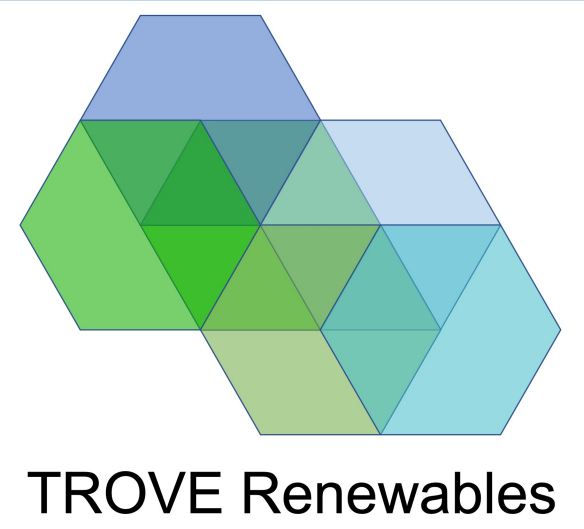


KnowledgeBases

The Global Status of Geothermal energy

Ben Duncan

20th May 2021

Agenda

- Basics / overview
    - Electricity
    - Direct
    - Timeline
- Case studies
- Future
- TROVE Demo

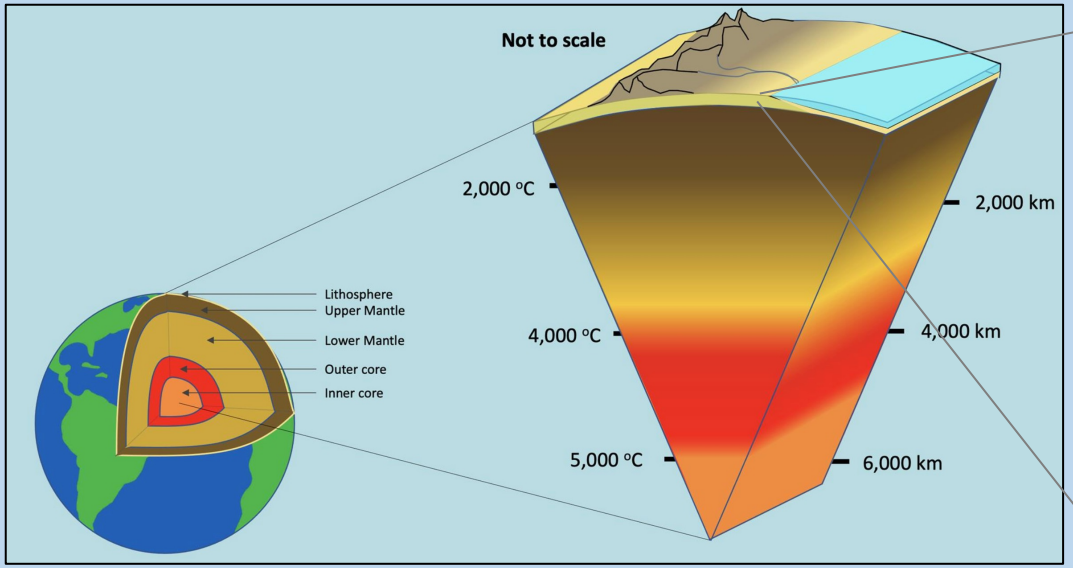
Geothermal Basics

Greek words, geo & therme

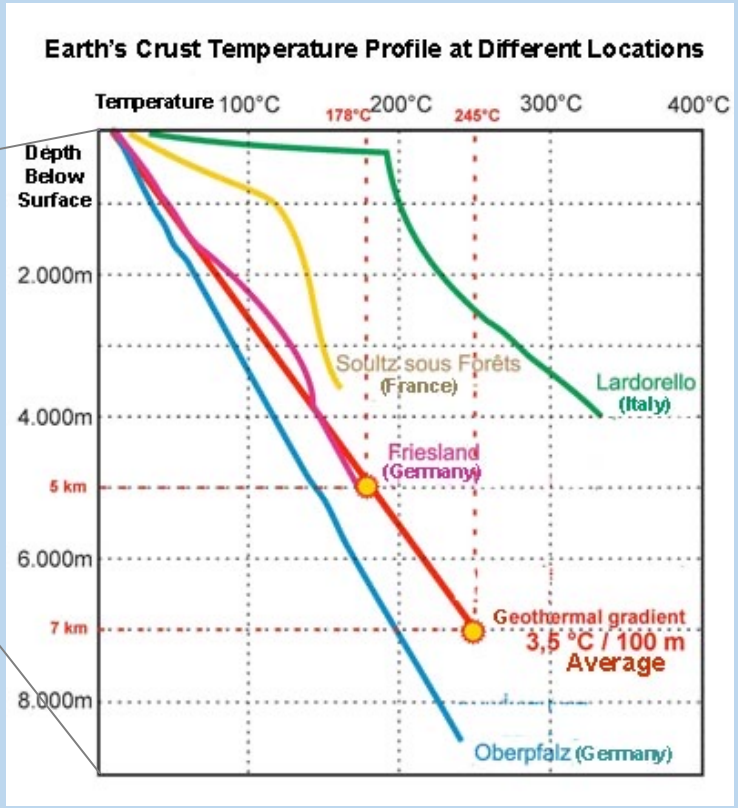
Heat increases with depth
Range of interest: ~10km and ~500 DegC

Radiogenic heat

Sustainable, reliable energy source!



6000 °C



https://i.stack.imgur.com/Gvtw7.jpg

Kilauea, Hawaii

Strokkur, Iceland

The Global Power Potential!

"Geothermal power has considerable potential for growth. The amount of heat within 10km of the earth's surface is estimated to contain 50,000 times more energy than all oil and gas resources worldwide"

Lets talk about energy!

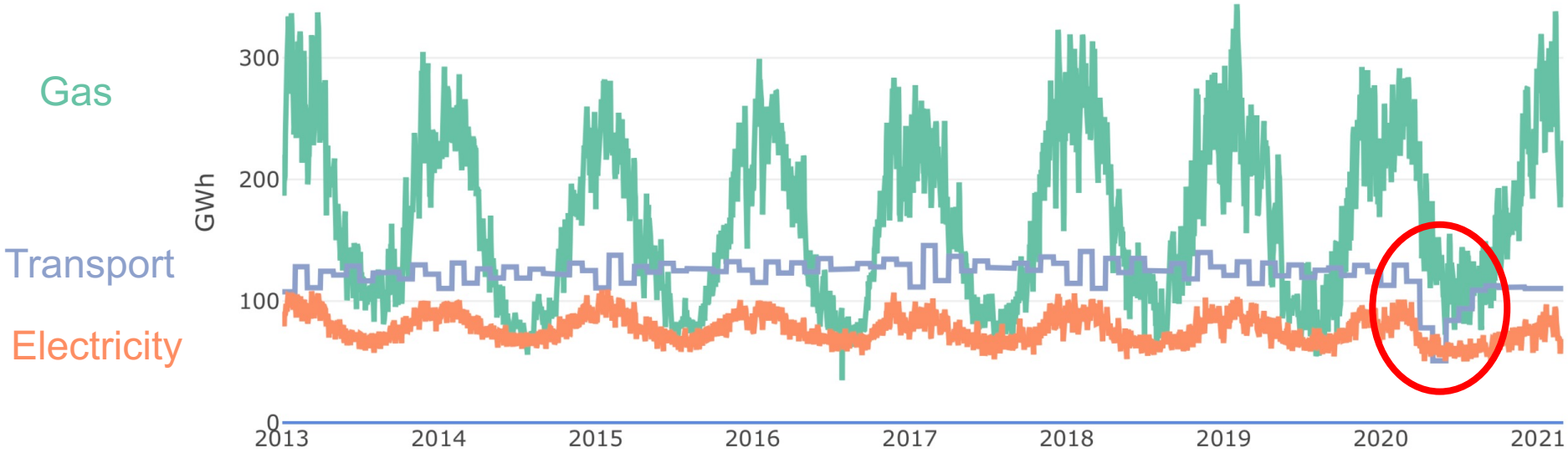
What's powering Scotland?

Renewables met 97% of Scotland's **electricity** demand in 2020!

2030 target is to generate 50% of all **energy** (electricity, heat and transport) from renewables.

2019 was 24% (Iceland is >82%)

Energy use in Scotland



Scottish Energy Statistics Hub

Uses of Geothermal energy

The type and scale of geothermal exploitation depends on the natural resources available

ELECTRICITY GENERATION

Requires high heat resources (>100DegC)

University of Calgary

DIRECT USE (Heating)

- Deep (e.g. sedimentary basins or granites)
- Shallow (almost anywhere!)

Geothermal Electricity

Geothermal Capacity (MWe)

TROVE Renewables

Iceland

Italy

Turkey

USA

Mexico

Kenya

Japan

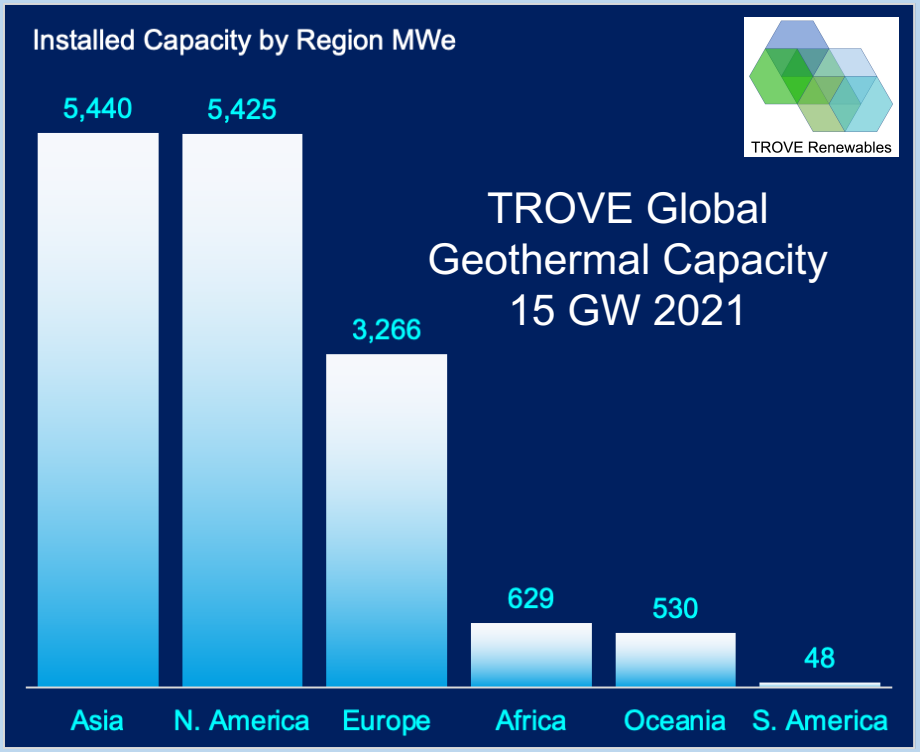
Philippines

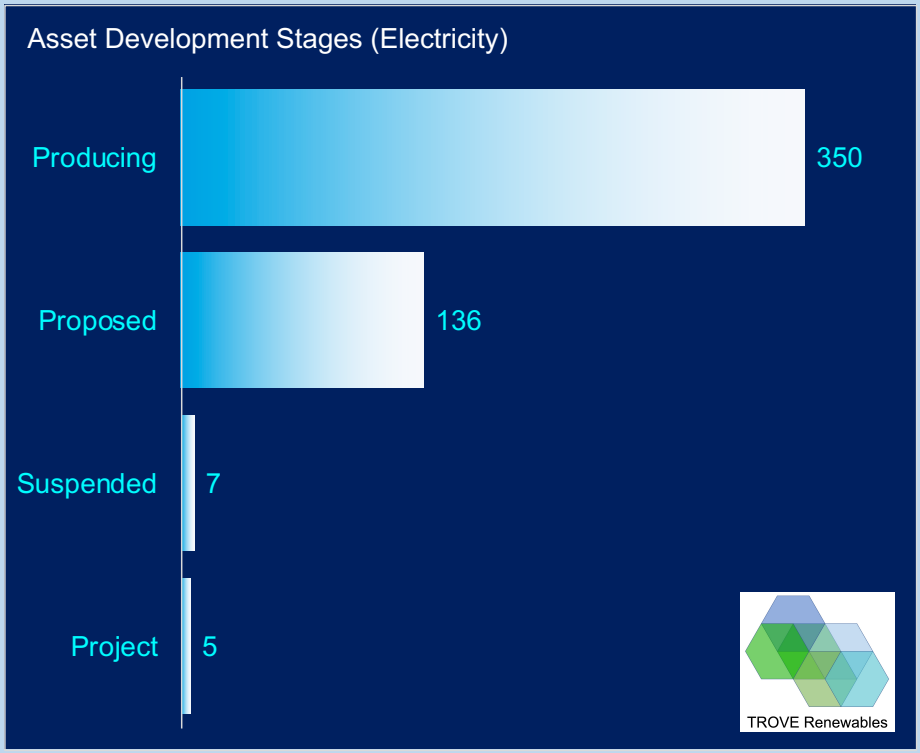
Indonesia

New Zealand

TROVE Geothermal

Aim = all geothermal electricity power plants
Plus an increasing amount of deep heating schemes





Shallow Geothermal (Ground Source Heat Pumps)

Heat exchangers utilising the steady temperature in shallow underground. Can be used almost anywhere!

China is the world lead

Also a si
Fran

The UK ar land currently have highest numbers of new installations in Europe.

TROVE excludes Geothermal <100m

Geothermal Direct Uses

WORLD GEOTHERMAL CONGRESS 2020 REYKJAVIK

Bathing (Everywhere there's hot springs!)

Use	Countries	Leaders / examples
Space heating	29	District: China, Iceland, Turkey, France and Germany Individual:Turkey, Russia, Japan, United States, and Hungary
Greenhouses	32	Turkey, China, Netherlands, Russia and Hungary
Aquaculture	21	China, United States, Iceland, Italy and Israel
Agricultural crop drying	15	Iceland Seaweed, Mexico Timber, El Salvador fruit
Industrial process heat	14	Boric acid production Italy, concrete curing Guatemala, milk pasteurisation Romania
Snow melting	5	Iceland, Japan, Argentina, USA, Slovenia

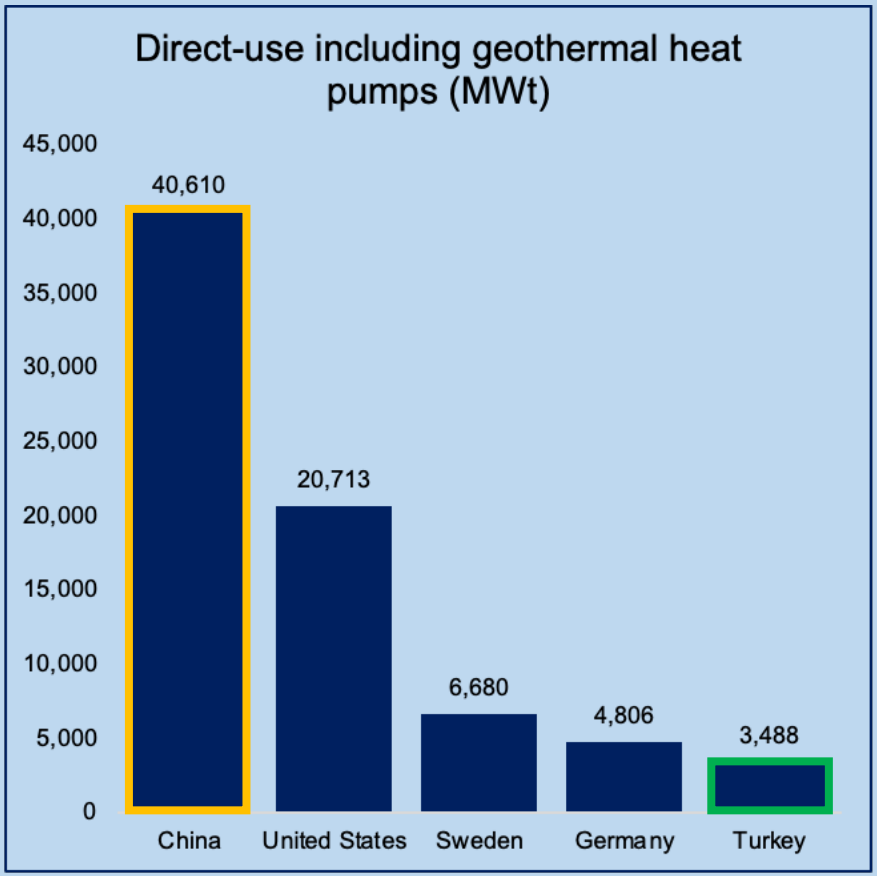
Hoogweg.nl

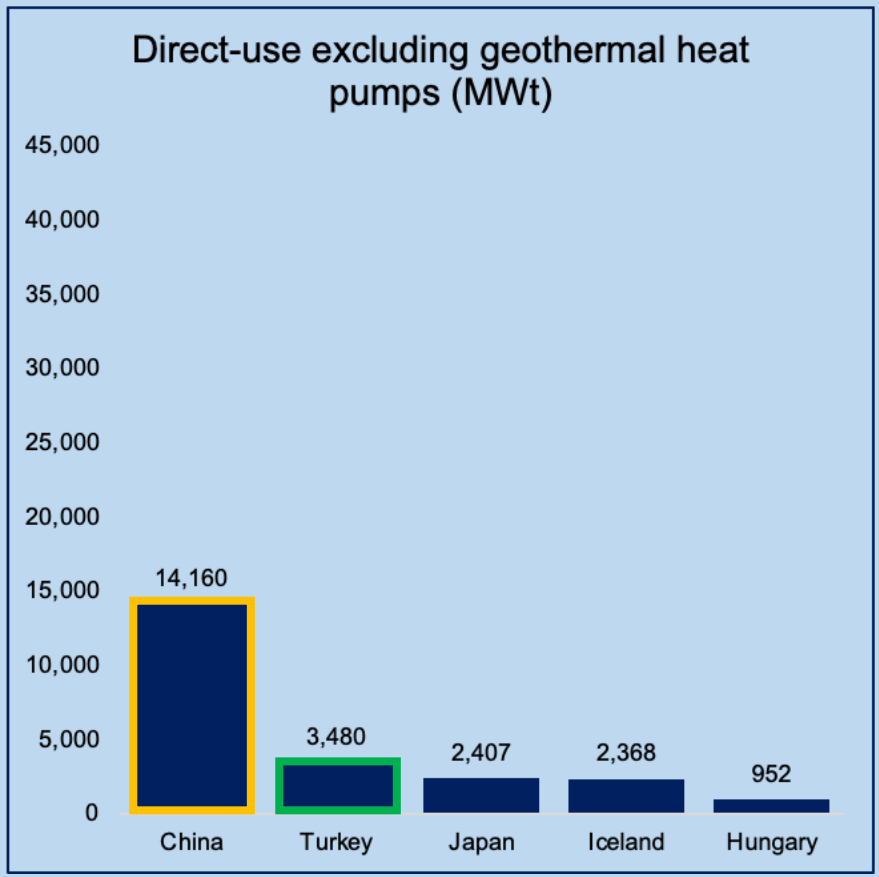
HOOGWEG

Netherlands and Hungary have a large direct use for agricultural.

https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2020/01018.pdf

Direct Use





Iceland is the world leader per capita (7MWt per 1,000 people)

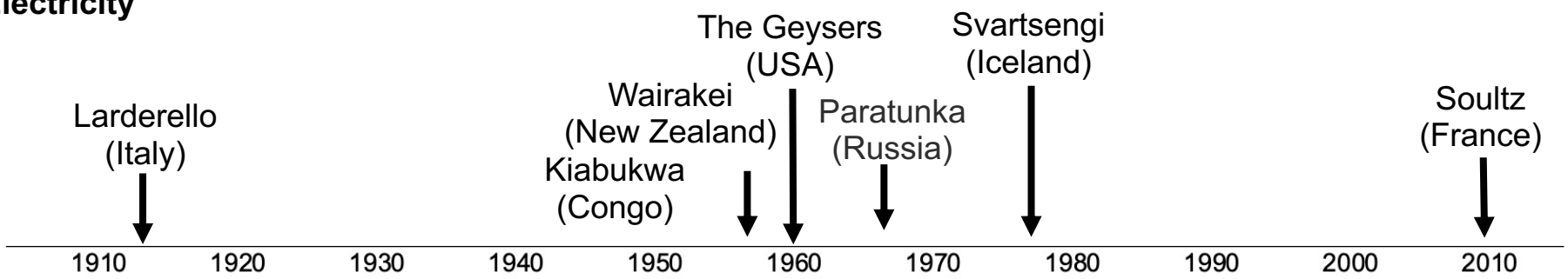
Historic Geothermal Power

Direct use

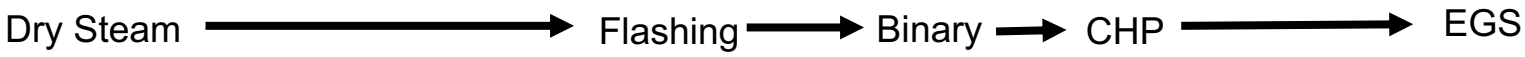
The world's first 'district heating system' was installed at Chaudes-Aigues, France, in the 14th century (Philip VI of Valois). Hot springs located above the village meant wooden pipes and simple taps were all that was needed.

1930 – Reykjavík, Iceland - District Heating System

Electricity



Technology



Sources in TROVE

TROVE Renewables

Case Studies

Case Studies – Larderello, Italy

The worlds first geothermal plant!

Enel Green Power constructed and still run the worlds first geothermal power plant in Tuscany - Larderello

In 1904 the first geothermal dynamo powered a lightbulb

In 1913 the first geothermal power plant came online with a capacity of 250 KWe.

- 2 wells producing fluids at 200 & 250 Deg C

By 1940 Capacity was 130MW

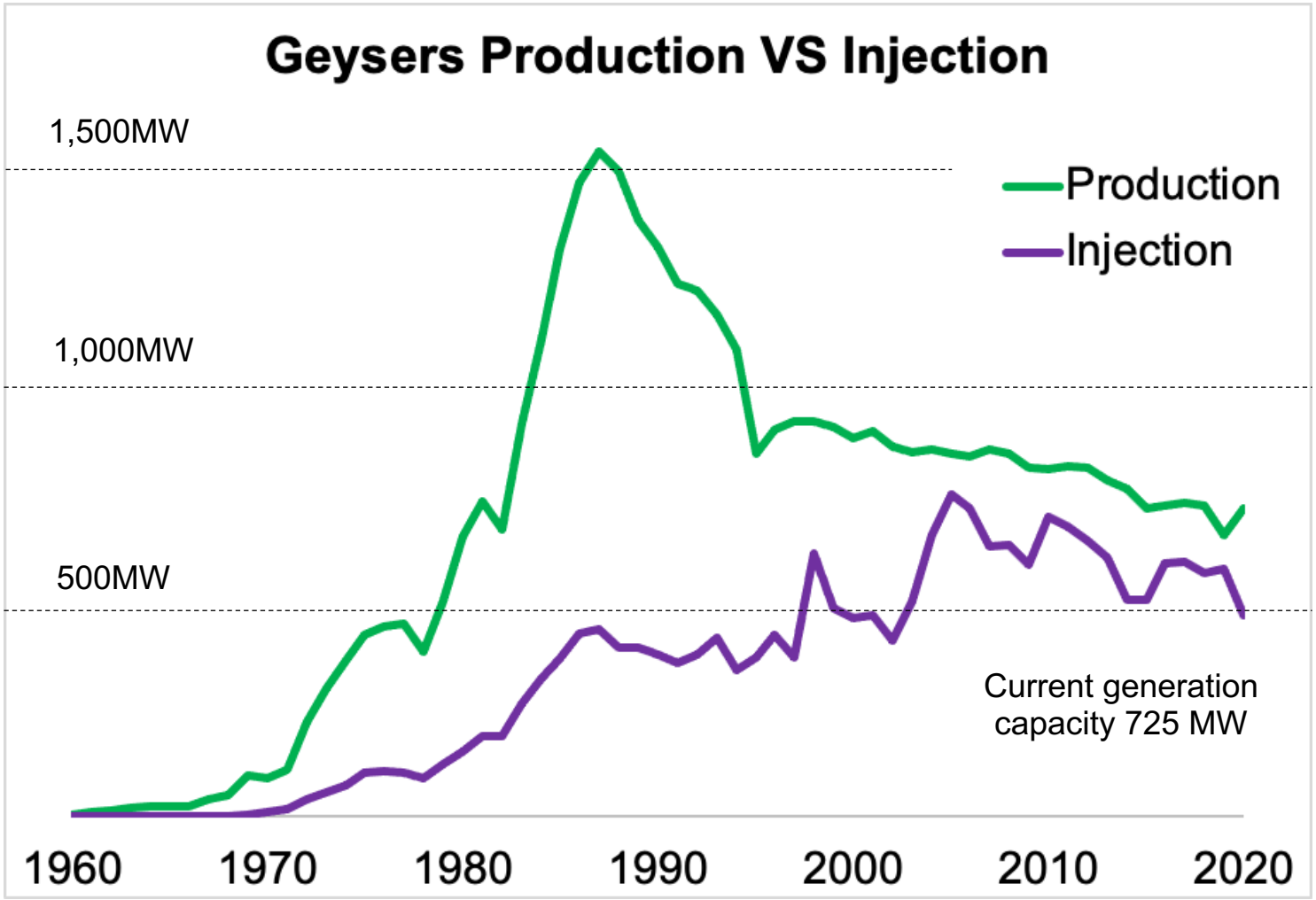
- Powered Italian railway system before WW2

Today the complex capacity is 526MW

- 21 Plants ~180 wells
- ~ 2% of Italy's energy

https://www.power-technology.com/features/oldest-geothermal-plant-larderello/

Case Studies – The Geysers/USA



https://www.nrel.gov/docs/fy21osti/77774.pdf
https://core.ac.uk/download/pdf/205991425.pdf

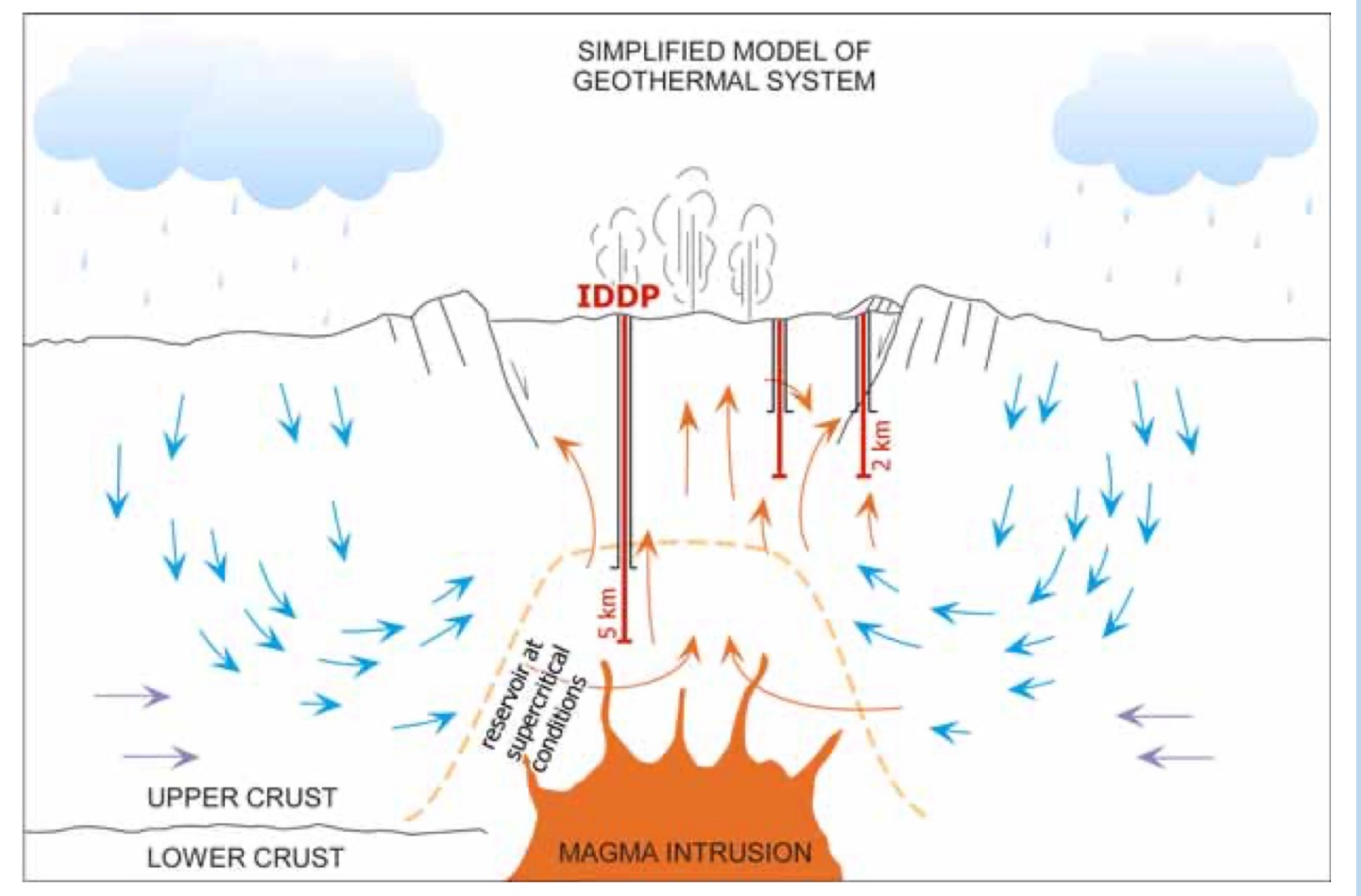
Image from Yellowstone Wyoming – no actual geysers at 'The Geysers' California

Case Studies - Iceland Deep Drilling Project

DEEPEGS GEOTHERMAL

DEPLOYMENT OF DEEP ENHANCED GEOTHERMAL SYSTEMS FOR SUSTAINABLE ENERGY BUSINESS

Reykjanes, IDDP-2 well at the Reykjanes Peninsula in Iceland reached the depth of 4,659 meters 2017.

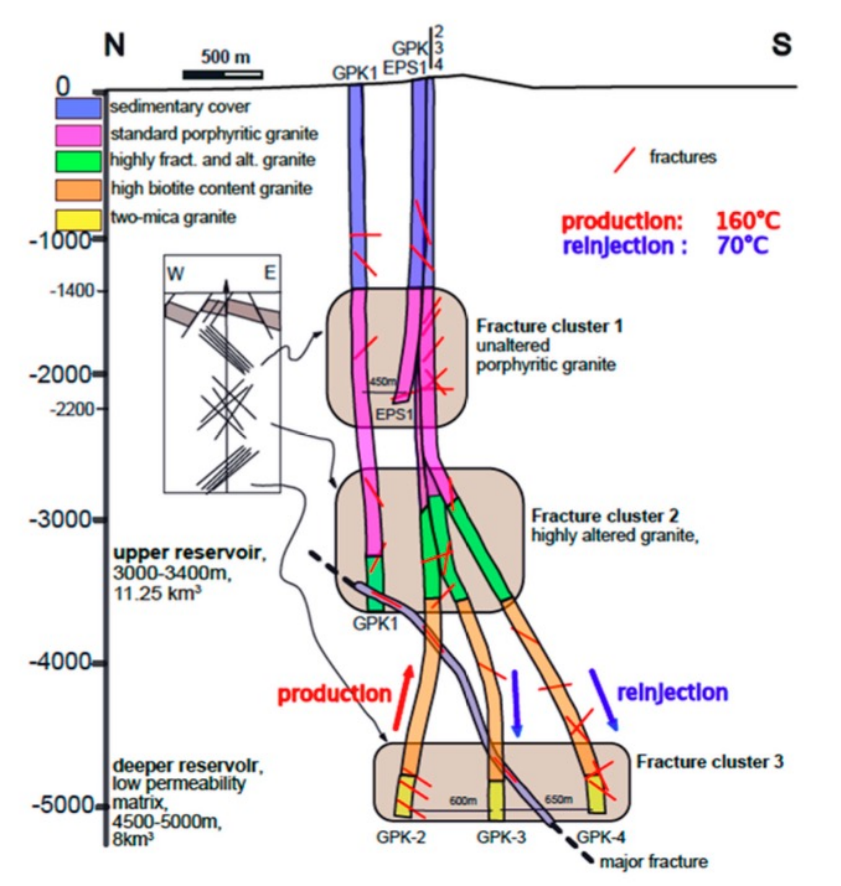


Pétursson 2008

Case Studies – Soultz
Enhanced Geothermal System (EGS)

DEEPEGS GEOTHERMAL

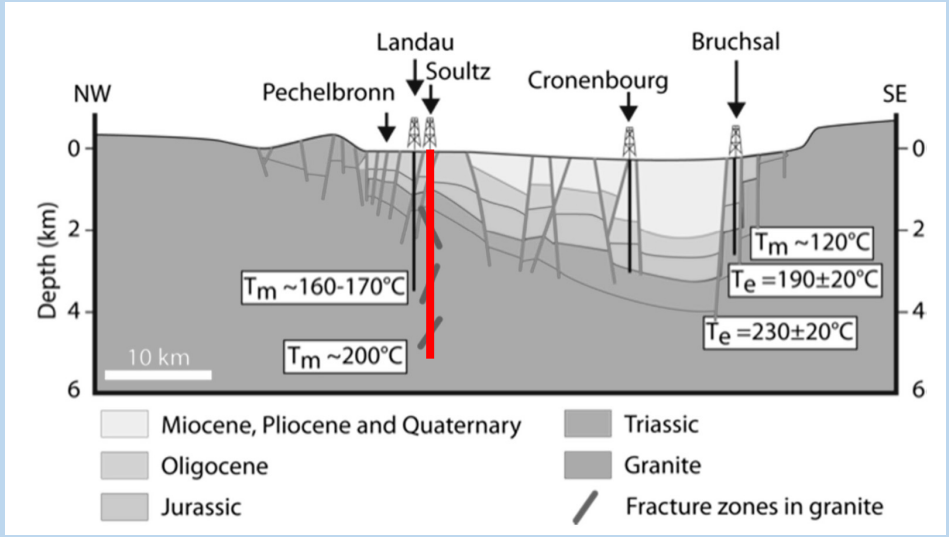
DEPLOYMENT OF DEEP ENHANCED GEOTHERMAL SYSTEMS FOR SUSTAINABLE ENERGY BUSINESS



Pilot European project started in 1987 based around a heat anomaly in French Upper Rhine Graben.

1.5 MW Power plant commissioned in 2010

Now also testing modular small scale ORC (Binary) machines

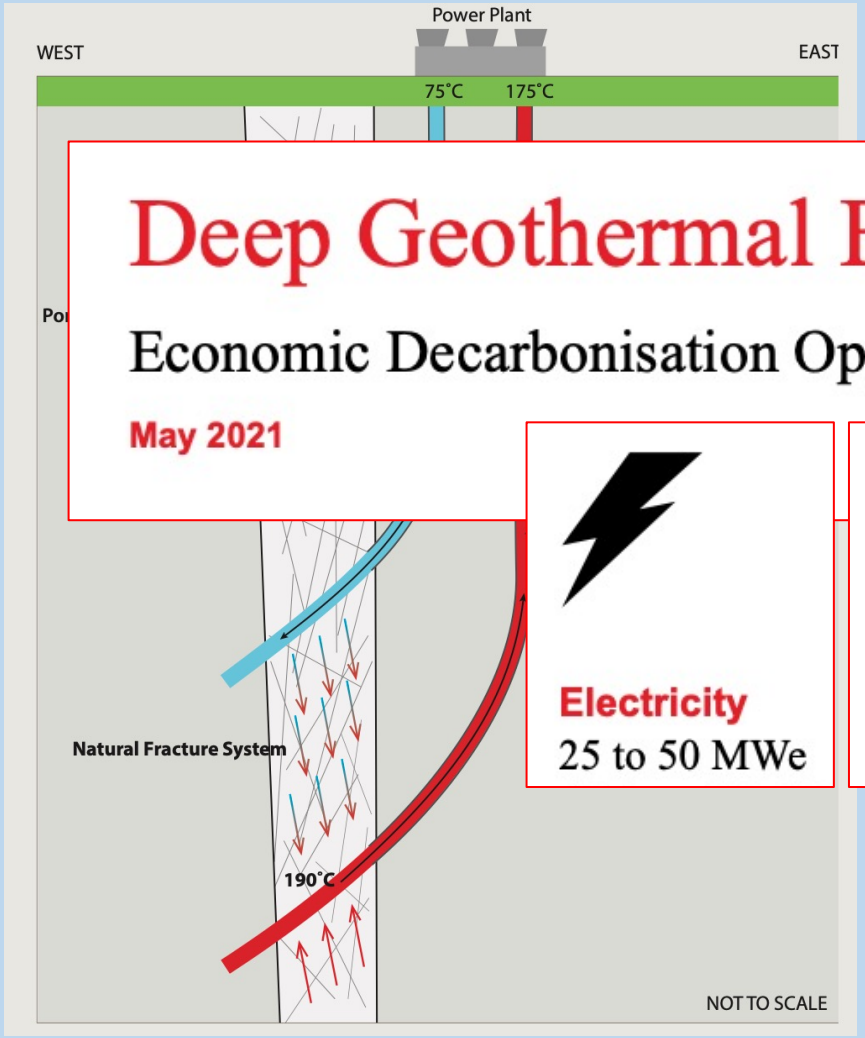


Ledésert & Hébert 2020

Case Studies - Geothermal Power in the UK

Power Purchase Agreement 2021

eden project



Deep Geothermal Energy

ARUP

Economic Decarbonisation Opportunities for the United Kingdom

May 2021

Electricity
25 to 50 MWe

Heat
>3,600 MWth capacity

https://www.geothermaldistillery.com/

GEL Geothermal Engineering Ltd

United Downs Deep Geothermal Power Project

THRIVE RENEWABLES

European Union European Regional Development Fund

CORNWALL COUNCIL

https://learninghub.rpsgroup.com/mod/hvp/view.php?id=3446

https://www.r-e-a.net/wp-content/uploads/2021/05/Deep-Geothermal-Energy-Opportunities-for-the-UK.pdf

Future

The next developments

District heating

Heat Exchangers

Understanding of geothermal resources

Political

Ground Source Heat Pumps (GSHP)

Use of Mine water

Enhanced Geothermal Systems

Advanced drilling techniques

Acid stimulation

Retrofitting wells

Modulation

Re-purposing hydrocarbon wells

Turbines/plants

Direct Lithium extraction

The next developments

Enhanced Geothermal Systems

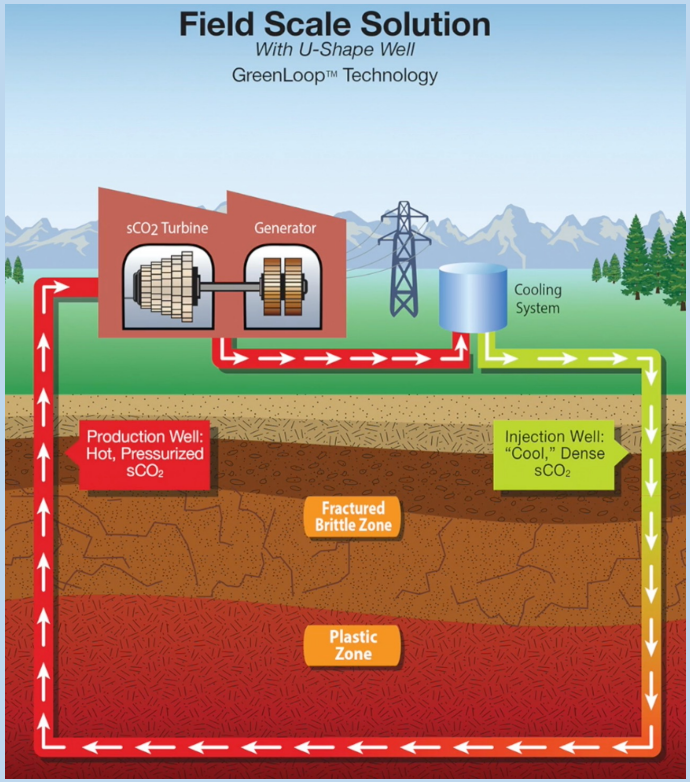
Formerly Hot Dry Rock

EGS involves drilling deeper and fracturing rock to create an artificial circulation system

Advanced Geothermal Systems

(Closed Loop Systems)

Closed Loop Systems



greenfireenergy.com

Closed Loop systems greatly reduces exploration risk because there is no need for subsurface permeability or large volumes of water in the resource.

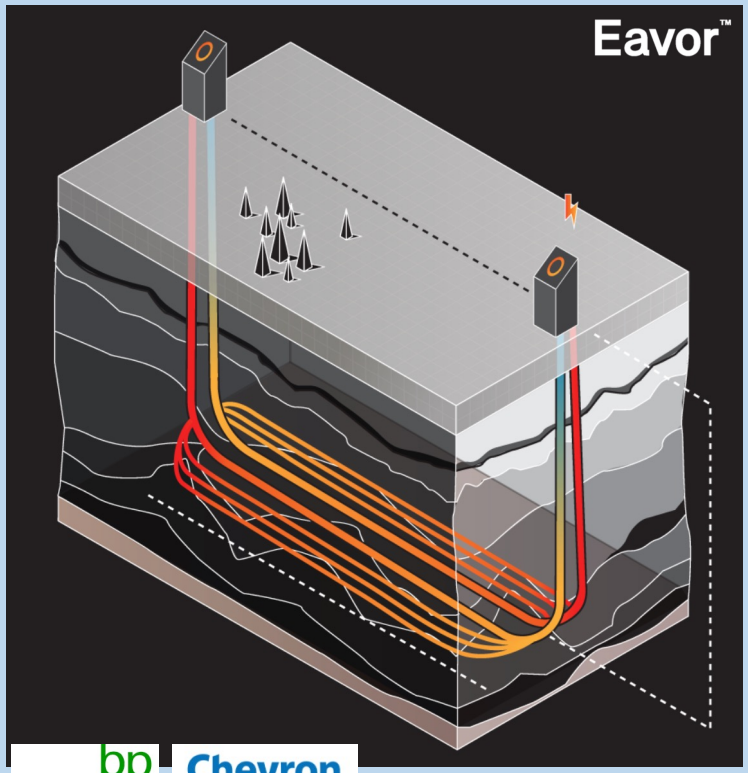
2019 Coso, California, demonstration plant

CeraPhi energy

SAGE GEOSYSTEMS

Rock Energy

CAUSEWAYGT
The Power Beneath Us



eavor.com

bp

Chevron

2021 Germany

Competitive cost of energy

Figure 6.4 LCOE of geothermal power projects by technology and project size, 2007-2021

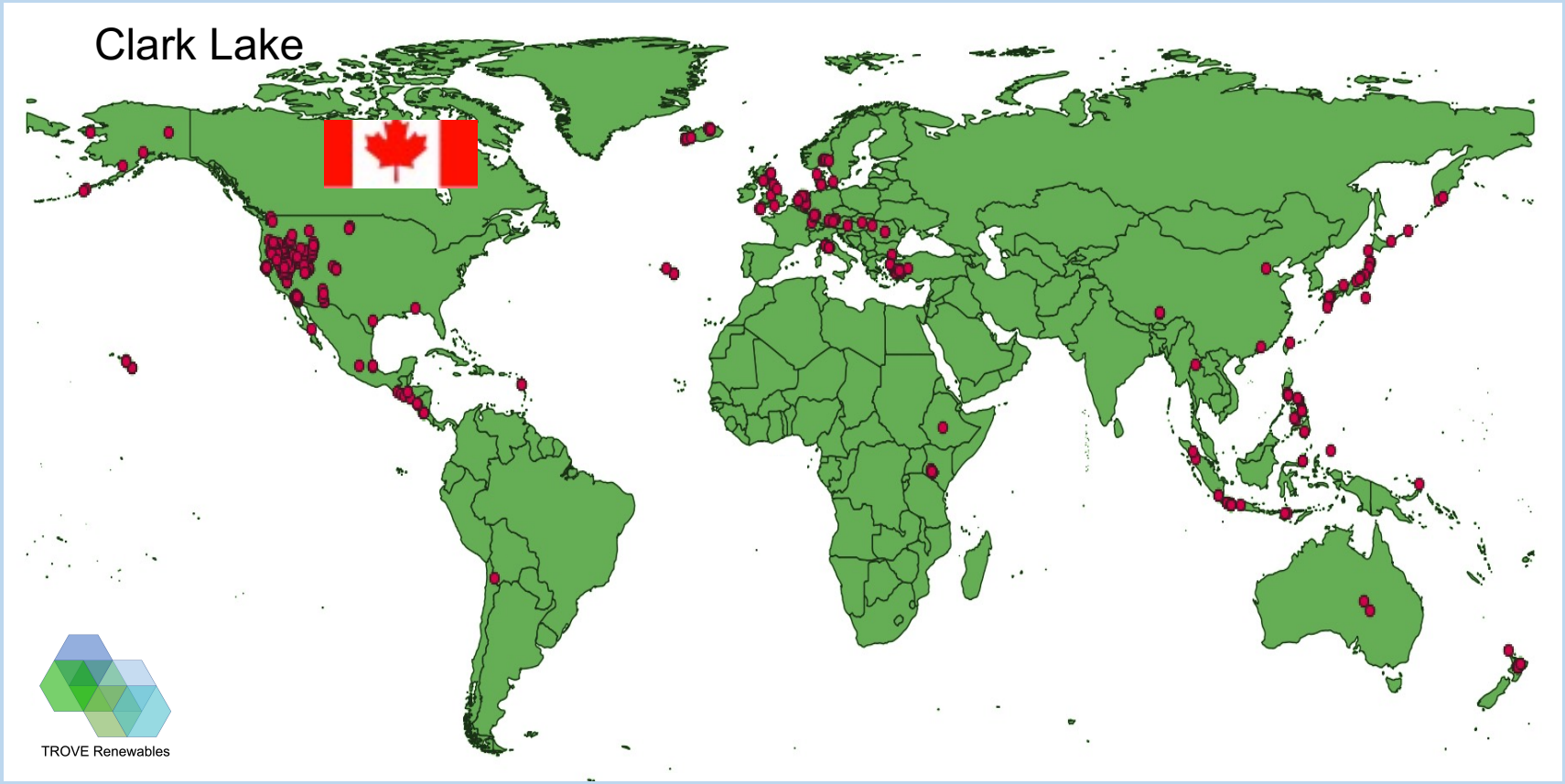
Source: IRENA Renewable Cost Database.

Already competitive in conventional locations.

Need more EGS pilots studies.

What is the future of Geothermal?

A geothermal revolution may be just around the corner!



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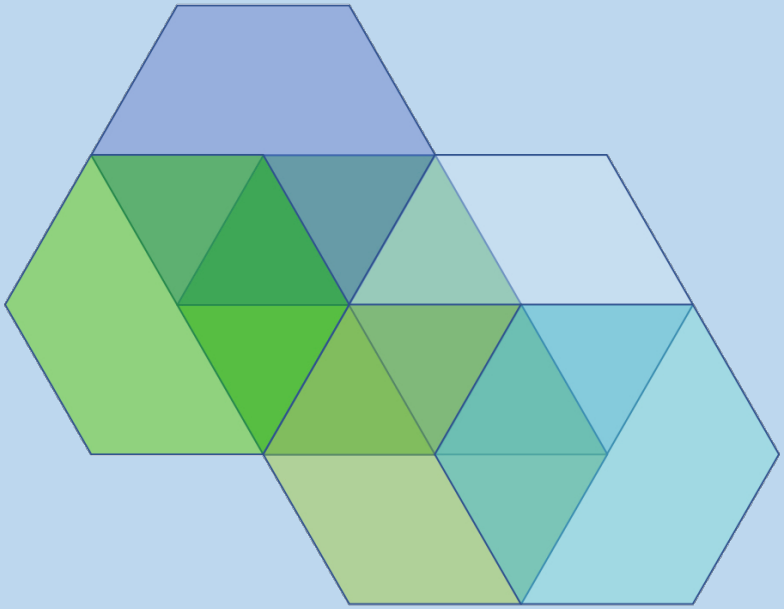

TROVE Renewables

Visit: www.TroveRenewables.com

Email: info@TroveRenewables.com