Overview of direct geothermal applications and uses worldwide

III GGDP Roundtable

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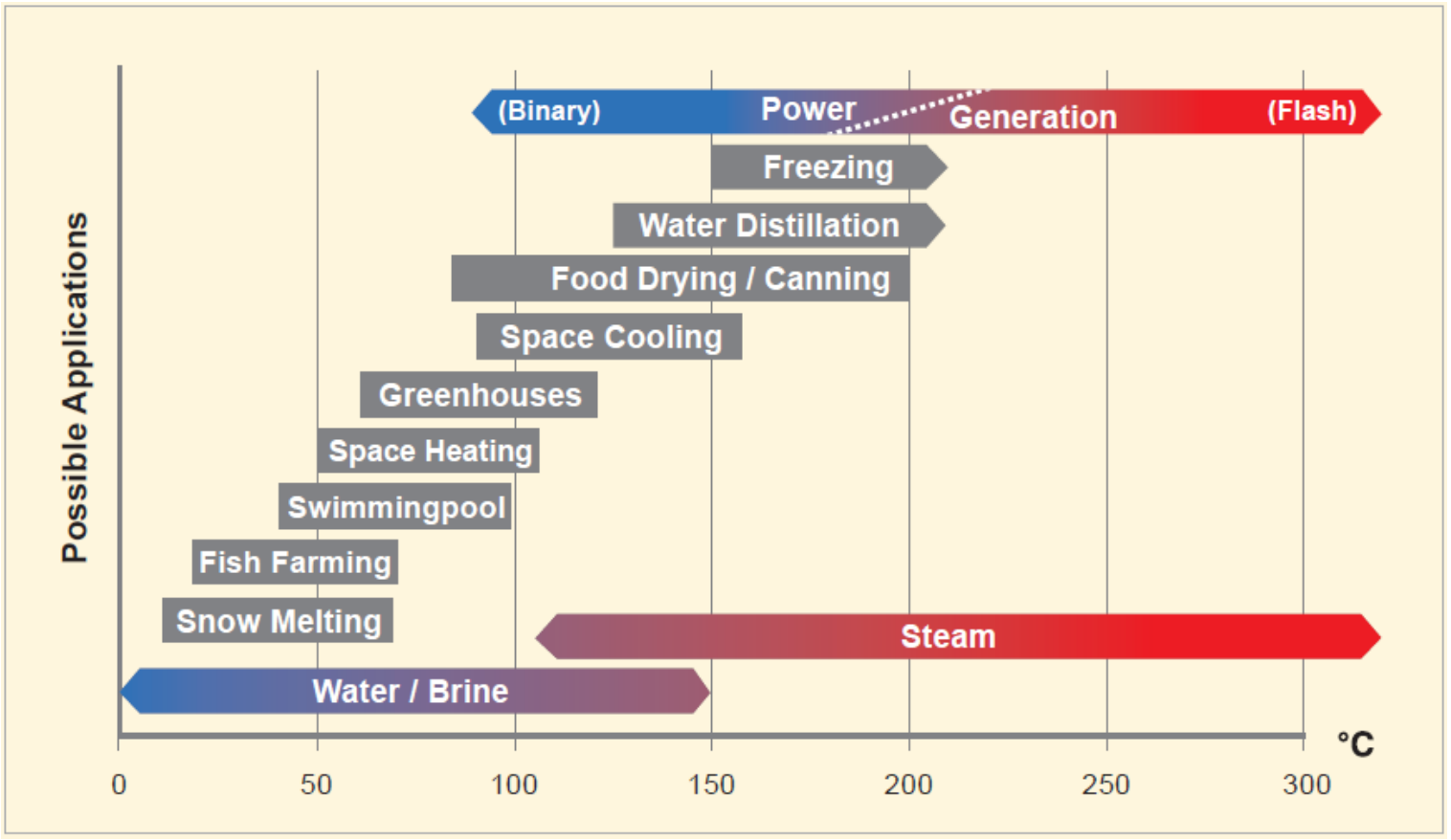
Modified Lindal diagram



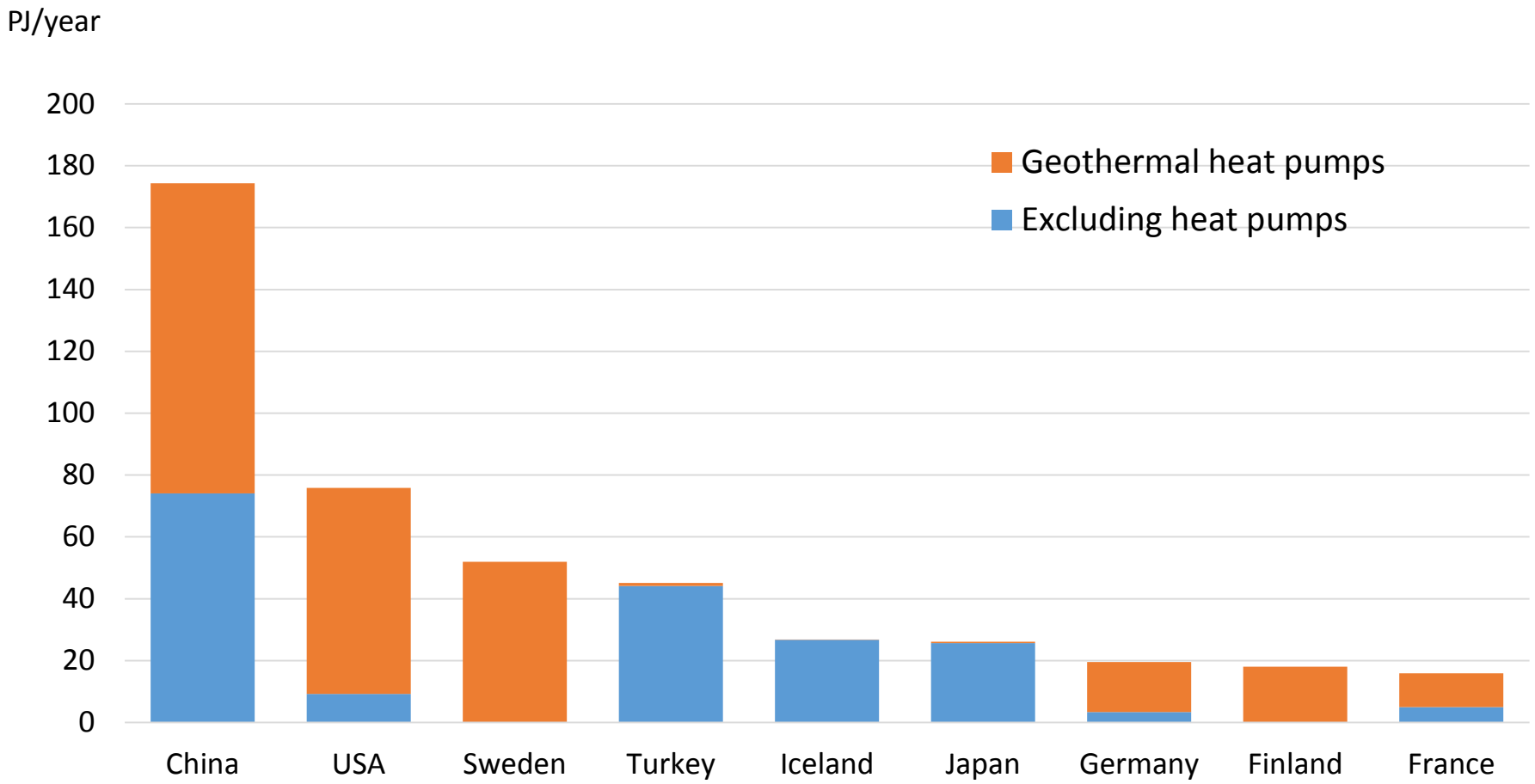
- The resource temperature limits the possible uses
- Cascade and combined uses enhance the feasibility

  Examples:

  - ✓ Use the same geothermal water first for industrial heating and thereafter for space heating (cascade uses)
  - ✓ A geothermal plant that produces both electricity and hot water for district heating (Combined Heat and Power - CHP)

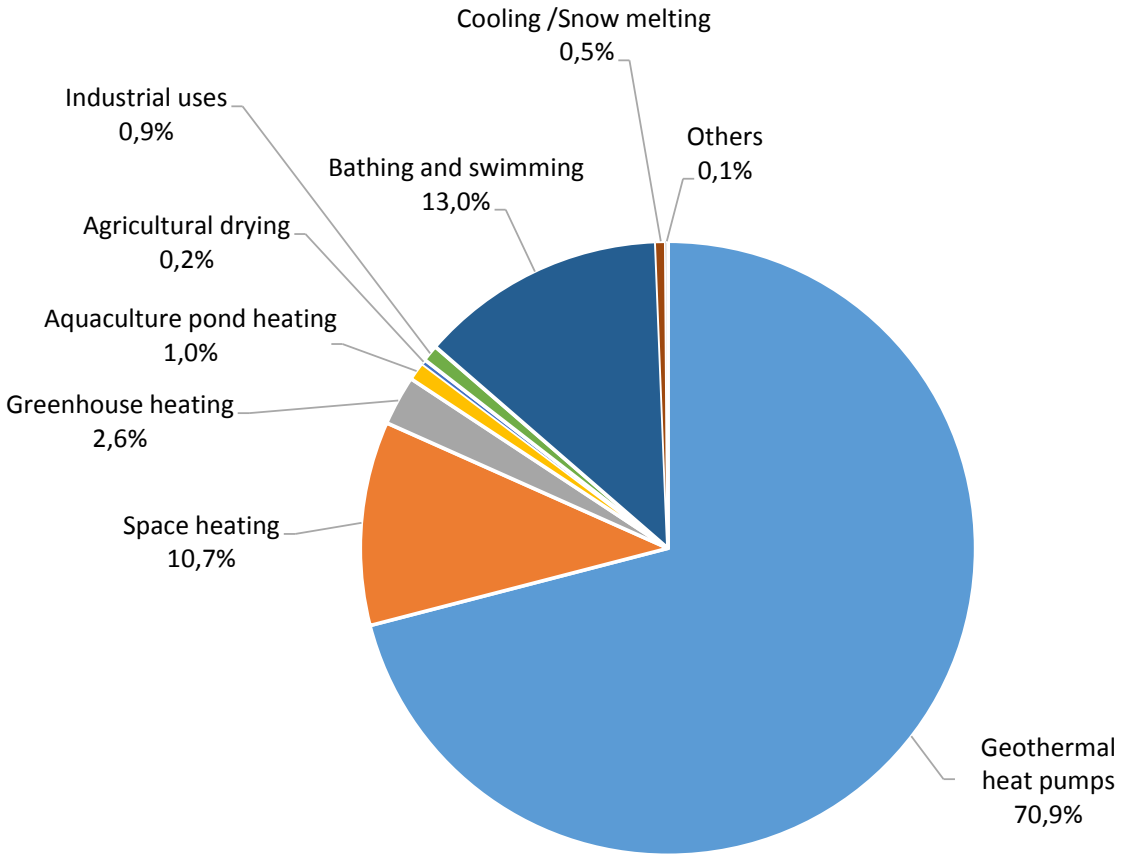
Source: Gehringer and Loksha, Geothermal Handbook: Planning and Financing Power Generation, ESMAP 2012

Countries with largest direct use of geothermal energy

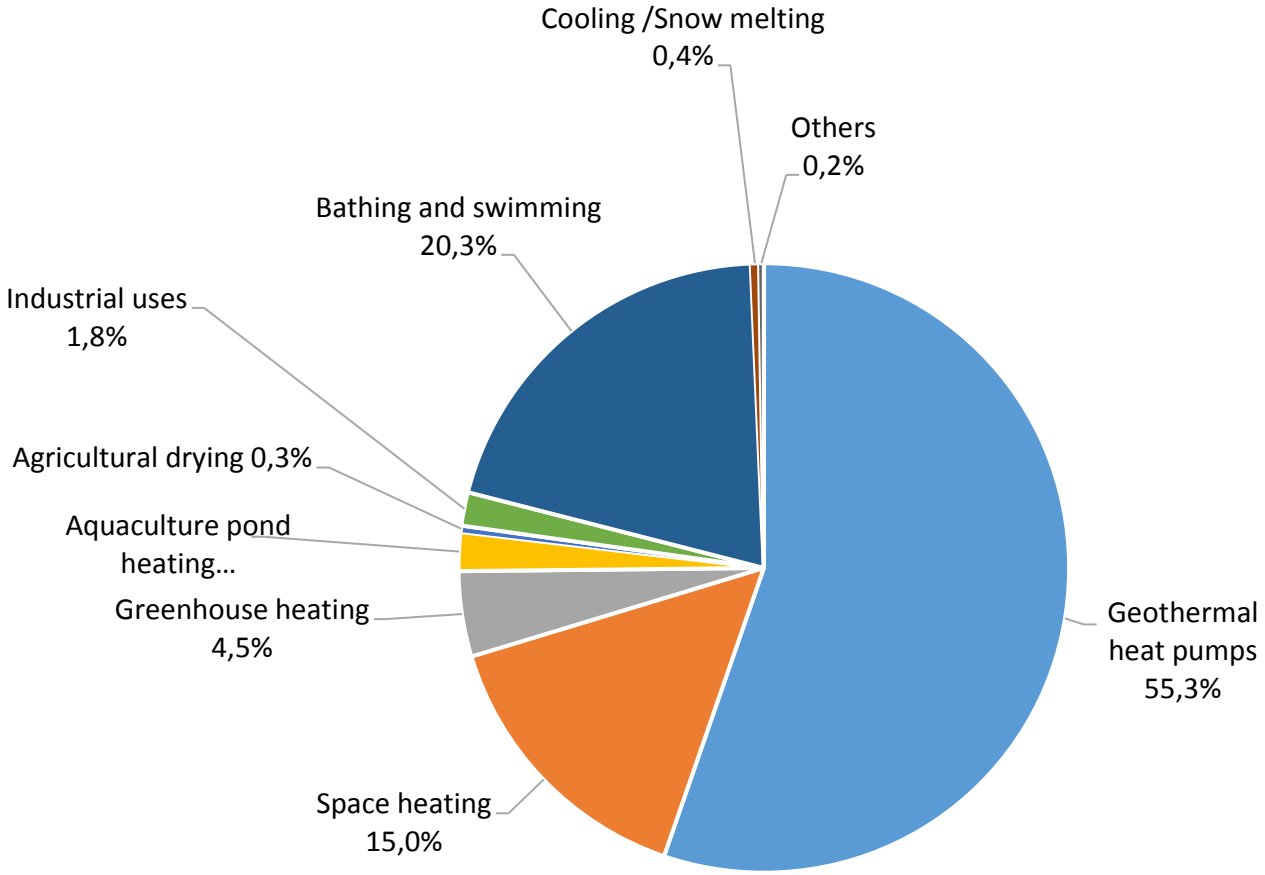


Source: John Lund, WGC2015, Direct Utilization of Geothermal Energy 2015 Worldwide Review

Worldwide direct use 2015



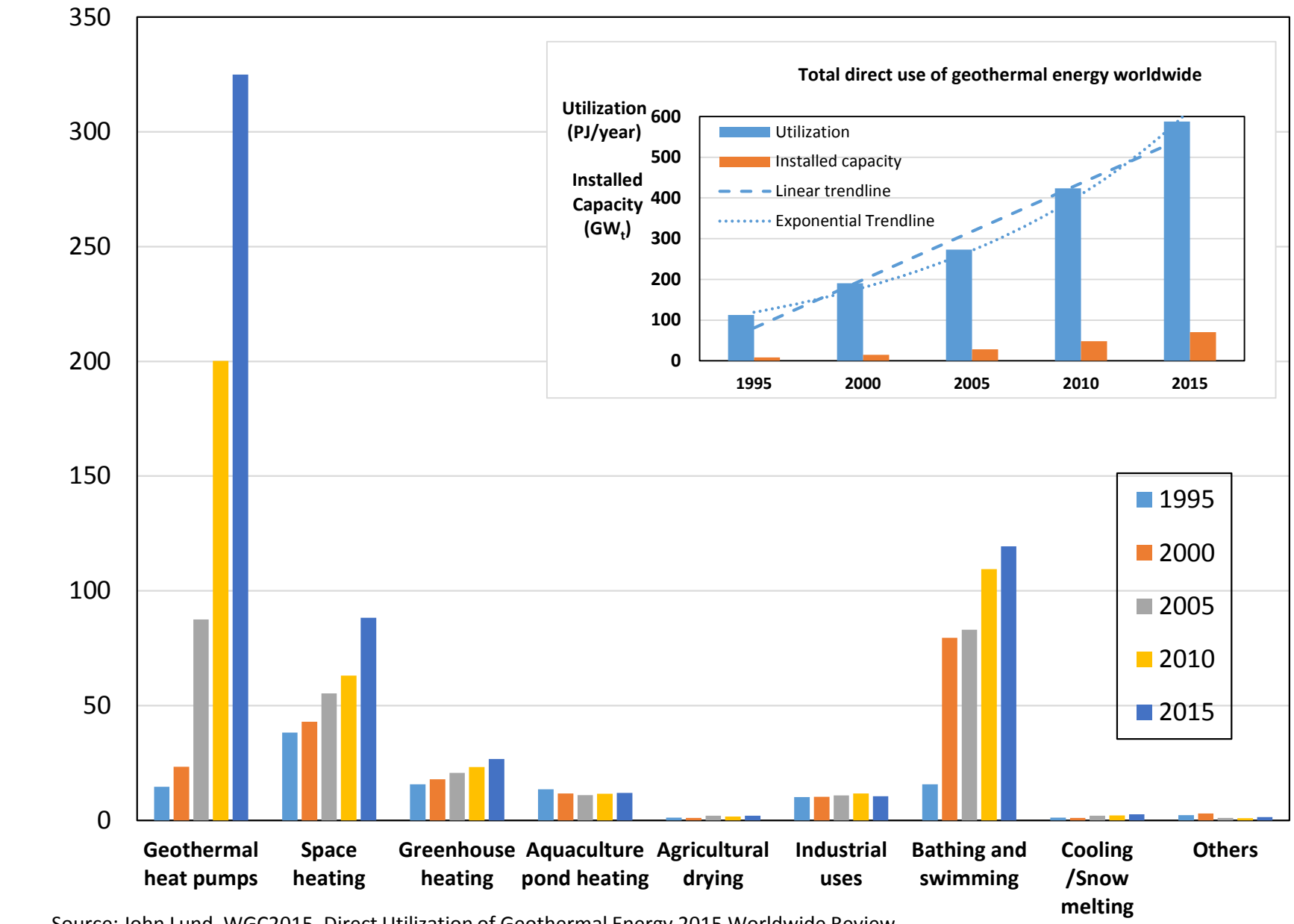
Capacity – Total: 70,329 MW_t



Annual utilization - Total: 588 PJ/year

Source: John Lund, WGC2015, Direct Utilization of Geothermal Energy 2015 Worldwide Review

Direct use of geothermal energy worldwide



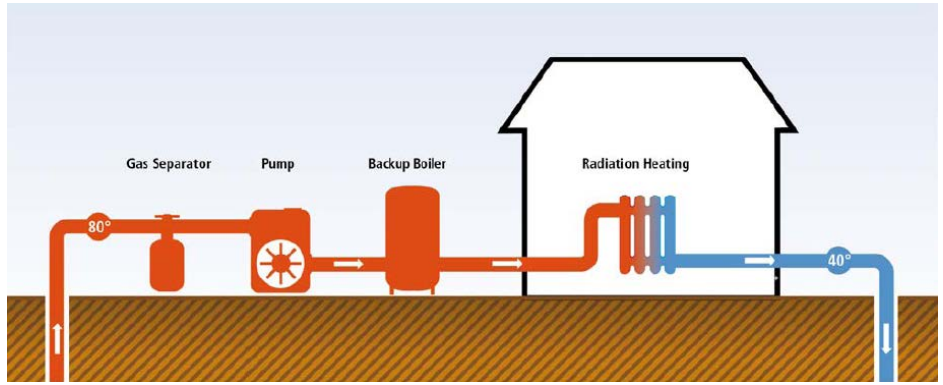
Source: John Lund, WGC2015, Direct Utilization of Geothermal Energy 2015 Worldwide Review

Space heating – main characteristics

- Space and district heating is among the most successful geothermal direct applications in countries with cold climate
- Leading countries: China, Iceland, Turkey, France, Germany, USA, Italy
- Chemical composition of the water is important

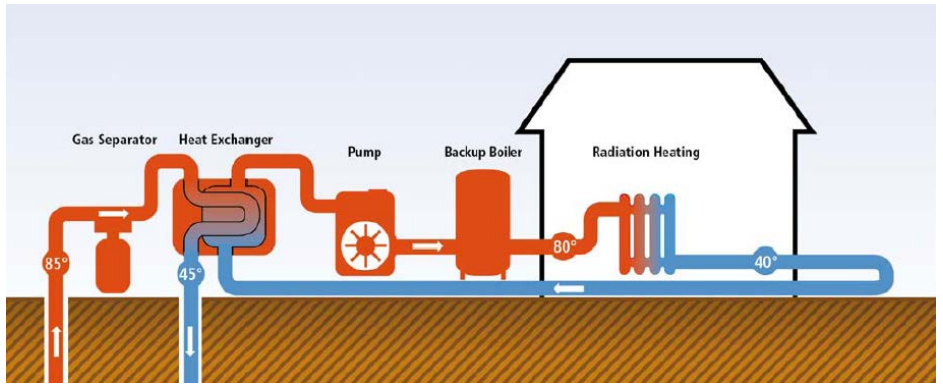
Open loop – single pipe system

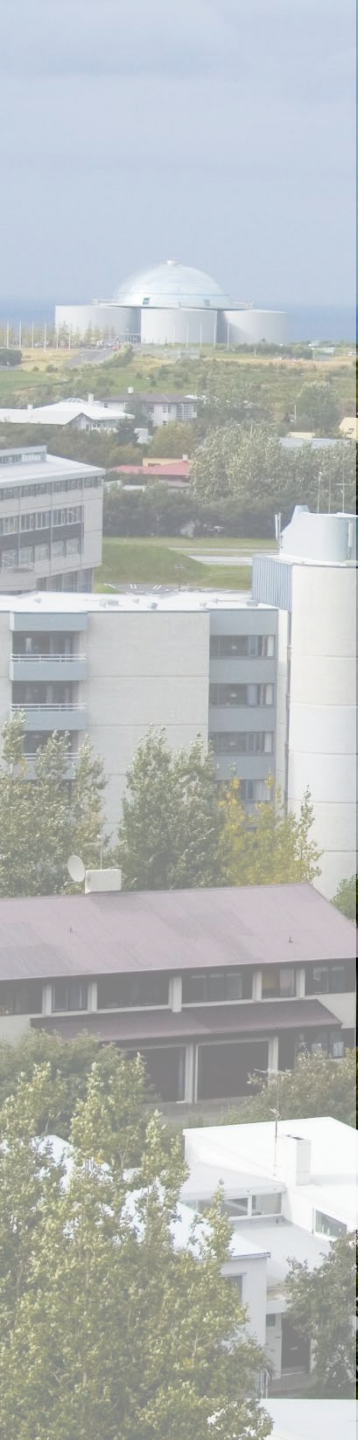
- Geothermal water used directly
- Spent water from radiators is reinjected or discharged to waste



Closed loop – double pipe system

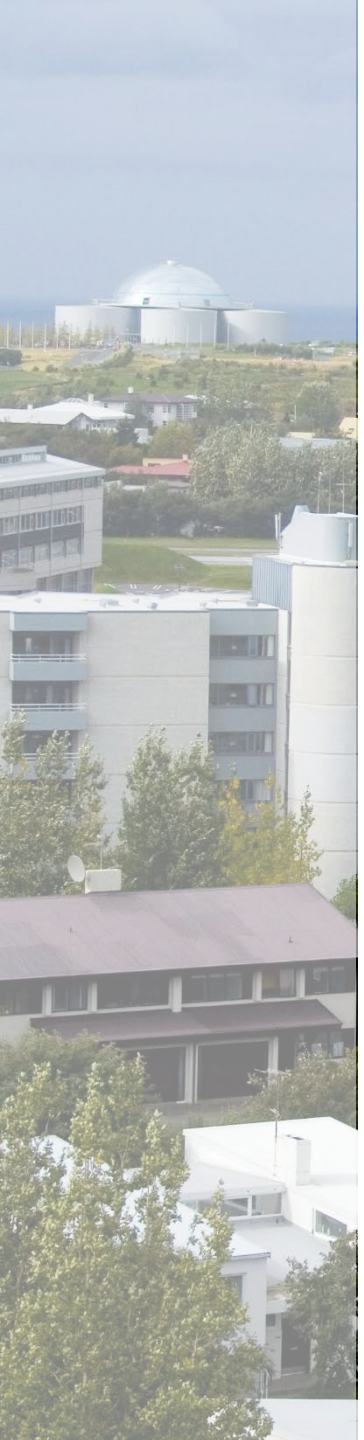
- Heat exchangers are commonly used
- Flexible - other energy sources possible





Space heating

- Preferred water temperature is in the range 60-90°C. Common return water temperature is 25-40°C
- Radiators or floor heating systems are commonly used. Air heating systems are also possible.
- Population density and distance between the geothermal field and the market is important for the economy of the system
- Generally no big problems related to utilization of this kind of utilization
- Co-generation (combined heat and power) enhances the economy of the system considerably
- Geothermal heat pump can be used if the temperature of the resource is too low for direct application

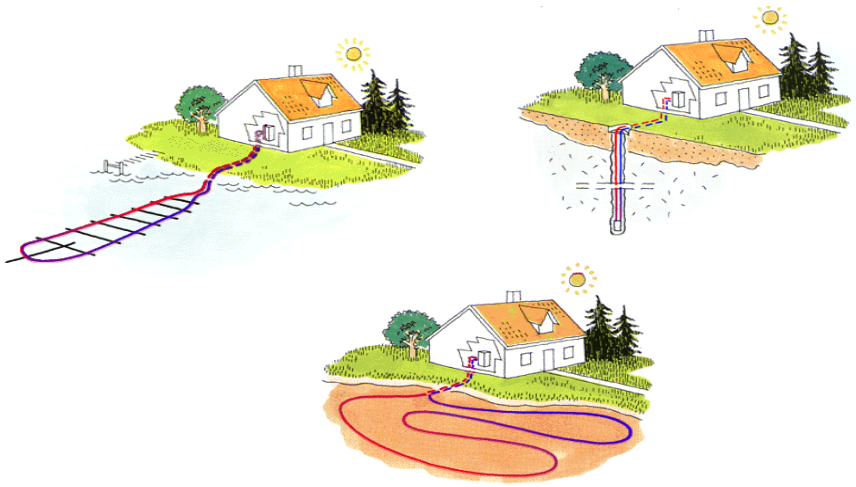


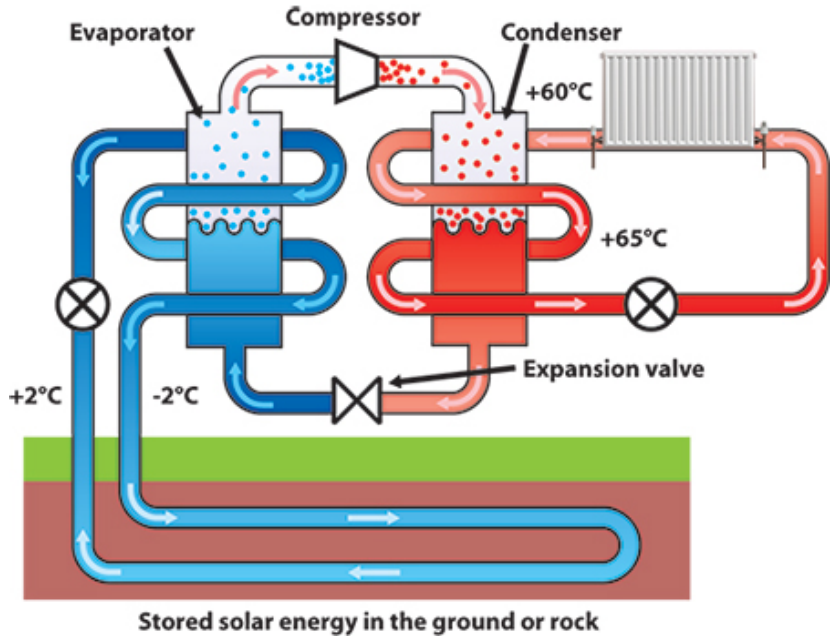
District heating in Iceland

- Over 90% of all houses in Iceland are heated by geothermal energy
- Reykjavík Energy is the owner of the largest district heating system in Iceland. They supply hot water to the capital area and serve about 240,000 people, over 70% of the population of the country.
  - ✓ Total number of employees is 450, turnover in 2015 about 320 million US$.
  - ✓ Utilize low-temperature areas within and in the vicinity of Reykjavík as well as high-temperature fields at Nesjavellir and Hellisheidi (co-generation plants).
  - ✓ Total installed capacity of the district heating system is 1,100 MWt and annual hot water production was 83 million m^3 in 2015.

Geothermal heat pump / Ground source heat pump (GSHP)

- A heat pump works in the same way as a refrigerator, but the purpose is the opposite (heating)
- Transfers heat from a heat source in the environment at a relatively low temperature (rock, soil, groundwater) to a place at a higher temperature (indoor air)
- Heat supplied to the building typically 3-5 times the electrical input needed
- Can be used for both heating and cooling
- Leading countries: China, USA, Sweden, Germany, Finland, France





Bathing and swimming

- Geothermal water has been used for bathing and health care for thousands of years
- Mainly use of low-temperature resource
- Temperature and mineral content is important
- Water use directly is desirable, sometimes treated (chlorine)
- Associated with most spas is the use of therapeutic mud (peoloids)
- Important social and cultural centers
- Common in connection with religious ceremonies
- Contributes to the development of sustainable tourism – Ecotourism
- Leading countries: China, Japan, Turkey, Brazil, Mexico

The Blue Lagoon

- Effluent brine from the Svartsengi geothermal power plant is disposed of into a surface pond called the Blue Lagoon
- Holds 6 million liters of 37-39°C seawater, which is renewed every 40 hours
- Is used by people suffering from psoriasis and other forms for eczema, who seek therapeutic effects from the silica rich brine
- Skin care products produced from the geothermal brine
- One of Iceland´s most popular tourist attractions with about 800 thousand visitors in 2015


The Blue Lagoon, Iceland


Landmannalaugar, Iceland


Olkaria, Kenya

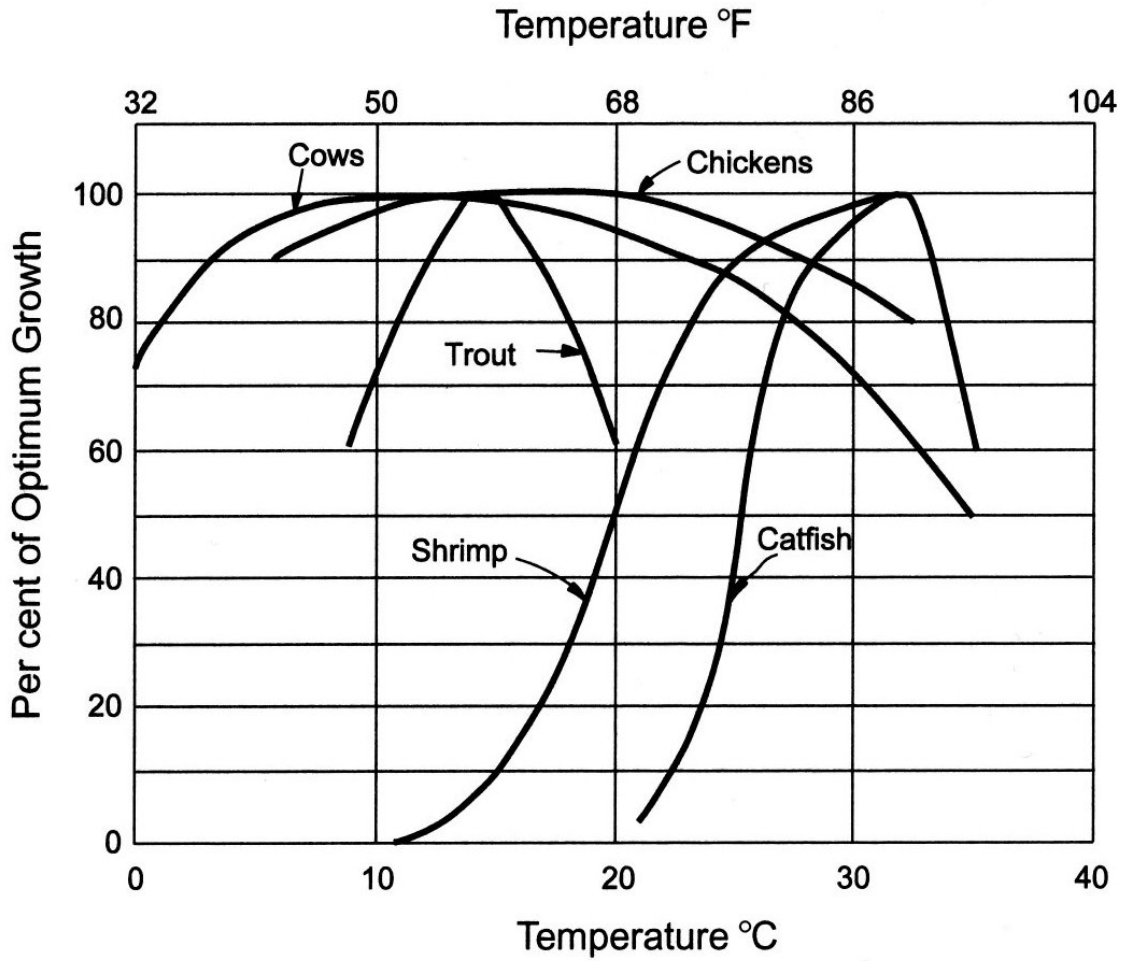
Greenhouse heating / Horticulture

- Raise a variety of crops: vegetables, flowers, house plants, trees
- Supply of heat around the clock in cold periods.
- Humidity control in hot regions, e.g. for roses in Kenya
- Counteract the desert cold at night, e.g. Tunisia
- Source of CO_2 for enrichment inside greenhouses, e.g. Iceland, Kenya
- Leading countries: Turkey, Russia, Hungary, China, Netherlands

Aquaculture

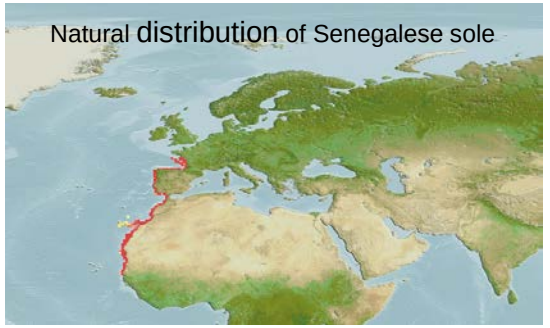
- Raising of freshwater or marine organisms in a controlled environment to enhance production rates
- Water quality and disease control are important in fish farming
- Tilapia, salmon and trout are the most common species, also tropical fish, lobsters, shrimp, and prawns
- The water temperature ranges from 13 to 30°C
- The growth rate can be increased by 50 to 100%
- A typical 2 ha facility in the temperature climate zone requires an installed capacity of 14 MWt.
- Leading countries: USA, China, Iceland, Italy, Israel

Optimum growing temperature for selected animal and aquatic species



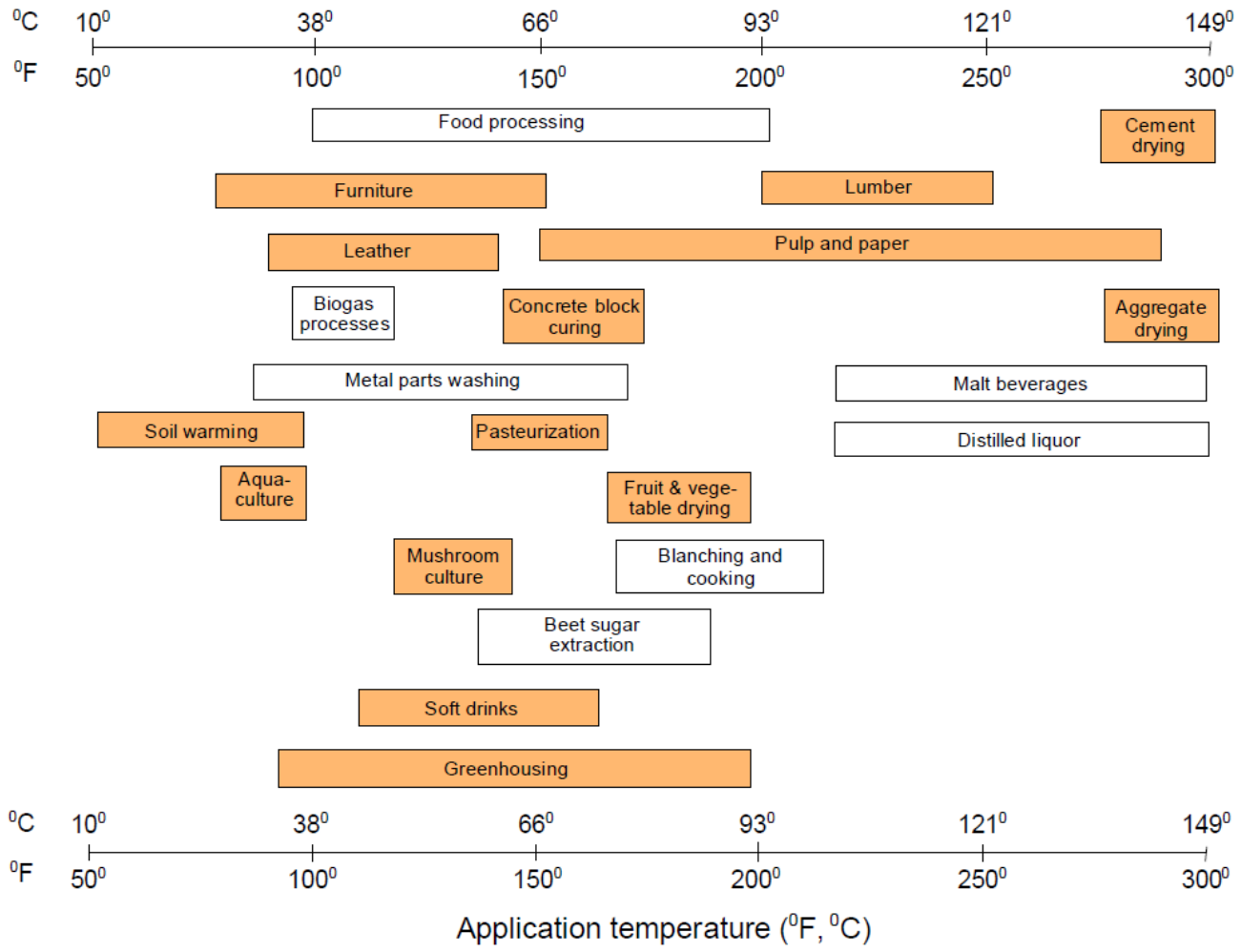
Fish farming plant at Reykjanes peninsula, Iceland

- The plant is breeding warm-water Senegalese sole by using effluent water from Reykjanes geothermal power plant.
- Indoor land-based plant, 22,500 m2
- The power plant uses a large amount of sea water for cooling and after the cooling process a part of the water at 35°C flows by gravity to the fish farming plant.
- There it is mixed with sea water that is pumped from wells and used in the farming at about 21°C.
- The fish is grown to about 400 g before it is slaughtered and transported fresh to markets in Europe.
- The production capacity is now 500 tons per year, but the planned production after reaching the final stage is 2,000 tons per year.



Industrial applications

- Drying - The most common operation (wood, natural fibers, grains, fruit, vegetables, spices, coffee, tea)
- Process heating – preheating of boiler water etc.
- Evaporation – extraction of salt and other minerals
- Distillation – liquor and hydrocarbon industry
- Washing – food industry
- Chemical extraction – gold separation from ores
- Pasteurization of milk
- CO_2 production
- Refrigeration – absorption freezing (lithium-bromide and ammonia)
- Industrial application tend to have high load factors (0.4 - 0.7) which reduce the unit cost of energy
- Leading countries: New Zealand, Iceland, USA, Italy



Pulp, paper and wood processing

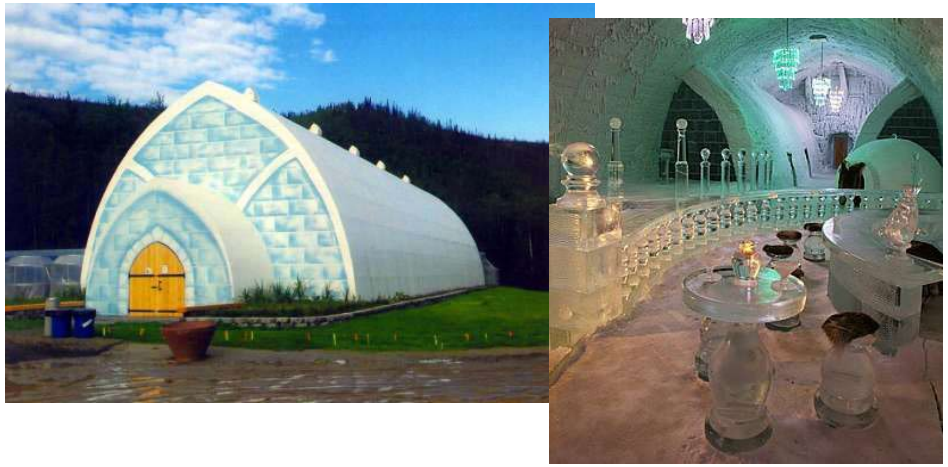
- Tasman Pulp and Paper Company Ltd., Kawerau, New Zealand
- Integrated newsprint, pulp and timber mills, operated since 1957
- Largest industrial direct heat user of geothermal energy worldwide
- Produces 181,000 tonnes of pulp and 363,000 tonnes of newsprint each year
- Uses an average steam flow rate of 340 tonnes/h from five wells
- Supply high-pressure steam to a sawmill for drying timber in kilns
- Generate 14 MW electricity using separated water.
- Supply small quantities of steam for greenhouse heating

Drying of fish in Iceland

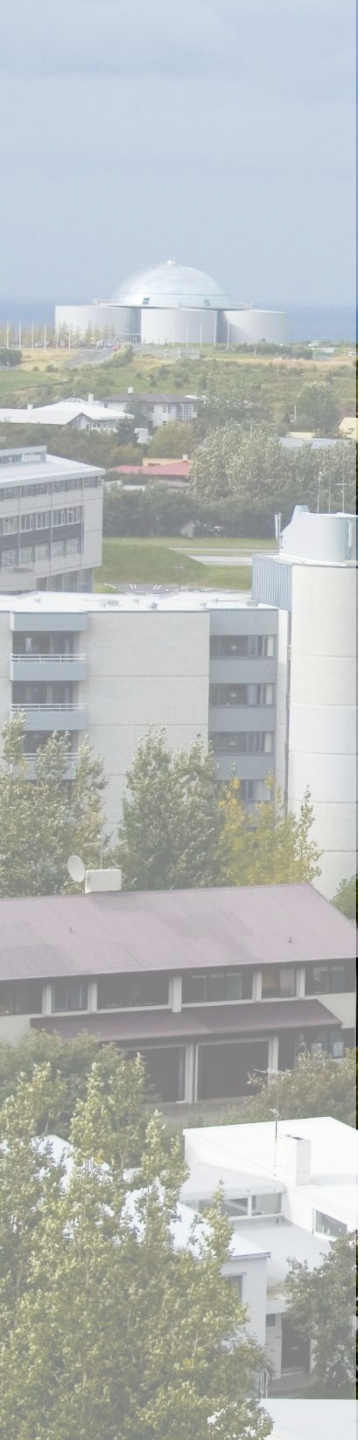
- Geothermal energy has been used for drying fish in Iceland for about 35 years
- Drying of salted fish, cod heads, small fish, stockfish and other products
- About 10 small companies are drying totally about 12,000 tonnes of codheads indoors using geothermal water
- One of the largest producers, Haustak, buyes 1.3 kg/s of steam from the nearby Reykjanes power plant to produce annually 2,500 tonnes of dried products from 12,000 tonnes of raw material
- Dried cod heads are exported to Nigeria for human consumption

Cooling / freezing

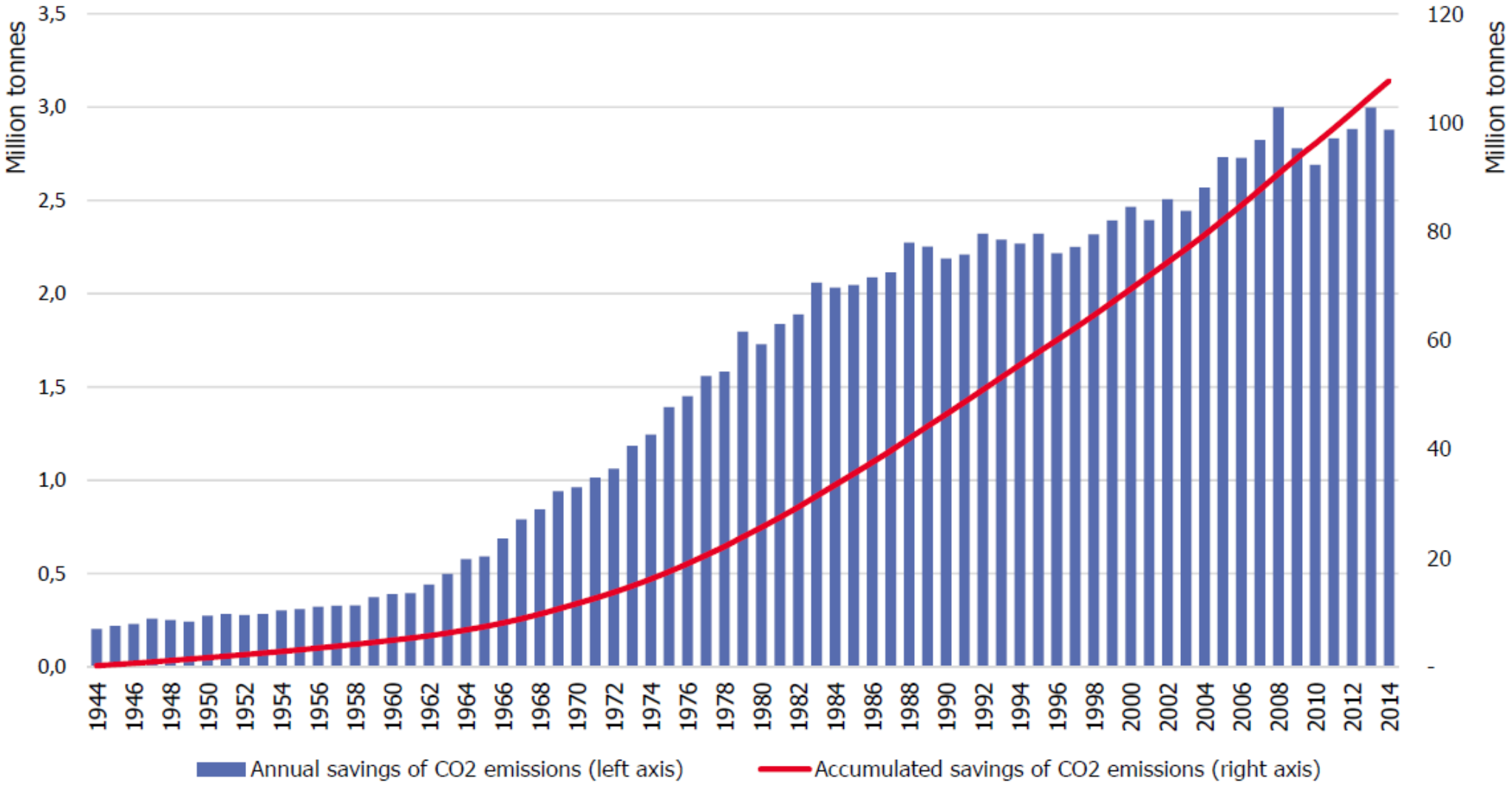
- Geothermal energy can be used for cooling and freezing by absorption technology
- The electricity driven compressor in a conventional refrigeration system is replaced by a system with a mixture of two different fluids, a refrigerant and an absorber ($LiBr/H_2O$ eða H_2O/NH_3) in a separate cycle.
- The refrigerant is boiled out of the solution by external heat (geothermal), condensed by external cooling and takes up thermal energy (cooling) when it evaporates at a low pressure before it mixes with the absorbent fluid again



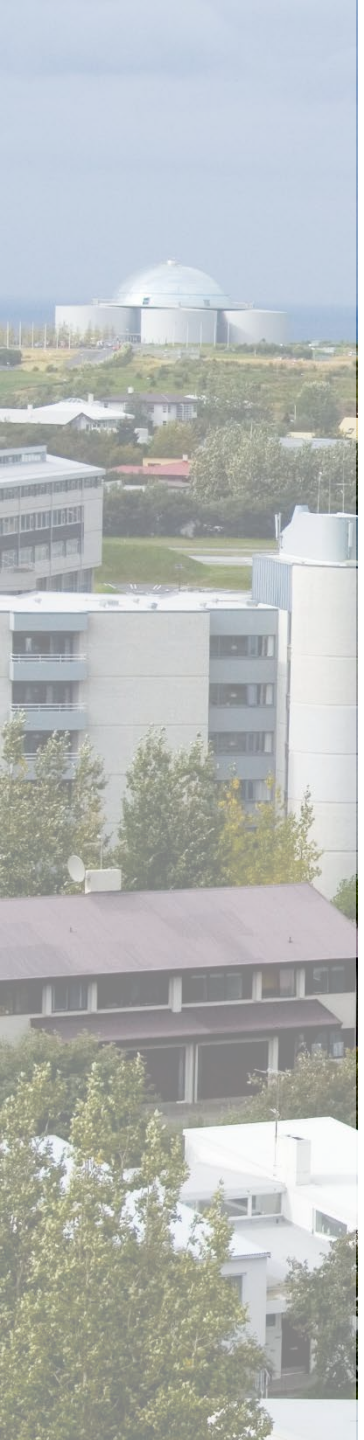
Cooling in an ice museum by geothermal energy, Chena Hot Springs, Alaska:
33 kW absorption chiller uses 5.4 l/s af 74°C geothermal water and 5 l/s af 4°C cooling water to keep -4°C indoor temperature.



Savings of CO_2 emissions in Reykjavik by geothermal heating



Source: Gunnlaugsson, 2015



Fuel oil and emission savings by geothermal direct use

Assuming that worldwide geothermal direct uses are replacing the use of fuel oil for heating, the current annual savings are (million tonnes per year):

	Fuel oil	Carbon	CO_2	SO_x	NO_x
If fuel oil would be used to produce electricity for heating	52.2	45.8	148.3	1.0	0.03
If fuel oil would be burned for heating directly	26.2	22.9	74.1	0.5	0.02

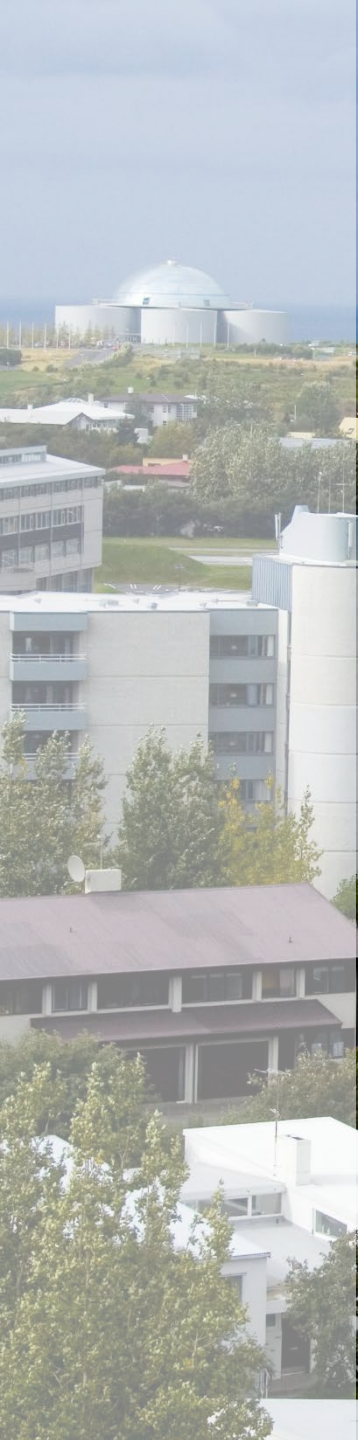
About 3.5 days of worldwide consumption (average)

About 1 days of worldwide emission (average)

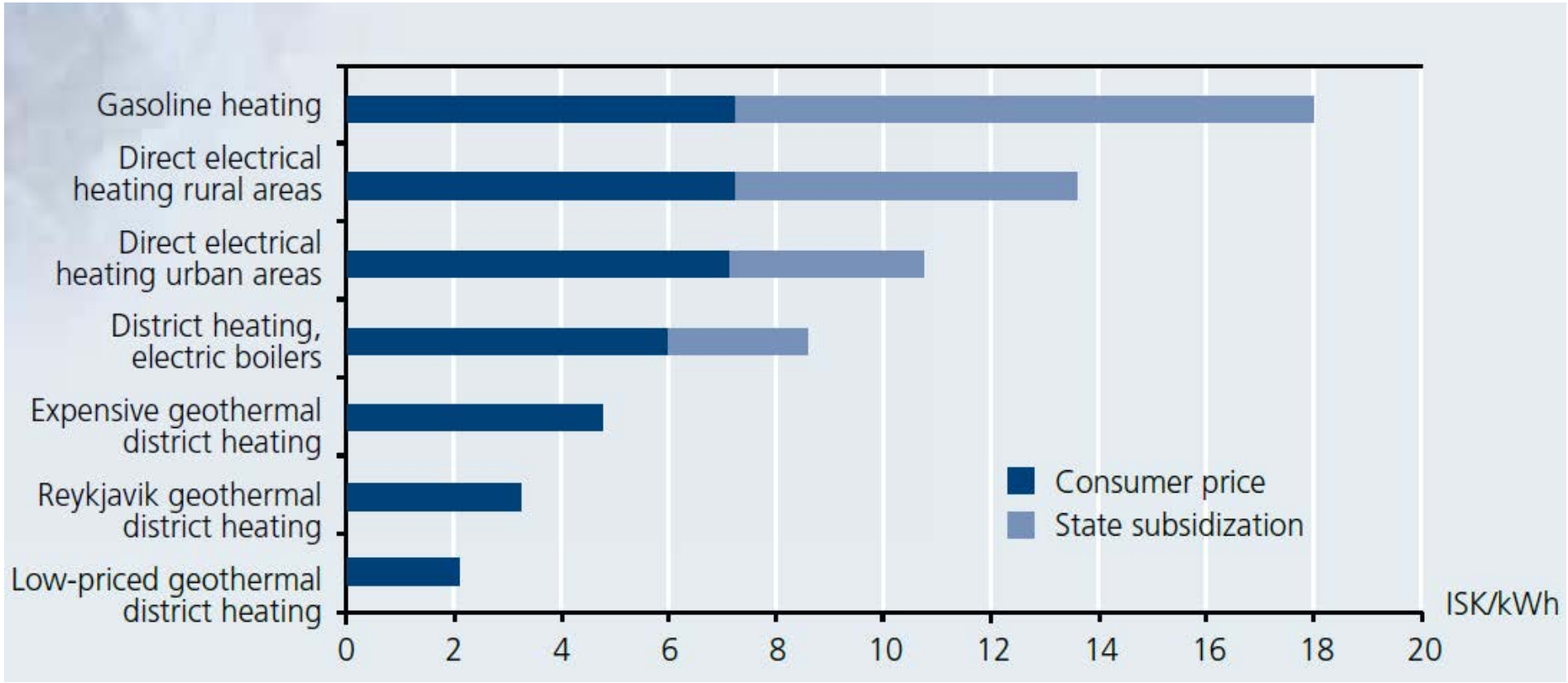
Assumptions:

- Efficiency 35% for electricity generation and 70% for direct heating
- Geothermal heat pumps in cooling mode are included
- Actual savings are somewhere between the two cases

Source: John Lund, WGC2015, Direct Utilization of Geothermal Energy 2015 Worldwide Review

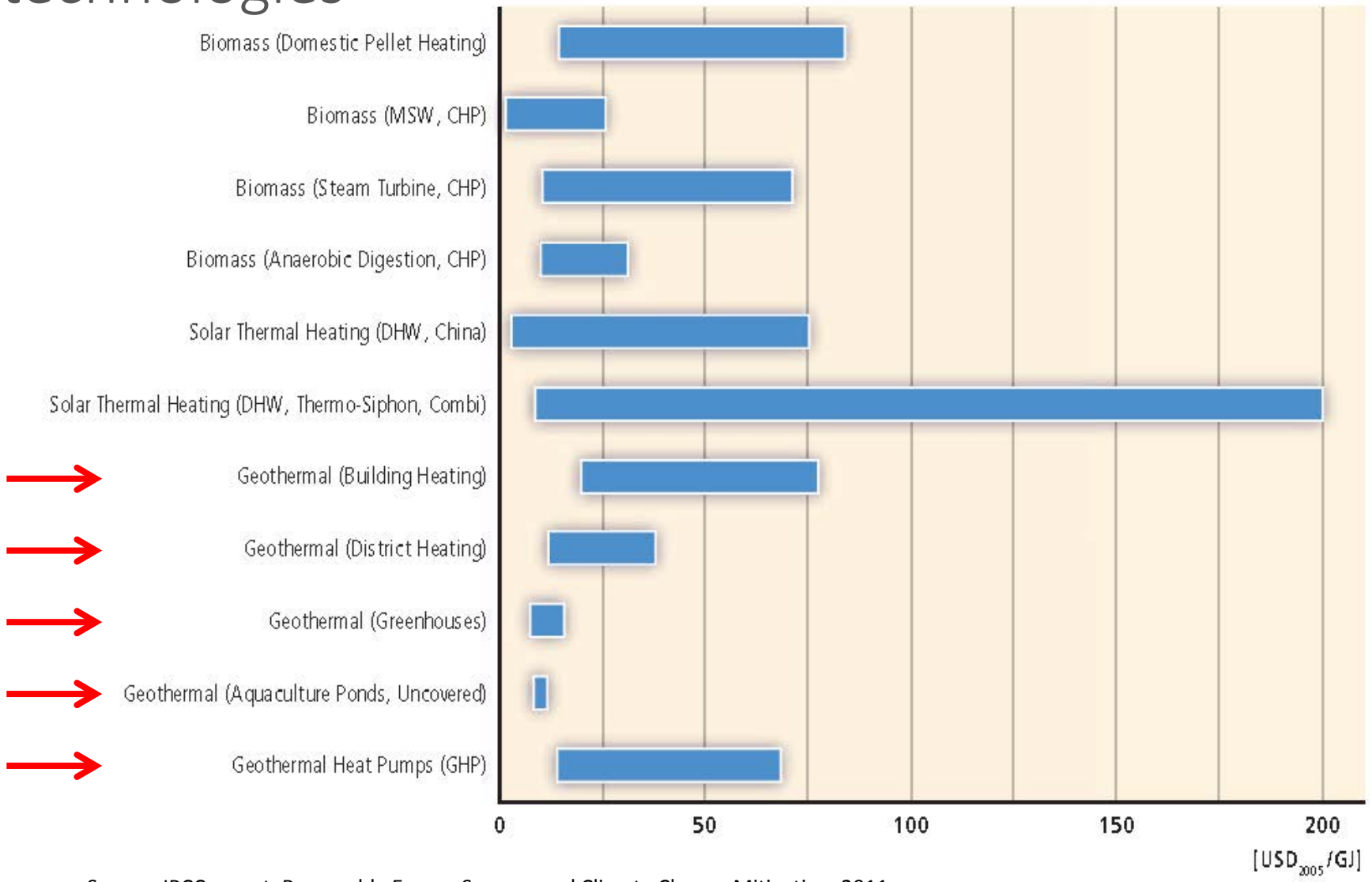


Energy prices for space heating in Iceland 2014



Source: Orkustofnun, Iceland

Levelized cost of heat (LCOE) for RE technologies



Source: IPCC report: Renewable Energy Sources and Climate Change Mitigation, 2011

Conclusions

- Increasing interest in “green” and “renewable” energy sources
- Geothermal direct-use is in main cases replacing fossil fuels and thus reducing greenhouse gas emissions
- Geothermal can make a major contribution to the world energy needs
- Geothermal heat pumps are the fastest growing direct use of geothermal energy – available anywhere for heating and cooling
- Low temperature combined heat and power plants using the binary cycle for power and cascading for space heating is gaining popularity
- However, “geothermal” is not well known and the benefits generally unknown – it needs to be promoted better


THANK YOU