

Geothermal Industry Overview

Roger Henneberger - Earth Science Manager, GeothermEx

27 November 2018



GeothermEx
A Schlumberger Company



Geothermal Industry Overview

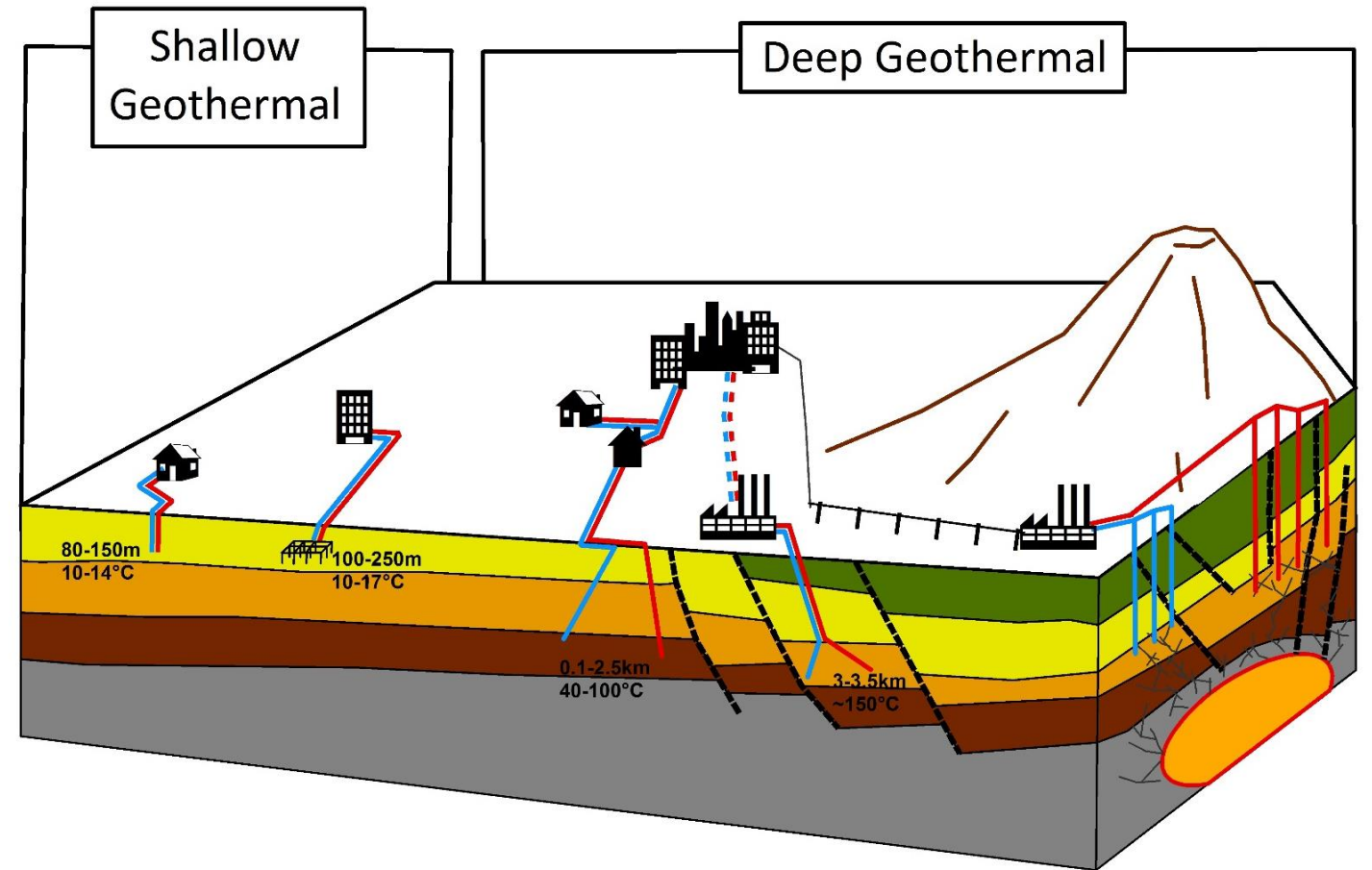
- What is it?
- Where do you find it?
- How much is there?
- Who does it?
- How much does it cost?
- Advantages and disadvantages

© 2018 Schlumberger. All rights reserved.

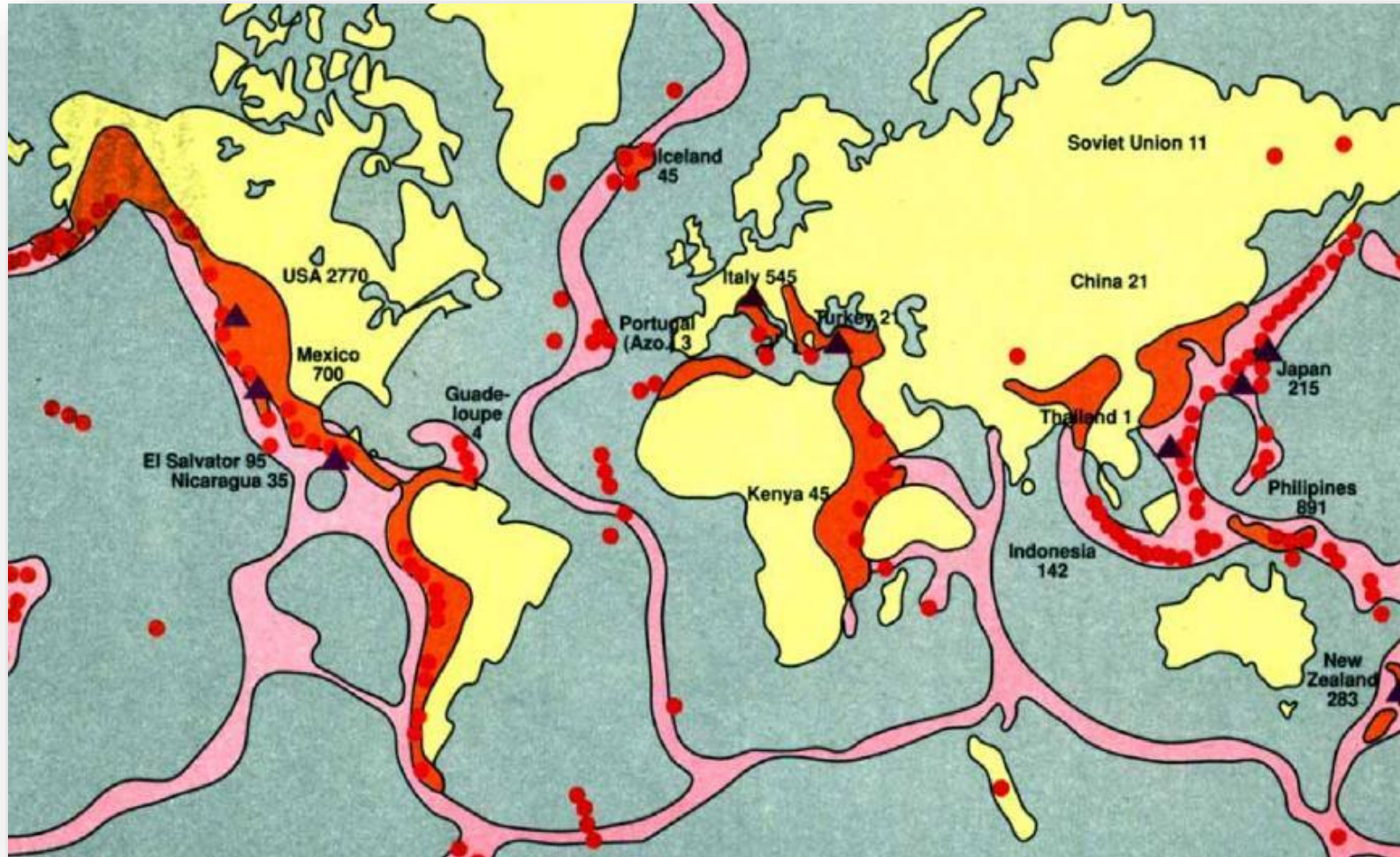
Other company, product, and service names are the properties of their respective owners.

What Is It?

- Shallower / lower-temperature resources more widespread, more suitable for direct use (and ground-source heating)
- Deeper / higher-temperature resource more restricted to volcanic and extensional terranes, suited for electric power generation



Where Do You Find It?



High-temperature geothermal regions

Where Do You Find It?

- Volcanic regions (plate boundaries and “hot spots”)
- Regions with high heat flow (usually tectonically active)
- Sedimentary basins

In 2015:

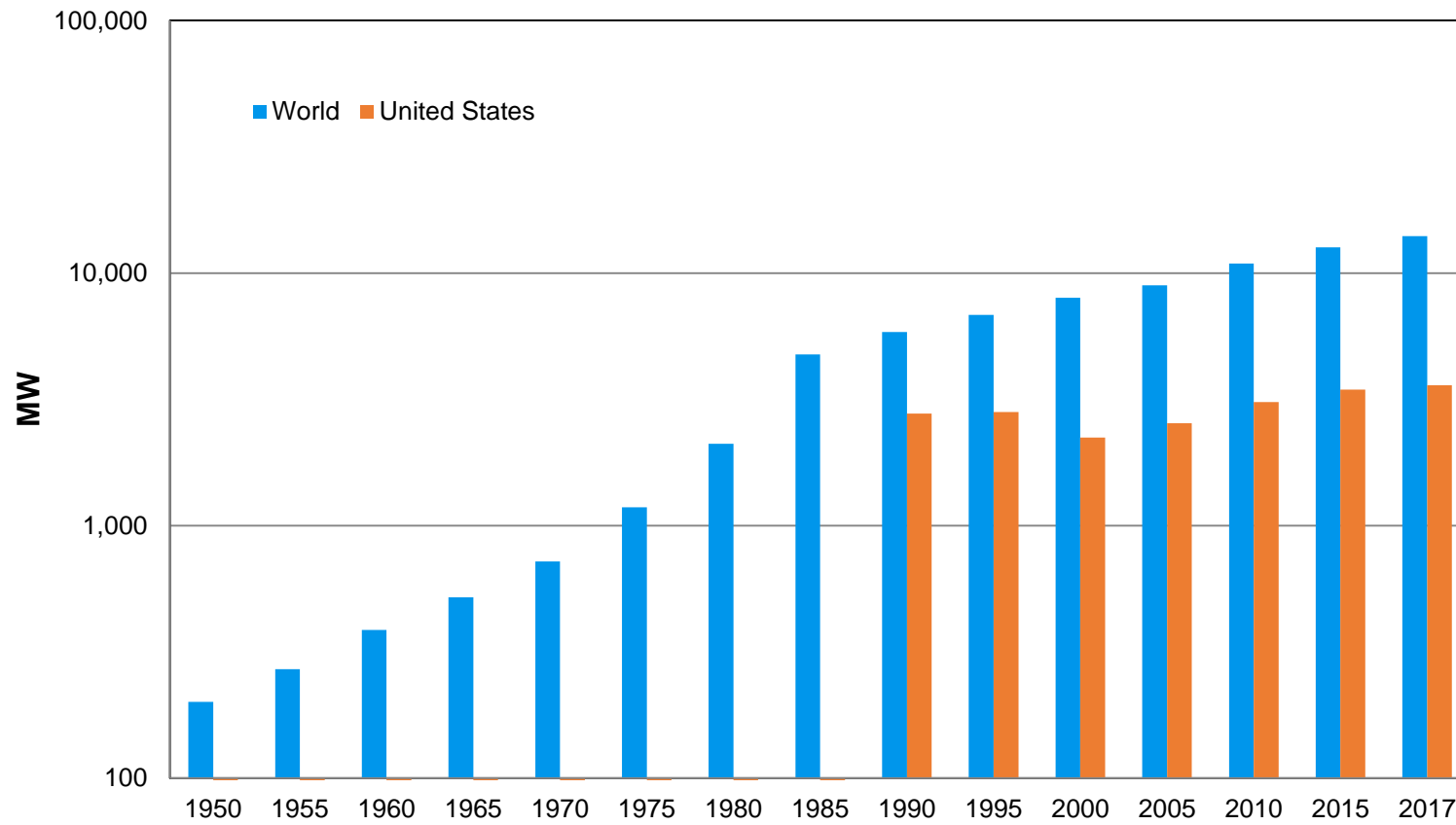
- 27 countries had installed geothermal power generation capacity
- 51 countries expected to have installed capacity in 2020

How Much Is There?

- World installed capacity (end 2017): 14,013 MWe (*Thinkgeoenergy, 2018*)
 - 1985-2010 compound annual growth = 4% (*Bertani, 2015*)
 - 2010-2015 = 3% annual
 - 2015-2017 = 5.3% annual
- World generation (2015): 73,549 GWh (66% capacity factor)
 - 1995-2010 compound annual growth = 4%
 - 2010-2015 = 1.8% annual
 - Approximately 350,000 BOE/day; 0.33% of world electric power generation

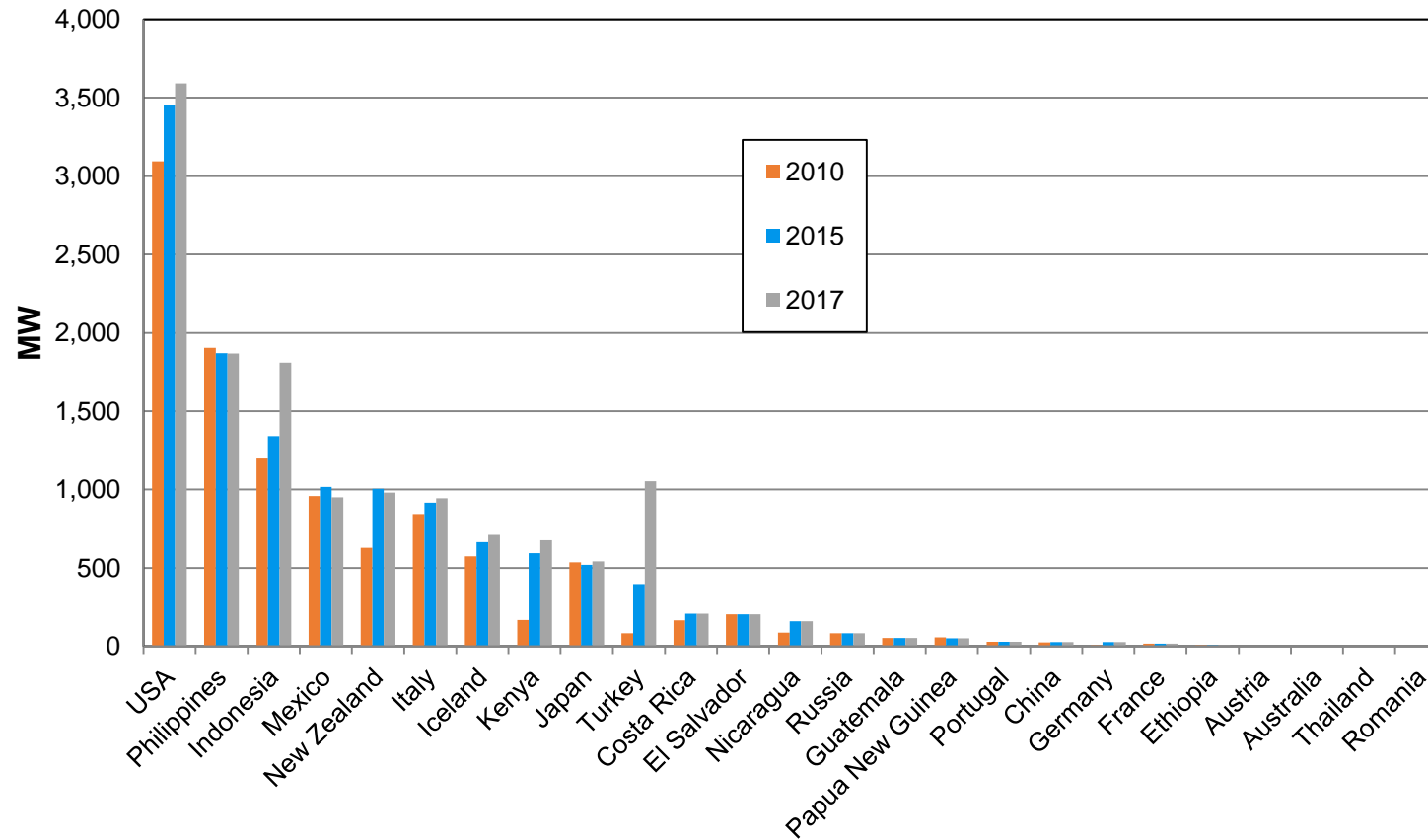
How Much Is There?

Installed Geothermal Generation Capacity 1950-2017



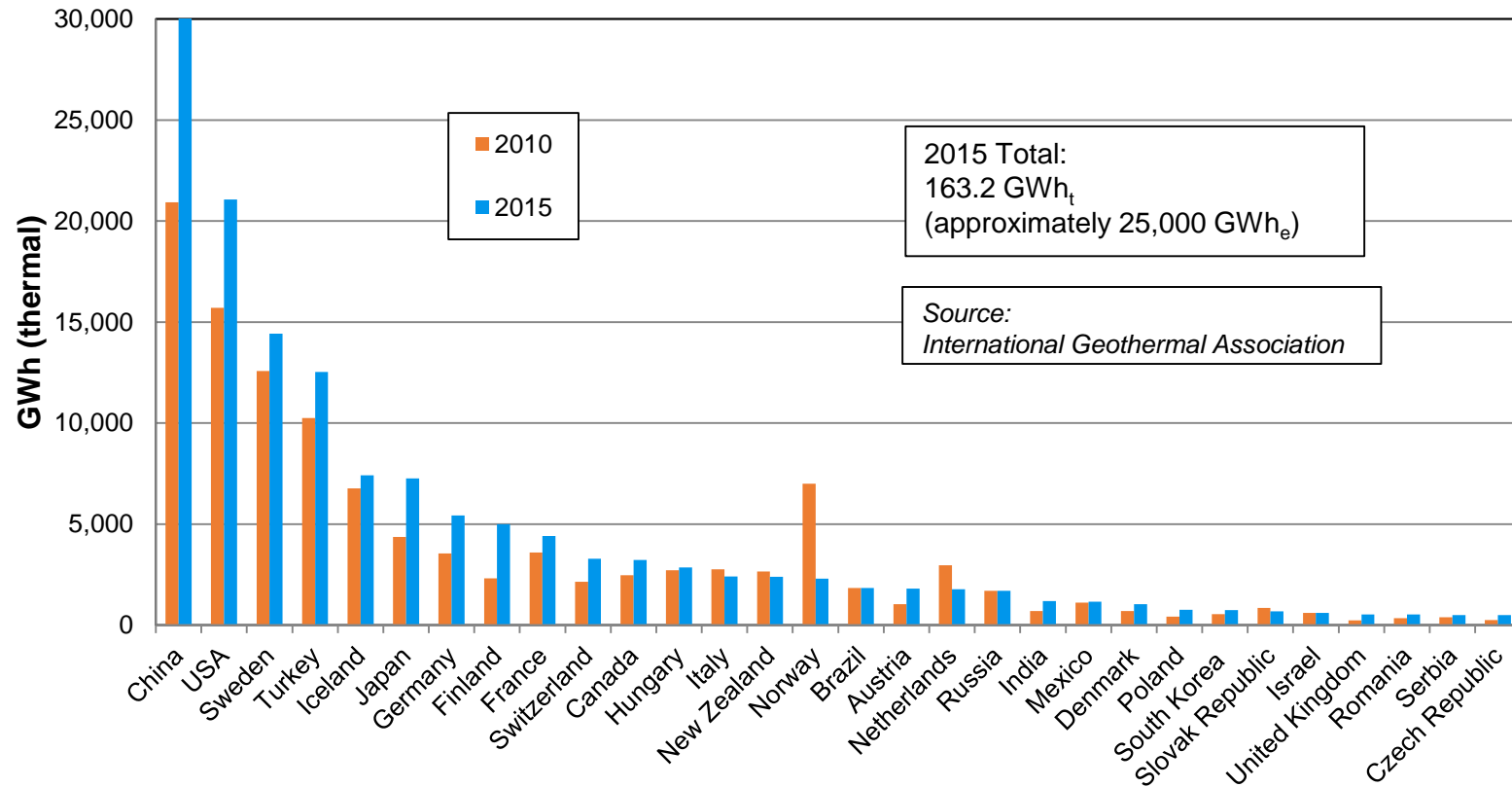
Where Do You Find It?

Installed Capacity by Country



Where Do You Find It?

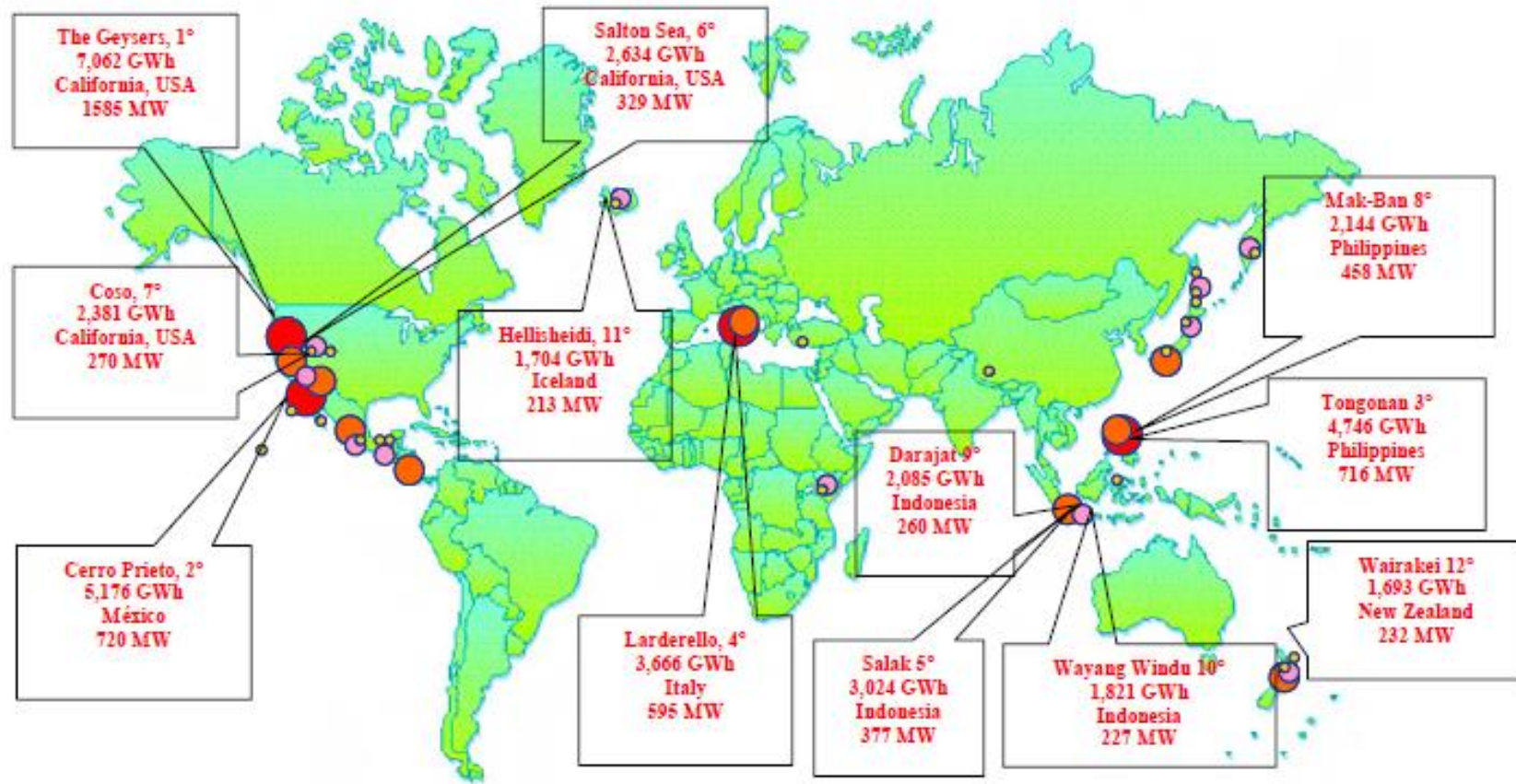
Direct Geothermal Use by Country (2015)



Where Do You Find It?

- As of 2015, 3 countries (US, PH, ID) accounted for 52% of installed capacity and 48% of generation (USA = 29%)
- 7 countries accounted for 81% of capacity and generation
- 16 countries account for 99% of capacity and generation
- 12 large fields (>200 MW each) account for 55% of capacity, out of about 100 fields developed (2010)

Where Do You Find It?



Who Does It?

- Government agencies
- Utilities (public and private)
- Energy companies (oil & gas)
- Independent power producers (IPPs)
- Industrial companies (manufacturing, mining)
- Promoters

Who Does It?

Leaders by Operator (2008)

- Chevron* 1,175 MW
- CFE (Mexico) 950 MW
- ENEL (Italy) 750 MW
- Calpine (USA) 720 MW
- PNOG-EDC (Philippines) 700 MW
- Ormat 475 MW
- Pertamina (Indonesia) 425 MW
- Reykjavik Energy (Iceland) 375 MW
- Terra-Gen (USA) 350 MW
- Contact Energy (New Zealand) 300 MW

Who Does It?

Other Notables (2018)

- Star Energy* (Indonesia) 875 MW
- Sarulla Operations (Indonesia) 330 MW
- Zorlu (Turkey) 330 MW

*Acquired >600 MW from Chevron in 2017

How Much Does It Cost?

- Total capital costs for project development (field + plant) are currently USD 4,000-6,000 per kW for many projects
- Drilling is typically about 40-50% of total development cost (average about USD 2,000 per kW); power plant and other surface facilities the rest
- Power sales prices in the range of USD 60 to 120 per MWh typically needed for projects to be profitable

Advantages

- Baseload generation
- Reliable (high plant availability factors)
- Low CO₂ emissions
- Small surface footprint
- Key resource in certain regions and countries
- Fuel-cost stability
- Energy diversity

Disadvantages

- High up-front capital cost
- High exploration and development risk
- Resource base smaller than some competitors
- Some projects affected by resource degradation
- Water consumption
- Over-promotion