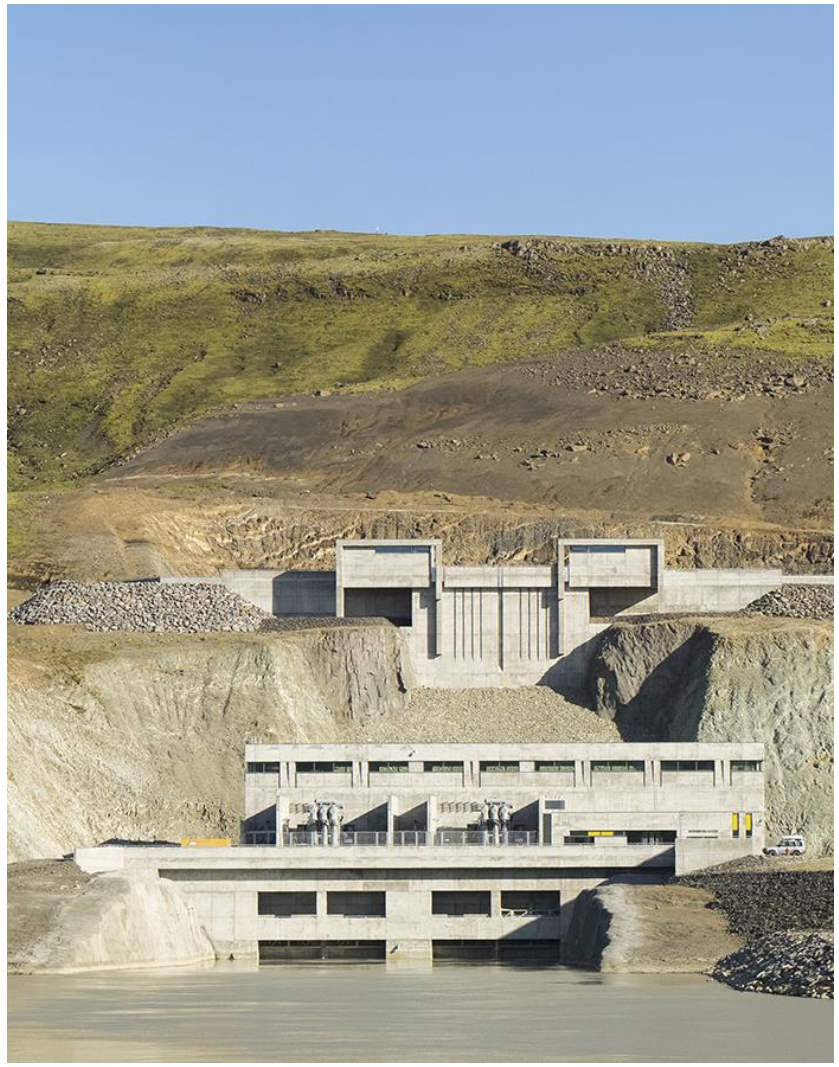
Founded in 1965 to generate electricity for power intensive industry

- Owned by the State and City of Reykjavik
- Equity from 3 hydro plants in river Sog and water rights in river Þjórsá
- Financing from the World Bank
- To provide the 2nd pillar in Iceland's economy (after fishing)
- 70% of power for 3 aluminum smelters (low electricity prices!)
- Power generator and sell only wholesale (>1 GWhr/year)

First projects built with international funding and know-how

- Búrfell Hydro Plant, 270 MW (1972)
- Sigalda Hydro Plant, 150 MW (1975)
- Hrauneyjarfoss, 210 MW (1979)

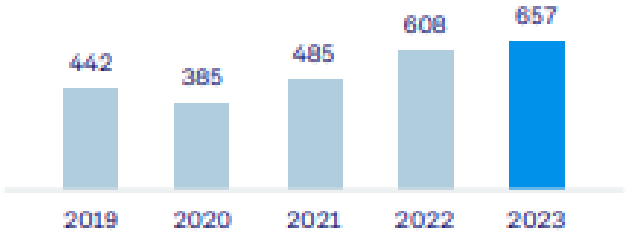
Since 1980's, building own power plants and exporting know-how



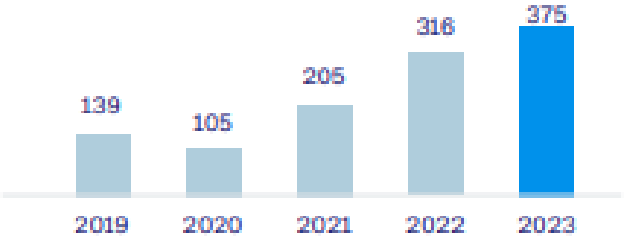
Financially strong

Key figures

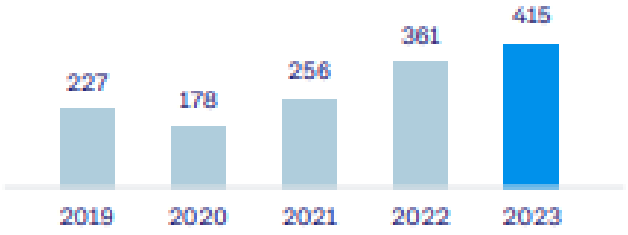
Operating revenues



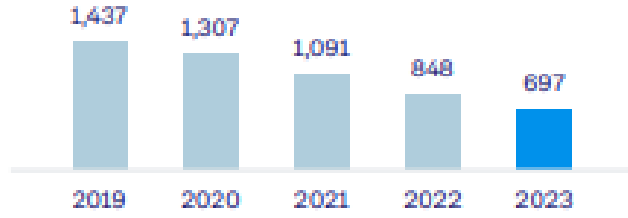
Profit before unrealised financial items



Cash flow from operating activities



Net debt



Landsvirkjun‘s Geothermal

Bjarnarflag, 1967/1969, 50 MW_{th} and 3 MW_e

Krafla, 1977/1997, 60 MW_e

Þeistareykir

High temperature geothermal field in NE-Iceland

- 30-50 km2
- Max. borehole temperature 380°C
- Capacity estimated up to 180 MW

Phase development

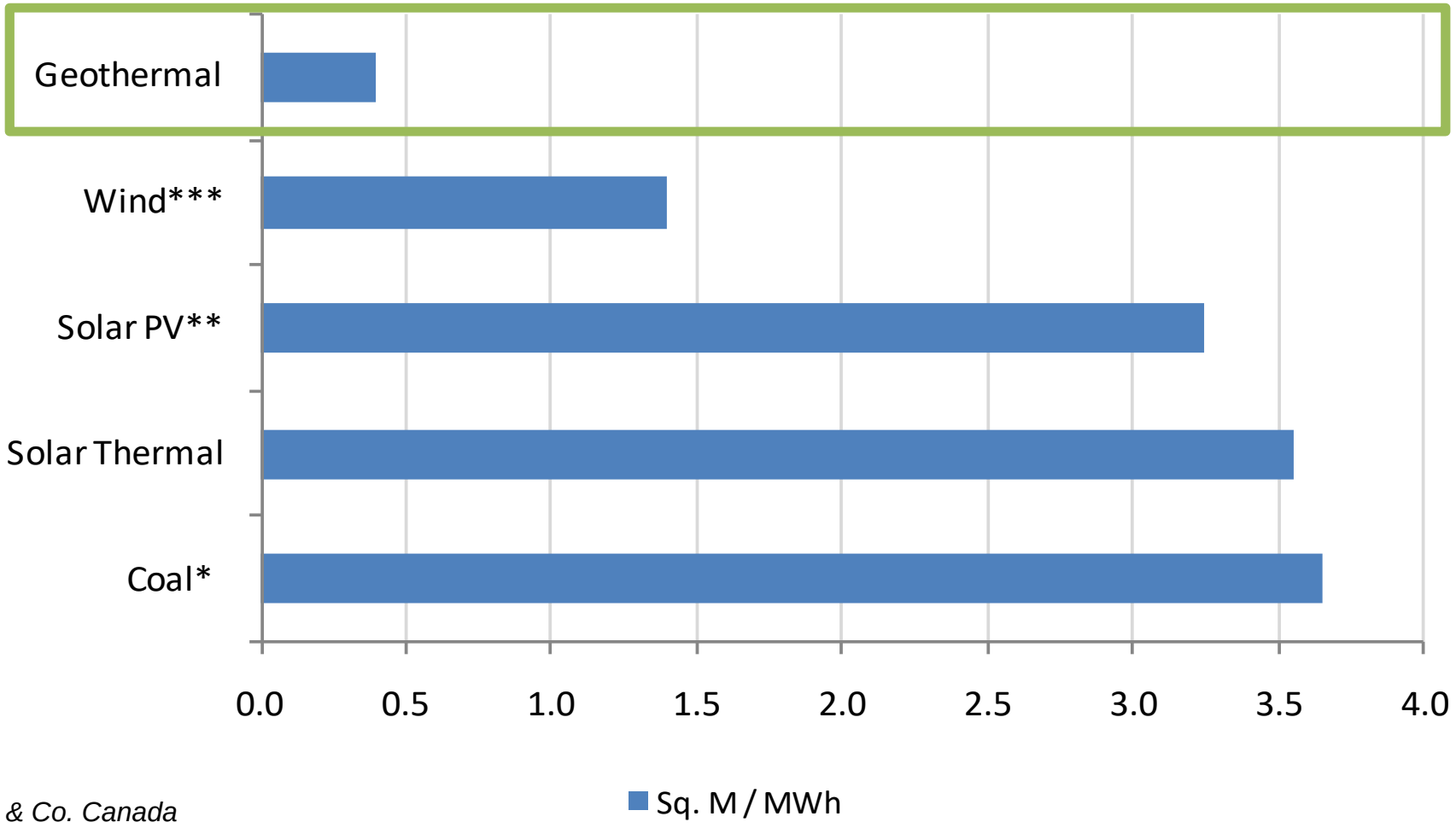
- Phase I: 45 MW online October 2017
- Phase II: 45 MW online April 2018
- Phase III: 45 MW construction likely 2025-2028
- Phase IV will be decided on later (depending on resource & demand)
- Optimisation: 25 MW, possible 2025-2027

Geothermal Project Development

Advantages of Geothermal?

Renewable Energy Challenges	Geothermal Advantages	
Intermittent Yield	***Base-Load Power***	Operates at 95%+ capacity factor or “up-time” and can provide baseload for a power system - a rarity for a renewable power source
High System Cost	***Low System Cost***	On a least-cost development planning basis, geothermal is typically cost-competitive with coal, natural gas, and hydro, and while more expensive per kWh does not have the storage costs associated with solar and wind
Large-Scale Land Needs	***Small Geographic Footprint***	Lowest land use per MW of any renewable energy source, and minimal environmental impact compared, for example, to large scale hydro
Evolving Technologies	***Mature Technology***	Well-proven steam power generation technology - the first geothermal plant built in 1904 still in operation today (Lardarello, Italy). While solar and wind are well established, storage and other renewables are still evolving.
Limited Off-Shoot Industry Potential	***High Off-Shoot Industry Potential***	In most countries with geothermal development various off-shoot industries have developed, e.g. spas & tourism, food processing, district cooling and industrial heating

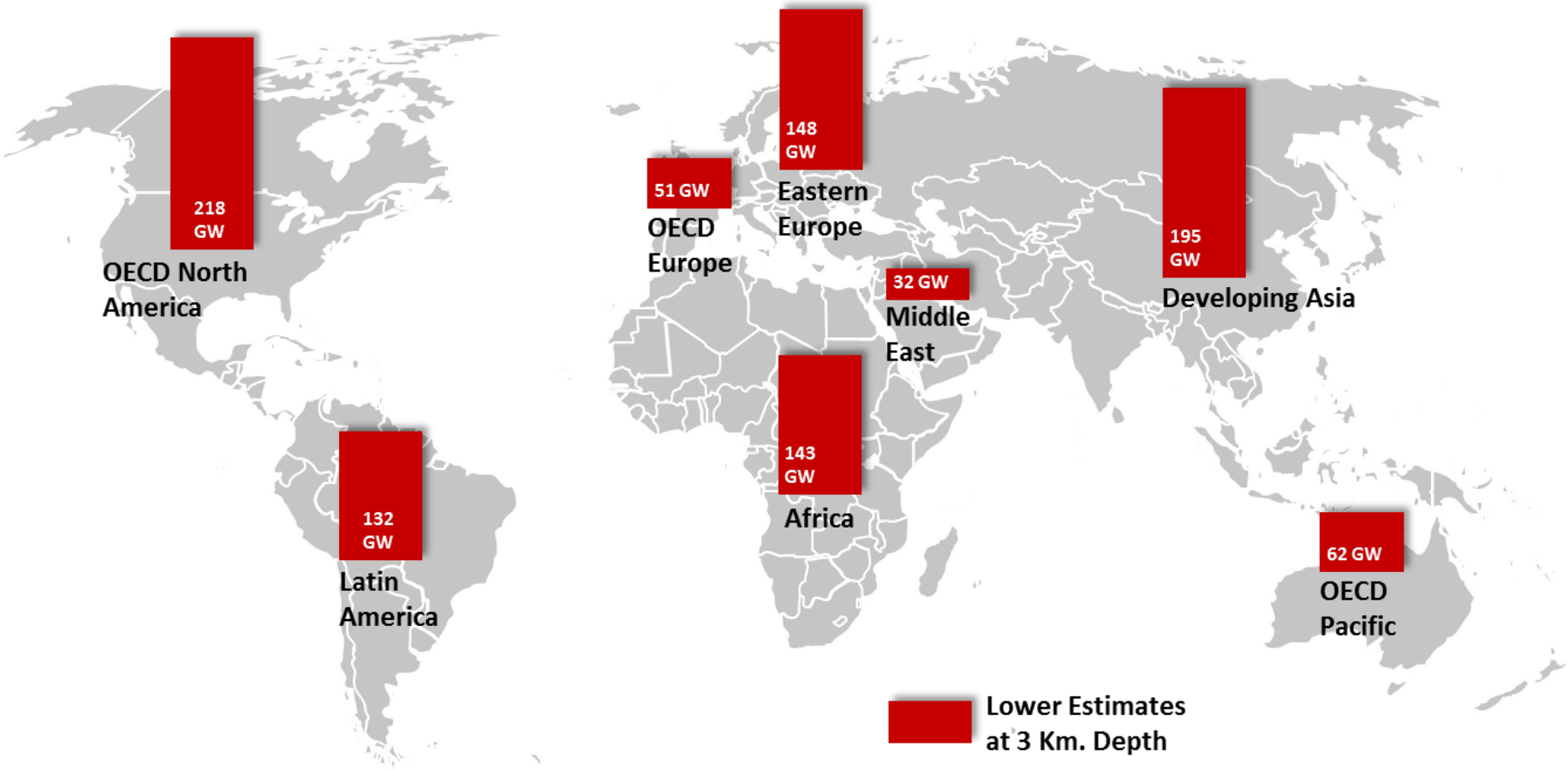
Land use per MWhr



Source: Jacob & Co. Canada

>99% of geothermal resources still to be utilised

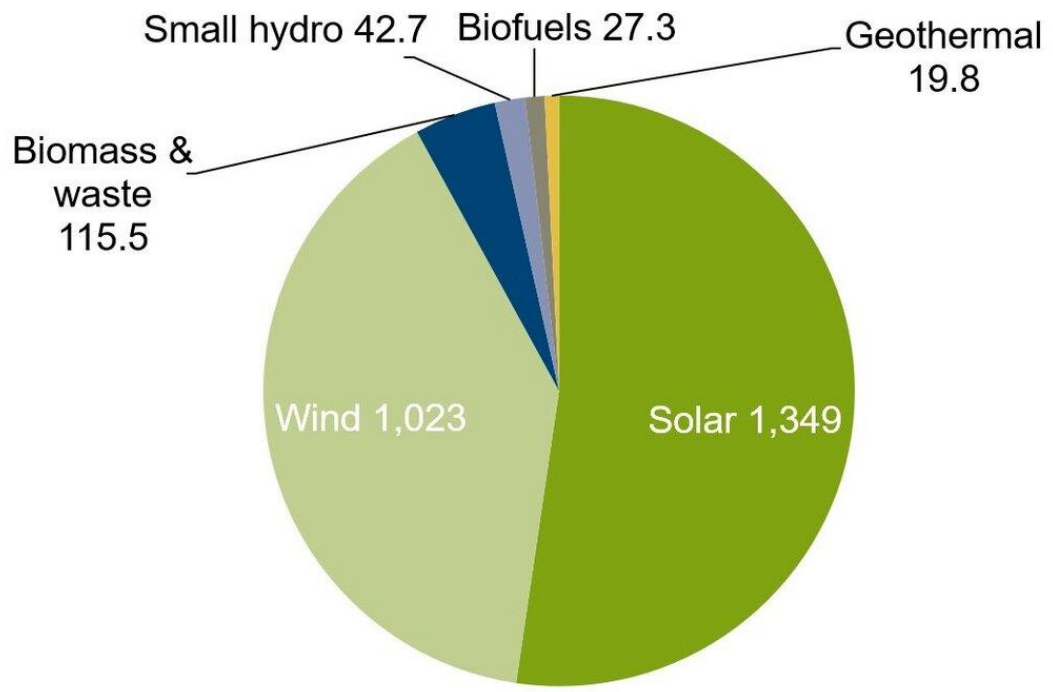
INTERNATIONAL PANEL ON CLIMATE CHANGE: WORLD GEOTHERMAL TECHNICAL POTENTIAL IN 2013 (GW)[1]



1) Global Geothermal Technical Potential Map (in GW) with lower estimates. (Here without Enhanced Geothermal Systems Potential). With capacity factor 90%.
Source: Intergovernmental Panel on Climate Change IPCC 2012 and calculations of Icelandic Geological Survey - ISOR January 2012.

Why not more investment in geothermal?

Figure 1: Global renewable energy capacity investment over the decade, 2010-2019, $bn

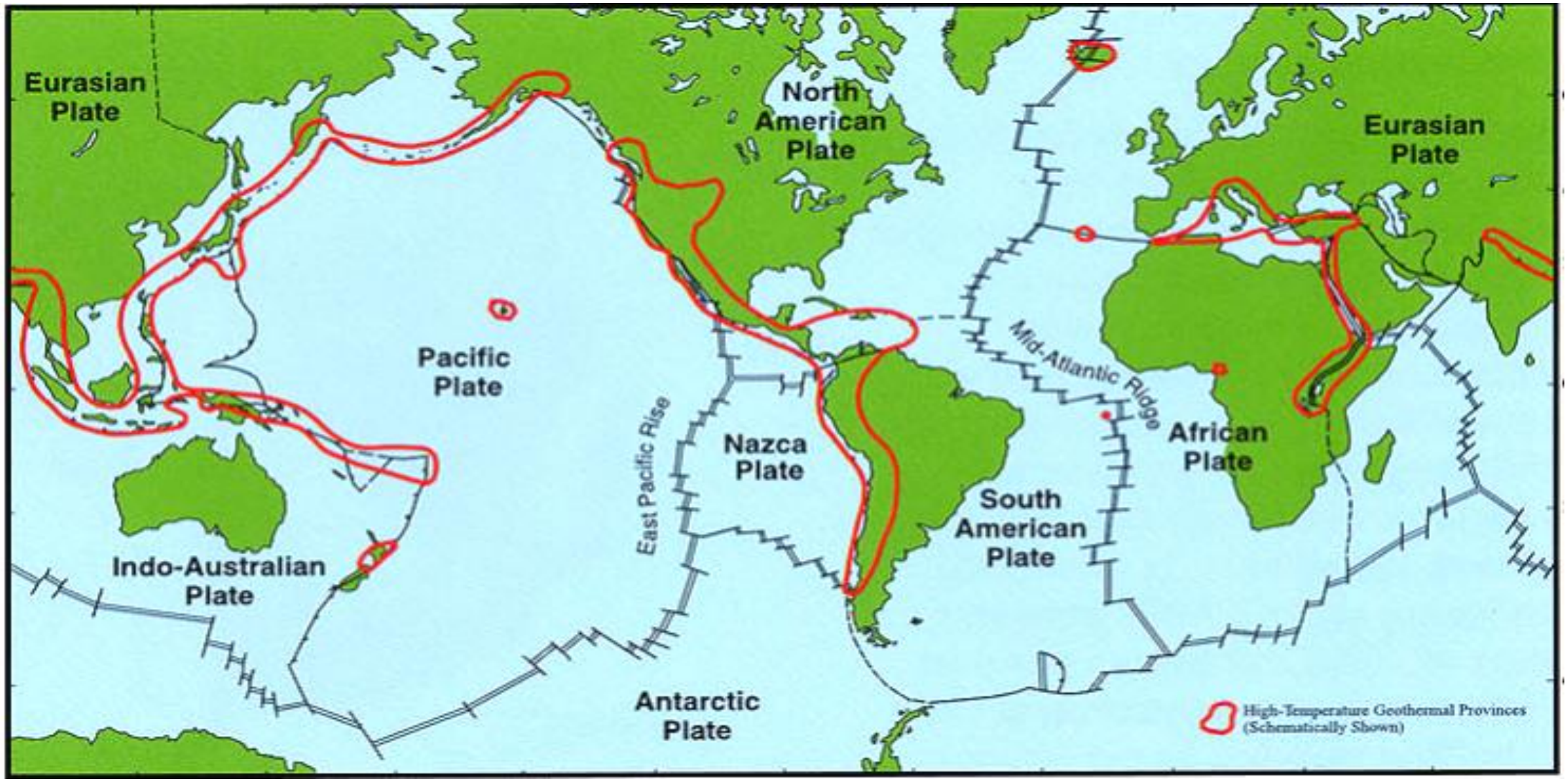


Footnote: Includes an estimate for 2019, based partly on provisional first-half data.
Source: Frankfurt School-UNEP Centre/BNEF (2019), Global Trends in Renewable Energy Investment 2019

My opinion:

- It is complicated!
  - We need more talented and experienced geoscientists and engineers
- It sounds too complicated!
  - We, engineers and geoscientists, need to learn how to present geothermal risk and reward to managers, investors and policy makers in a language they understand

Where is potential for HT Geothermal?



The Path to Big Investment Decisions

1. **Desktop Phase**
   - Screening of options
   - Brief engineering and economic evaluation
2. **Research Phase**
   - Investment study, start working on rights etc.
   - The project goes public (reputational risk starts)
3. **Feasibility Phase**
   - Full engineering, securing rights, permitting etc.
   - Investment Decision
4. **Tendering & Construction**

Port of Rotterdam NL

Golden Gate Bridge, California

Hoover Dam, Nevada

Heathrow Airport, Terminal 5

We use „stage gate process“

Reconnaissance	Pre-Feasibility	Feasibility	Project Design	Construction	Operation
• Desktop Study • Surface Exploration – Phase I (geology, geochemistry, geophysics) • Exploration Report	• Exploration Program • Exploration / Appraisal Drilling • Reservoir Assessment • Pre-Feasibility Report	• Confirmation Drilling • Reservoir Engineering • Feasibility Study • Value Engineering • Decision to tender	• Tender Design • Tendering and Procurement • Financial Analysis • Decision to construct	• Construction • Project Control and supervision • Commissioning • Hand-over	• Operation • Monitoring • Maintenance • Make-up drilling • Refurbishment • Decision to abandon

Permits – Public Acceptance (political risks) – Energy Markets & Grid

So how do we explore geothermal fields?

First: Identify resrouce

- Geology: Nature and size of field
- Geopysics: Temperature alteration, fractures
- Geochemistry: Signals about temperature and fluid chemistry

⇒ Geothermal model

Next: Proof resource

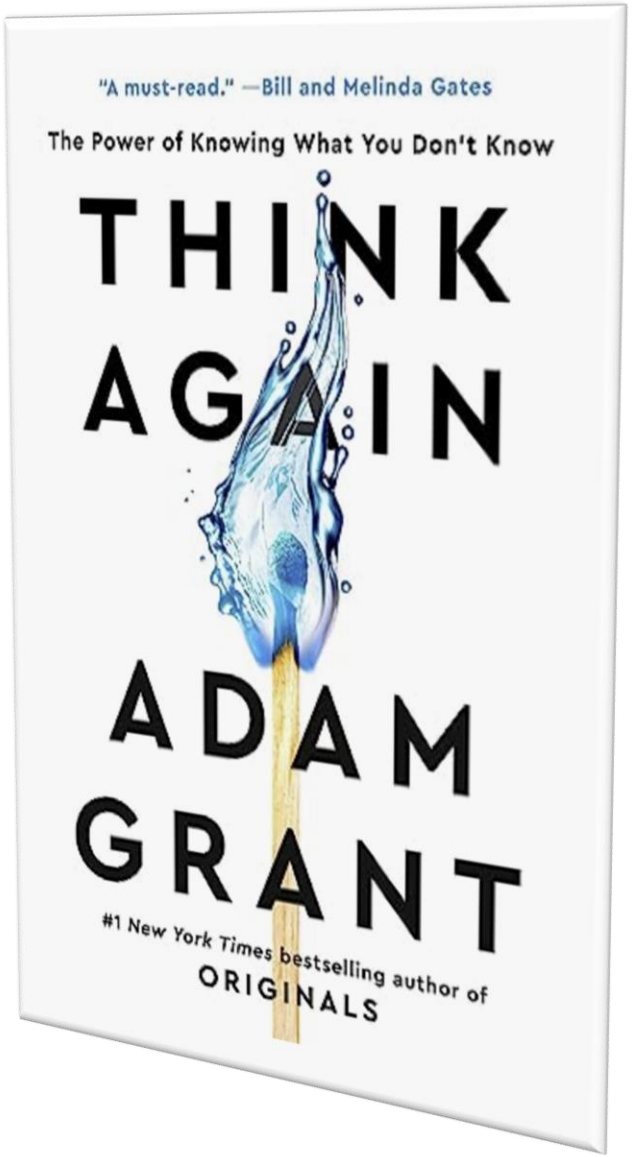
- Drilling and flow testing exploration wells

⇒ Reservoir model and simulation

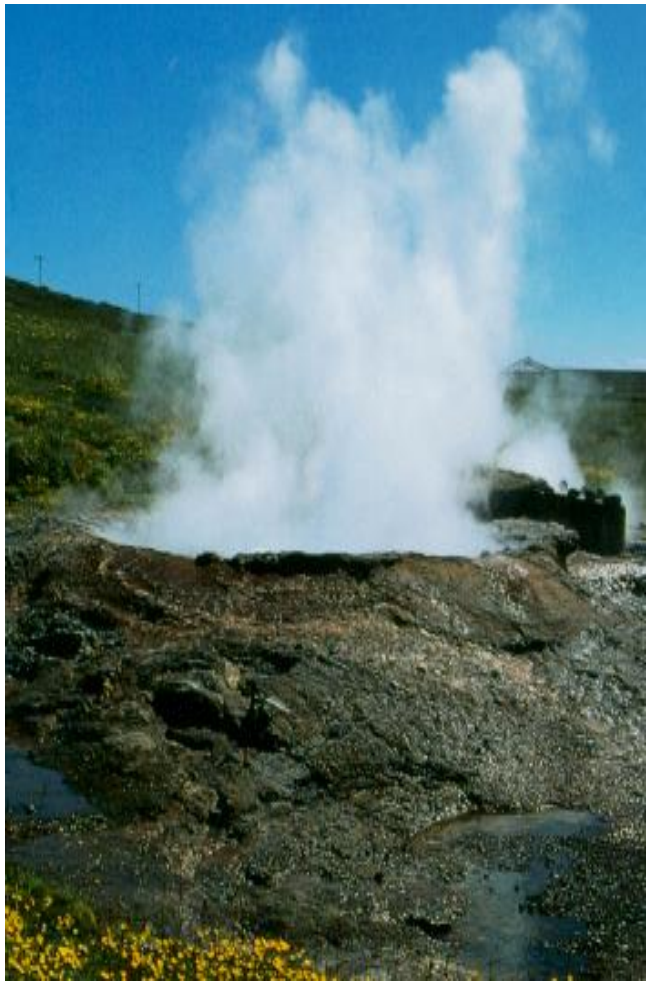
Then: Production drilling

- Each well is treated as a research well

⇒ Continues updating of Geothermal & Reservoir Models



What do we need to develop geothermal resource successfully?



Opportunity
+
Skills
+
Time
+
Money
+
Luck

Dr. Bjarni Pálsson
Director Geothermal Development

My background

Background

Education

- C.Sc. Mechanical & Industrial Engineering, University of Iceland
- M.Sc. & Ph.D. Petroleum Engineering, Heriot-Watt University, UK Scotland

Background & experience

- Worked in various geothermal projects in Iceland since 1996, mainly with Landsvirkjun - the national power company of Iceland
- Some international experience through Landsvirkjun Power Ltd. (Italy, Turkey, Kenya, Caribbean, Germany etc.)

Committee Work

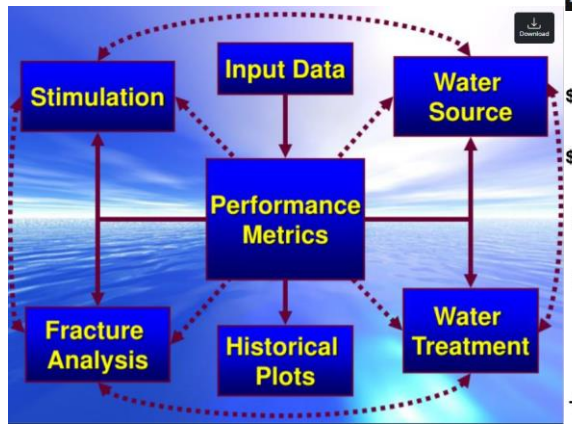
- Board of International Geothermal Association (IGA) 2010-2016 and 2023-2026
- Chair of the World Geothermal Congress 2020 (WGC 2020+1)
- Board of Geothermal Association of Iceland 2008-2014, president 2012-2014
- President Project Management Association of Iceland 2004-2006

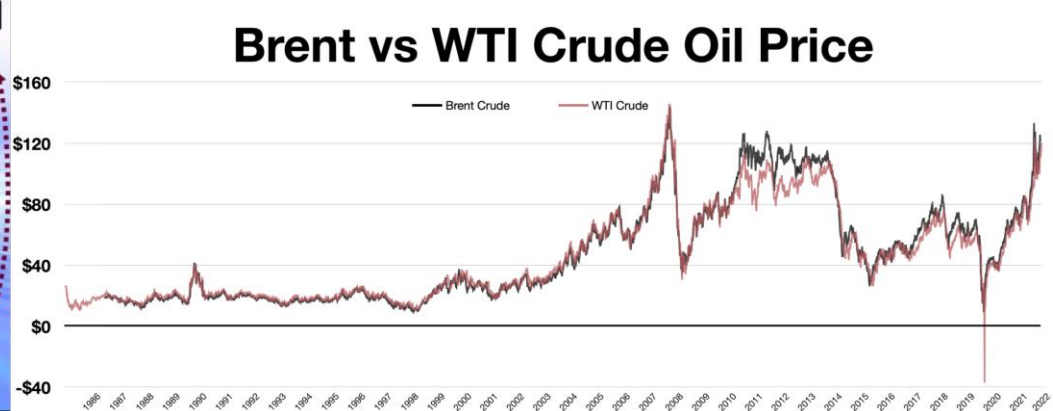
Profile: https://www.linkedin.com/in/bjarni-palsson-08b27a29/

Why Ph.D.?

- Heriot-Watt University Edinburgh - A world class university in one of world‘s most likable cities, not to far away from Iceland
- Oil price reccord low, <$10/bbl
- I almost went to work for BP in Algeria
- Firstborn to be expected
- Offered a unique opportunity to work as project manager, leading a team of 5 Ph.D.s and Post docs at Heriot-Watt on a large multi-national project:

Produced Water Re-Injection JIP



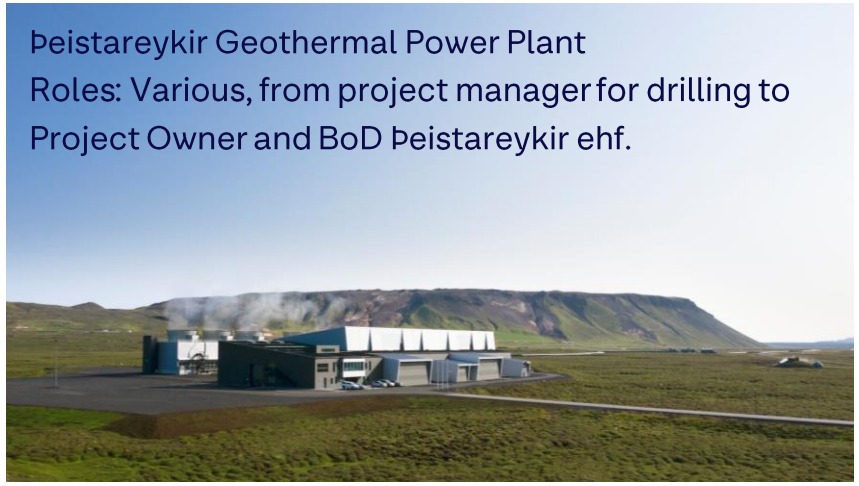


Key resonsibilities for Landsvirkjun

Key responsibilities for Landsvirkjun

- Assistant site manager for extension of the 60 MW Krafla Power Plant, 1996-1997 (VGK/Mannvit)
- Project manager drilling projects, 2002-2009
- Project manager for the Iceland Deep Drilling Project (IDDP) 2007-2011 – Worlds hottest geothermal production well, > 450°C
- Project Manager for the preparation of several power projects from 2002-2011:
- 150 MW of Krafla Power Project (Extension, still feasibility stage)
- 90 MW Bjarnarflag Power Project (New, still feasibility stage)
- 180 MW Þeistareykir Power Project (Under construction)
- 135 MW Hágöngur geothermal projects (Early exploration)
- Manager power projects department, 2011-2015
- Geothermal, hydro power and wind energy
- Manager Geothermal Department, 2015-2018 and Geothermal and Wind Department 2018-2021
- Development of new geothermal projects and plant optimisation (exploration & drilling, permits, feasibility etc.)
- Steam supply and geothermal exploration for operation and construction projects (drilling, geosciences, environment)
- Executive Director Geothermal Development, since 2021

The highlights…



More highlights...

First windpark in Iceland
Role: Project Owner 2011-2018

Búrfell II Hydro Project
Role: Project Owner, preparation 2011-2016

Krafla Magma Testbed
Roles: Project Owner from start

Gufustöðin Geothermal Power Plant, renewal
Roles: Project Owner in planning

Personal life...

Family: A married father of 3 children

- Wife: Unnur HR Manager for the Icelandic Tax Office
- Children: Kristján Frosti (25), Álfheiður (20), Páll Theodór (16)

Hobbies:

- Family
- Football
- Outdoor activities
- Travel
- Reading

Background

- Son of teachers
- Three sisters
- Born in Breiðholt in Reykjavik

Personal motivation

Keep Connection between industry and academia

- Participate in World Class R&D projects like IMPROVE, KMT and others
- Teach in GRÓ-Geothermal Training Program (UNESCO)
- Adjunct in Reykjavik University, School of Energy
- Take summer intern every summer

Networking

- Participate in Conferences and Events
- Maintain extensive knowledge network (1800 followers on LinkedIN)
- Participate in Societies

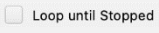
Always driving to be better as a professional and as a person!

Notkunarleiðbeiningar

Myndefni

Til að hlaða inn mynd á skilgreindan myndflöt í sniðmátinu skal smella á takkann með merki fyrir mynd.
Upp opnast valgluggi þar sem finna skal viðeigandi skrá og ýta á Insert.

Einnig er hægt að smella á myndina og þar velja Change picture > From a File ...



Myndbönd

Til þess að nota myndbandsklippur er hægt að sækja klippur frá brandportal.landsvirkjun.is og draga þær inn á glæruna. Mikilvægt er að setja myndbandið aftast með því að smella á Picture format > Senda Backwards.
Til þess að láta klippuna spilast endalaust þá smelliru á Playback > Loop until Stopped.

Letur

Til þess að textinn birtist réttur í sniðmátinu skal vera búið að sækja leturgerðina LV Sans áður en sniðmátið er opnað. Þegar leturgerðin er sótt í fyrsta sinn gæti þurft að endurræsa tölvuna. Ef ekki er mögulegt að nota þá leturgerð af einhverjum ástæðum skal ávallt nota leturgerðina Arial í staðinn.

Hægt er að sækja letrið inn á brandportal.landsvirkjun.is

Litir

Aðeins má nota þá liti sem eru í „Custom Colors“ rammanum.

Ásýndin okkar hefur ávallt einkennst af bláum tónum. Litirnir eru valdir sérstaklega með það í huga að virka vel á stafrænum miðlum.

Hægt er að sjá litanúmerin inn á brand.landsvirkjun.is

Footer

Sniðmátið er þannig stillt að sjálfkrafa birtist enginn texti á „footer“ svæði glæranna til hliðar við lógóið, nema svæðið sé virkjað sérstaklega.

Til að virkja „footer“ stillingarnar skal velja takkann Header & footer undir flipanum Insert. Þar skal haka við viðeigandi atriði. Þar er auk þess hægt að stimpla inn titil glærukynningar innar (sem er hægt að færa yfir alla kynninguna sjálfkrafa) og kaflaheiti (sem þarf að stilla fyrir hverja glæru) ef valið er að skipta kynningunni niður í kafla

Gröf og töflur

Til eru sniðmát fyrir bæði kökurit og súlurit. Skulu notendur halda sig við þær tvær tegundir eins og hægt er. Til að breyta gildum og breytum í gröfunum skal fyrst smella á grafið, síðan á takkann Edit Data in Excel undir flipanum Chart Design.

Punktar

Til að virkja píluútlitið á punktum í textaboxunum skal ýta á Inndráttar takkann, í staðinn fyrir að smella á punkta takkann eins og venjulega.

Táknmyndir

Táknmyndir má nálgast á yfirlitsglæru inn í sniðmátinu en til að nálgast nýjasta pakkan af táknmyndum má finna þær inn á brandportal.landsvirkjun.is