The Global Geothermal Energy Market

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Current Status of Geothermal

- Only 0.1-0.3 % of world energy demand is met by geothermal, despite a theoretical 1 TW power potential and 30-60 TW in direct use
- The industry is slowed down by green field risks, large upfront capital investment, and power generation costs exceeding other locally available options
- The human resource pool, number of development companies and investors willing to enter the industry are also limiting factors
- Rising prices of fossil fuel is changing the scene
- Current growth rate is few hundred MW per year while the potential is in the GW range

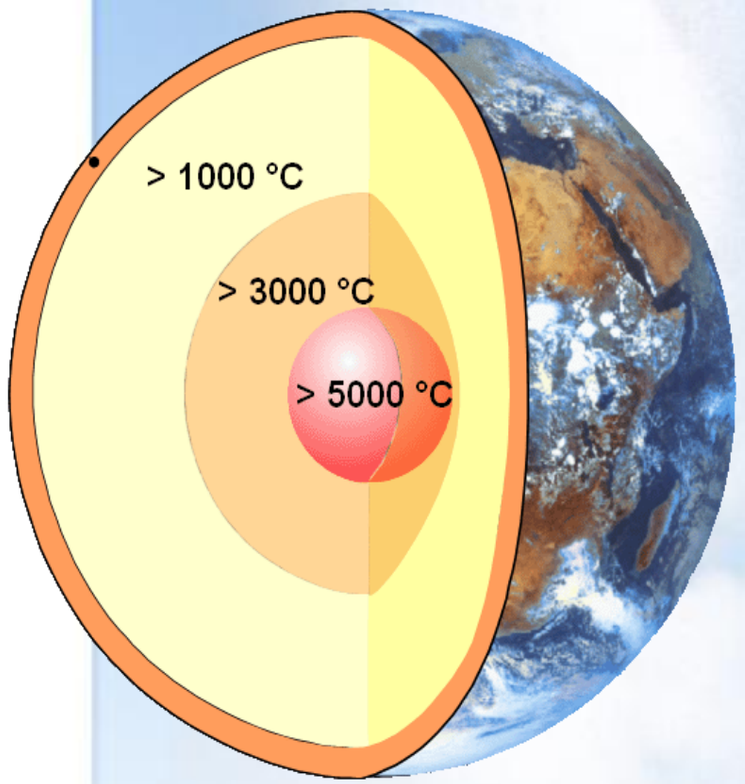
High and Low Grade Geothermal

- High grade resources confined to active plate boundaries and volcanoes
- Typically hosting 220-350 °C water and steam saturated reservoirs at 700-3000 m depth
- Most economic for power production

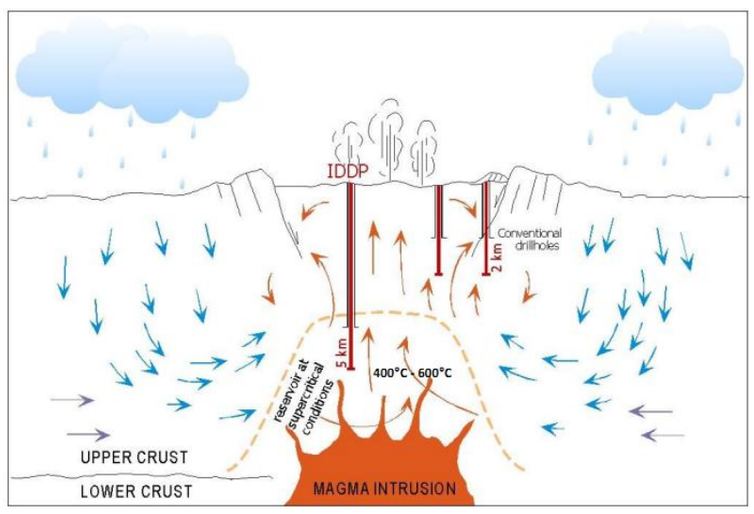
- Low grade resources (<150 °C) found worldwide
- Direct use applications most economic
- With emerging technologies and proven permeability in sedimentary basins below 2 km depth, cooling by absorption chillers is attractive

Origin of Geothermal Heat

- Radioactive decay generates the heat
- Heat flows to surface by conductive and convective processes
- Global heat loss by conduction is 44 TW and by magma convection around 3 TW
- Stored heat in topmost 3 km of continental crust estimated at 43×10^6 EJ
- World annual consumption in 500 EJ range

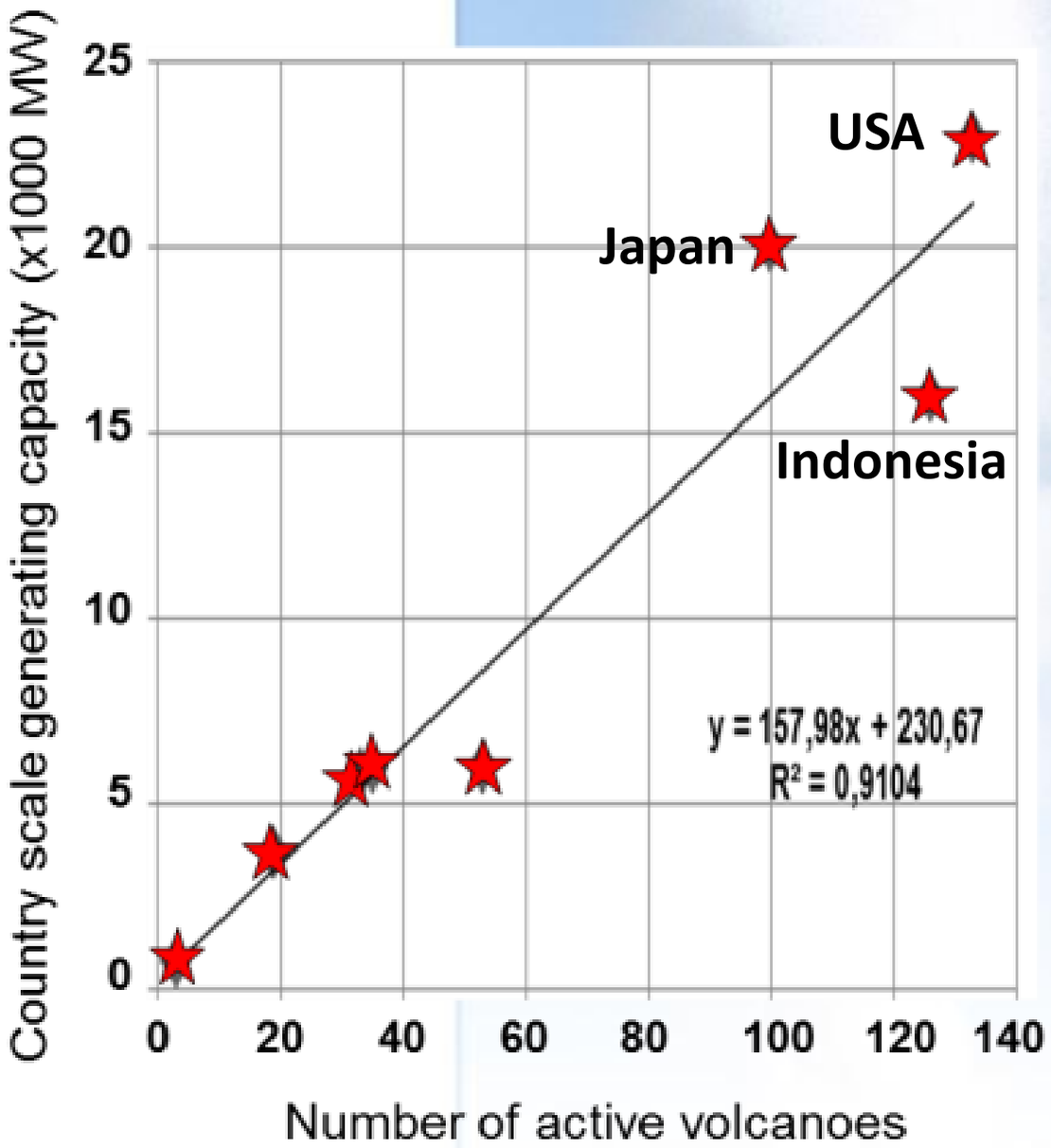


Source: Stefansson V., 2005: World Geothermal Assessment. Proc. World Geothermal Congress



Active Volcanoes and Power Potential

- The number of active volcanoes and a country scale geothermal power potential correlate
- On the average each active volcano can sustain about 160 MW electric
- The world potential is ~200 GW if all the 1322 accessible volcanoes are developed
- Higher if hidden resources are assumed to exist



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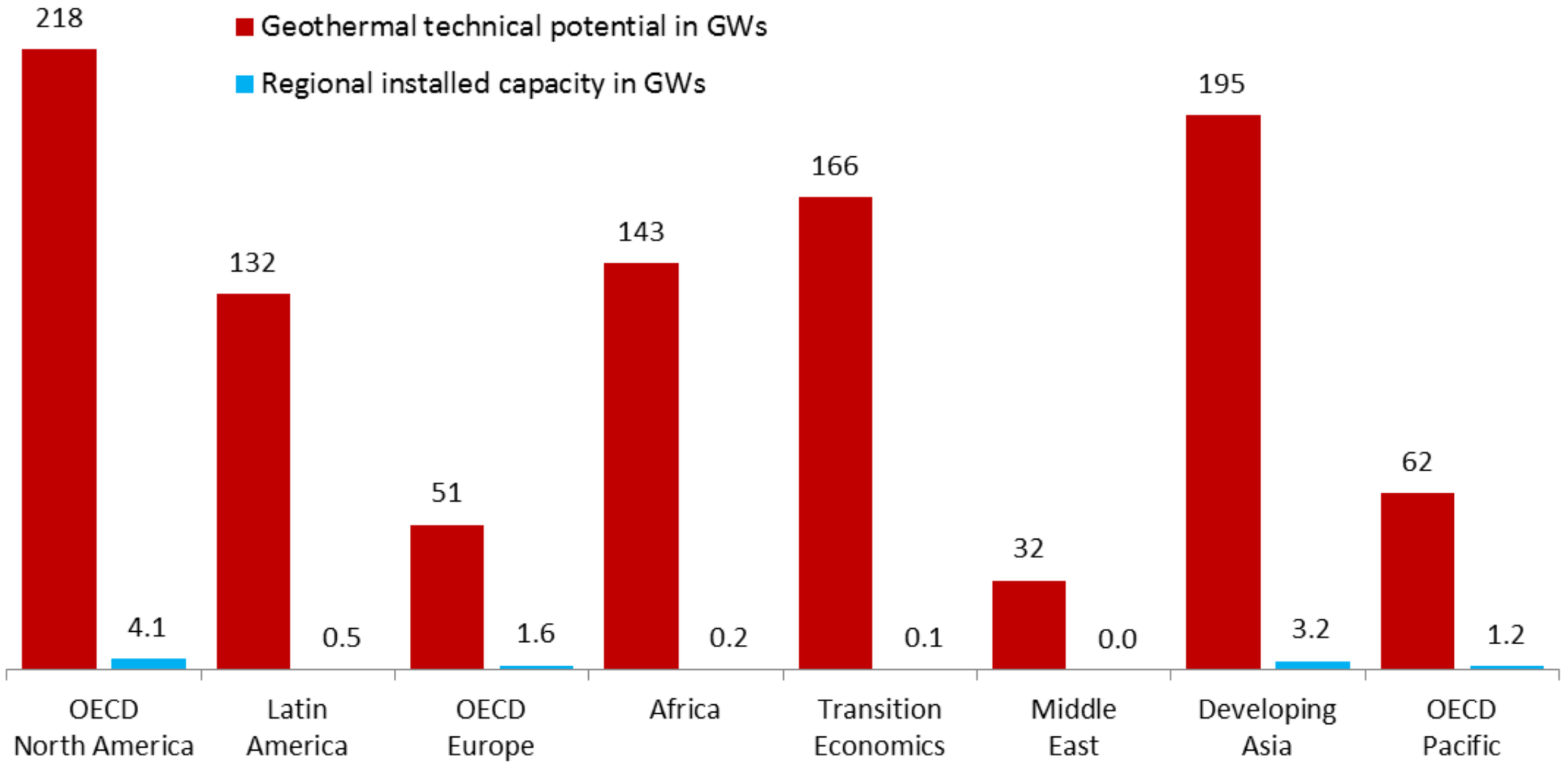
1 TW Theoretical World Power Potential



- Based on assessment by Intergovernmental Panel on Climate Change (http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch04.pdf)
- Excluding EGS, topmost 3 km of dry land only and 90 % capacity
- Only 1% developed today

RE < C

http://www.google.org/rec.html

- Recent geothermal power projects in Iceland and New Zealand demonstrate that renewables compete with fossil
- Quality resources and average well success > 5 MW
- Right developer mind set and risk attitude
- Existing and functional legal and permitting environment
- Long-term, base-load power purchase agreements
- IPPC (2011) reports US 4.9 to 9.2 US cents per kWh as levelized cost of geothermal energy



Growth Regions for Geothermal Power

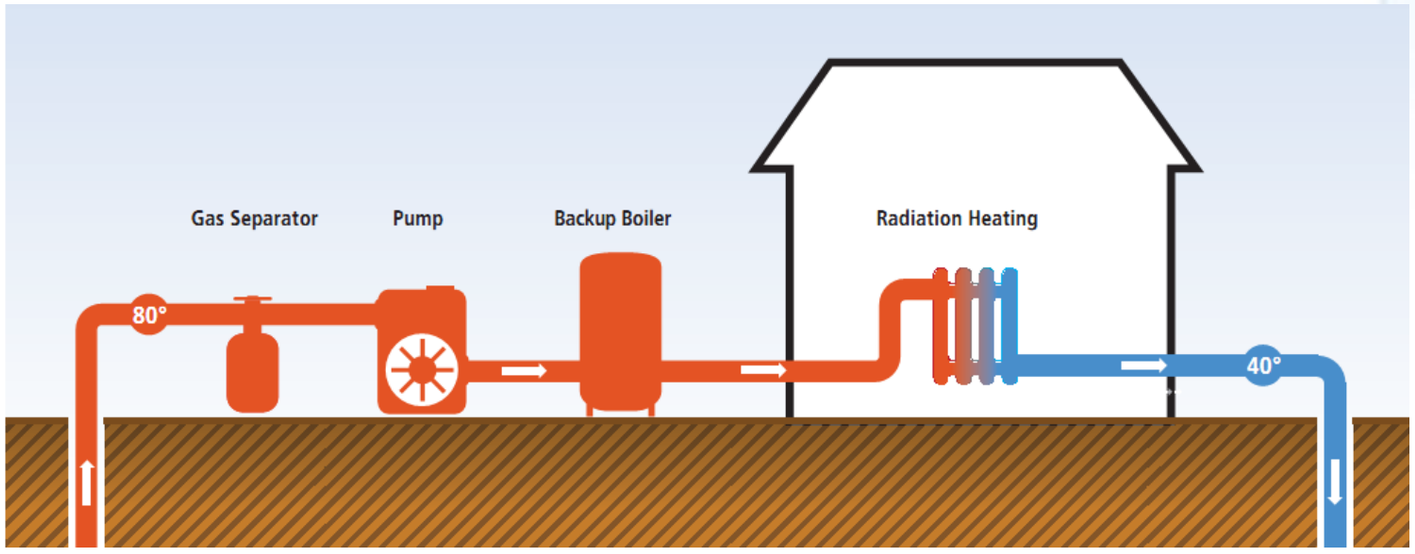
- Many of the best reservoir in G-20 countries already taken
- Developing countries host vast potential and 10-20 % of the energy mix already from geothermal in some
- Country risk is a barrier, mostly due to lack of legislation, permitting culture and non-transparent application processes
- Opportunity for international energy institutions
- Stranded power regions to be connected by subsea cables



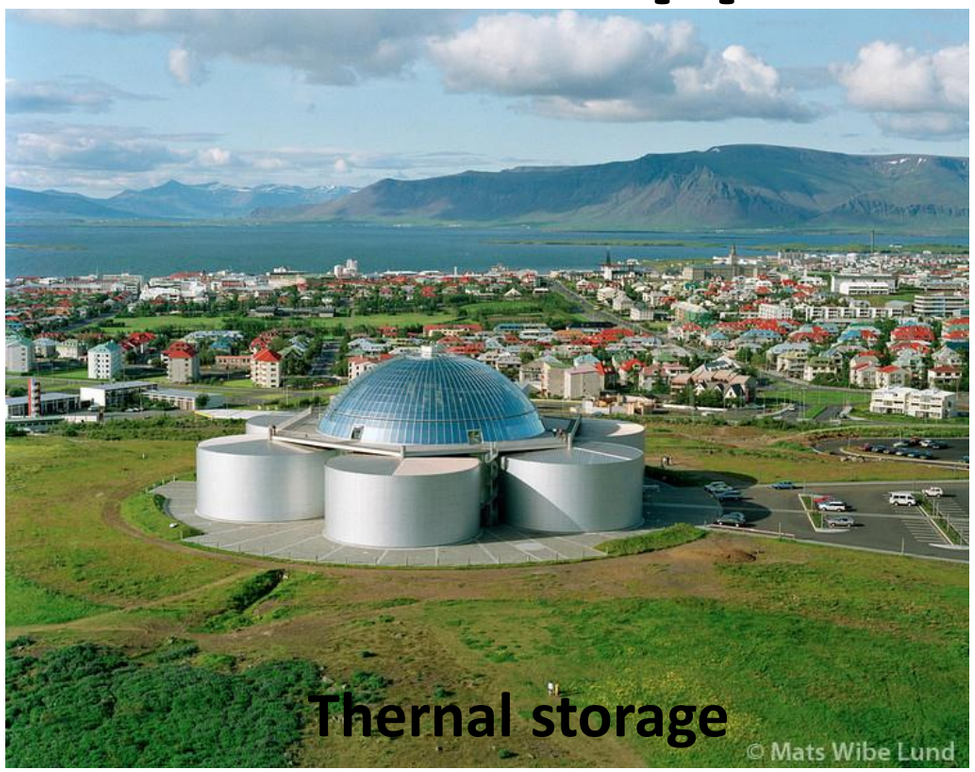


Direct Use Applications

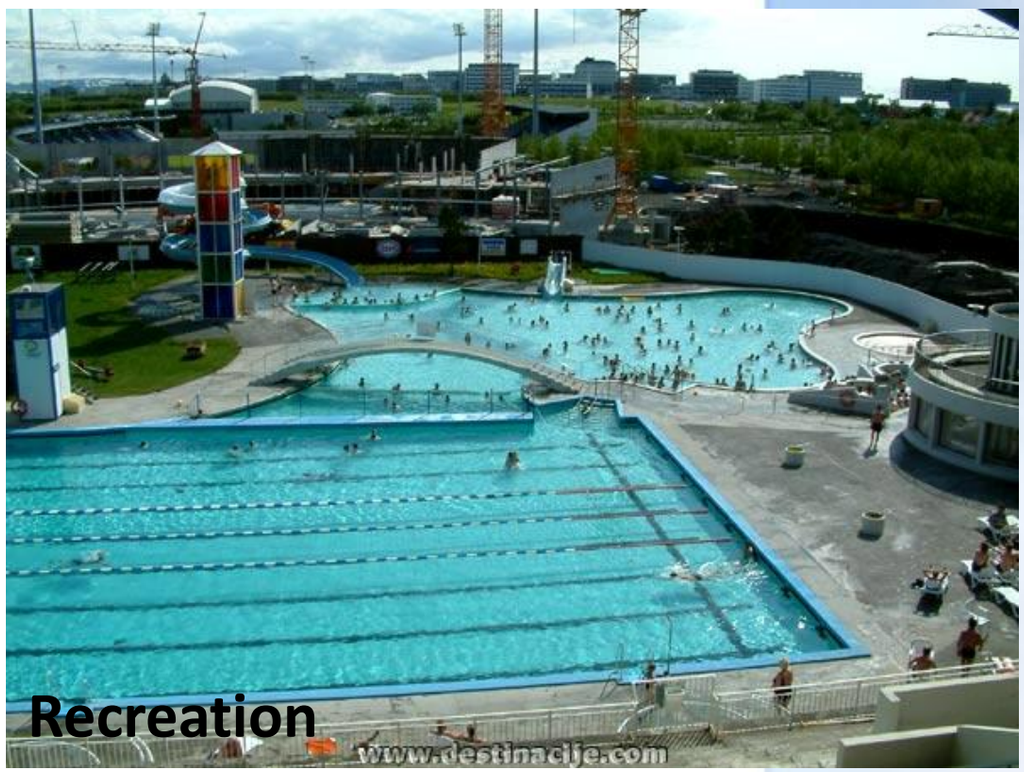
- Low-grade resource potential is large and favorably distributed worldwide
- Require its own energy distribution systems, consisting of often closed loop insulated pipes buried under ground
- Reykjavik Energy already has 1 GW of capacity
- Handle well peak load, energy storage, are safe and simple to manage and can be supported by many heat sources other than geothermal



Direct Use Applications



Thernal storage



Recreation

Environmentally benign

Small surface footprint

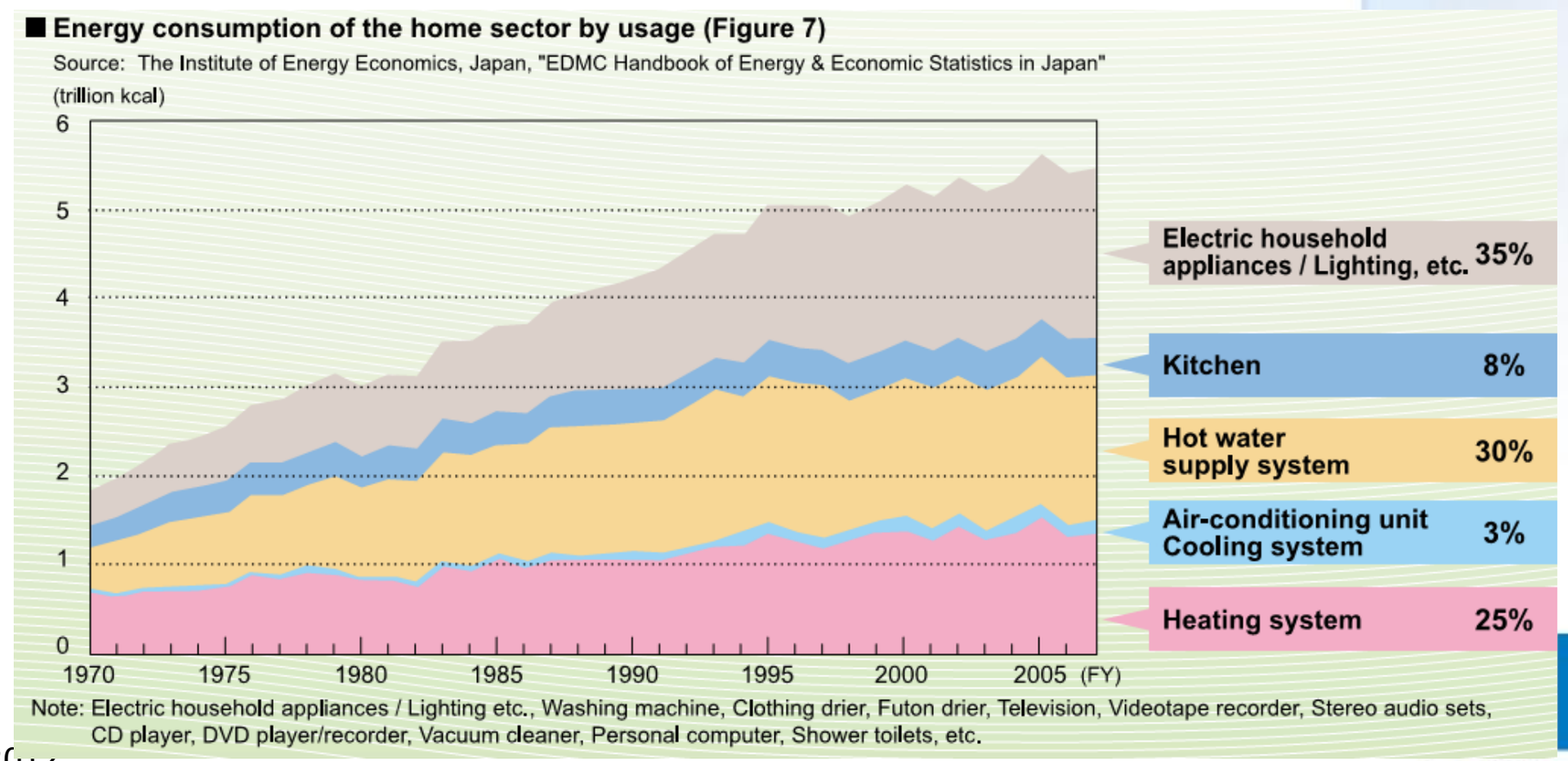
Development Rates and Costing

- Installation cost of each MW in power 3-5 MUSD
- Development time of 50-100 MW projects tapping into high grade reservoirs is 3-5 year
- Historically the world industry has commissioned 100-200 MW of power annually
- New low grade applications also in the few hundred MW range but development time and cost is less
- Economy of geothermal projects gets better if co-generation is possible

Reykjavík Geothermal

The Japan Case for New Development

- Second highest world potential of 20 GW - high grade
- Industry needs to adapt to environmental and social value of many volcanoes – hide the power plants ?
- Large market for house heating and hot tap water
- Growth potential is high if both markets can be served



Conclusions

- Geothermal is an underdeveloped opportunity in the renewable energy sector
- Power projects are geographically constrained to active plate boundaries while direct use has potential in most areas
- Geothermal power is price competitive if tapping favorable reservoirs and in the right business environment
- Substantial power potential in developing countries
- Japan has large growth potential and geothermal can contribute to its future energy mix, particularly if central heating system can accommodate other renewable energy projects