Geothermal Energy

Lecture 3

Source: https://archive.epa.gov/climatechange/kids/solutions/technologies/geothermal.html

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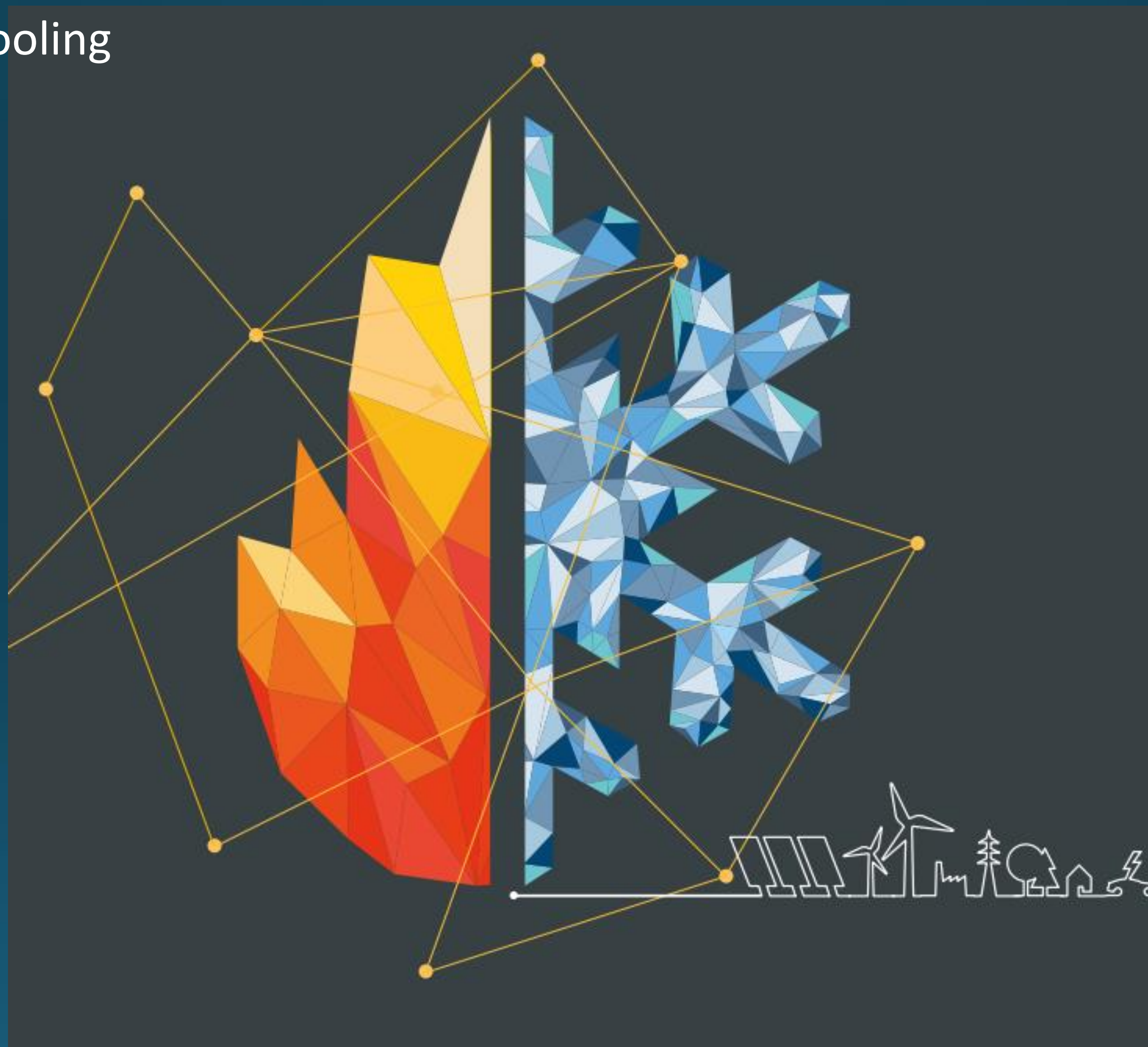
Geothermal Energy

Heating & Cooling



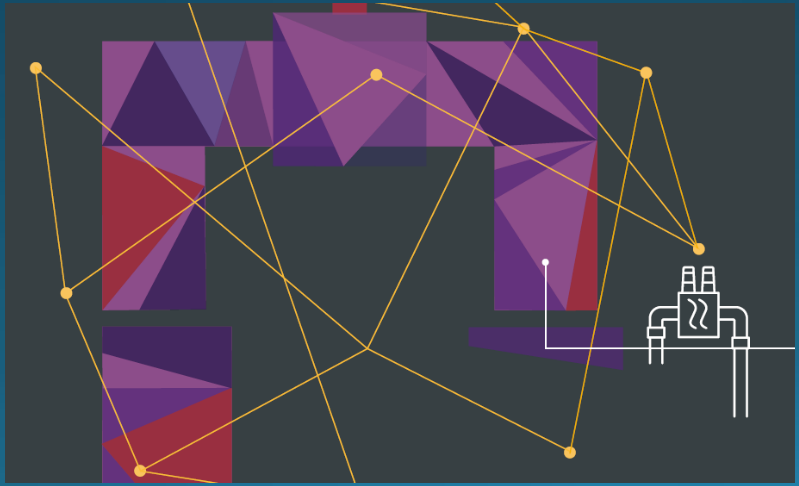
Source: www.irena.org

Heat Pump efficiency

The energy efficiency of heat pumps can be measured in several ways. Common ways are an instantaneous performance index called the coefficient of performance (COP) and the seasonal performance factor (SPF).

(COP) is the ratio of the energy output (the heat flow) to the energy input (the electricity consumed) at a given moment. A heat pump with a coefficient of performance of four, for example, is supplying 4 kWh of heat while consuming only 1 kWh of electricity. The 3 kWh of difference comes from the ambient heat extracted from the heat source.

(SPF) is the seasonal average of the coefficient of performance, expressing the ratio of the total heat supplied to the electricity used by the heat pump over a year.



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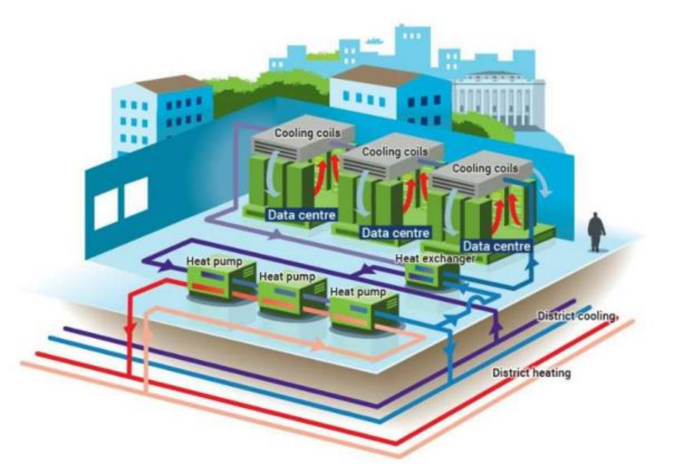
Heat Pumps: Heating & Cooling

Currently, heat pumps satisfy a minor share of residential heat demand – around 8% in 2021. Policies that can effectively accelerate their uptake include **fiscal and financial measures** such as loans, grants and subsidies.

China provided government subsidies equal to around 10% of the retail price of heat pumps, depending on their rated heating capacity and efficiency. As a result, over half million heat pumps were sold in 2019.

Heat pumps can also be combined with solar thermal preheating (as in some district heat networks in Denmark) or waste-heat recovery to further boost efficiency and reduce costs.



Source:https://heatpumpingtechnologies.org/annex47/wp-content/uploads/sites/54/2019/03/task3-report.pdf

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Heat Pumps figures

Almost 180 million heat pumps were used for heating in 2020, as the global stock increased nearly 10% per year over the past 5 years.

Although some are reversible units that only partially cover space and water heating needs, growth is evident across all primary heating markets – North America, Europe and Northern Asia.

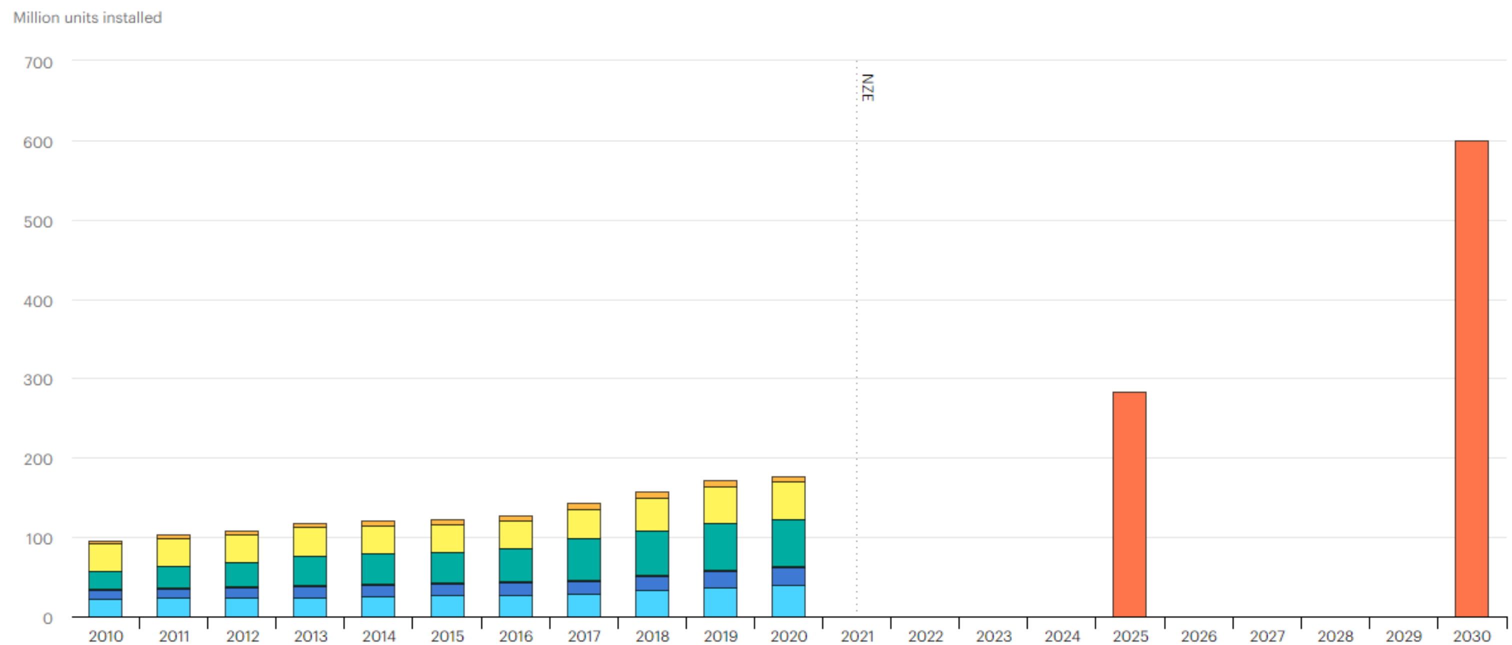
Heat pumps have become the most common technology in newly built houses in many countries, but still only meet 7% of global building heating demand.

Source: https://www.coolingpost.com/

https://www.iea.org/reports/heat-pumps

Geothermal Energy

In the Net Zero Emissions by 2050 Scenario, the installed heat pump stock reaches 600 million by 2030. Further policy support and innovation will be needed to reduce upfront purchase and installation costs, remove market barriers for renovations, improve energy performance and phase out refrigerants with high global warming potential.



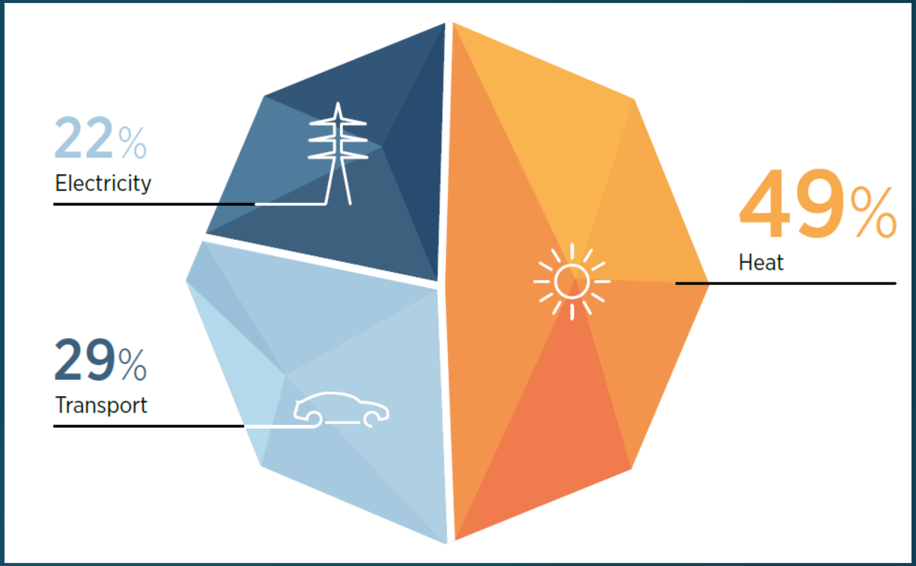
Installed heat pump stock by region and global Net Zero Scenario deployment, 2010-2030

https://www.iea.org/reports/heat-pumps

Renewable Energy

Heat Pumps: Heating & Cooling

Energy consumption (2019)



Source: www.irena.org

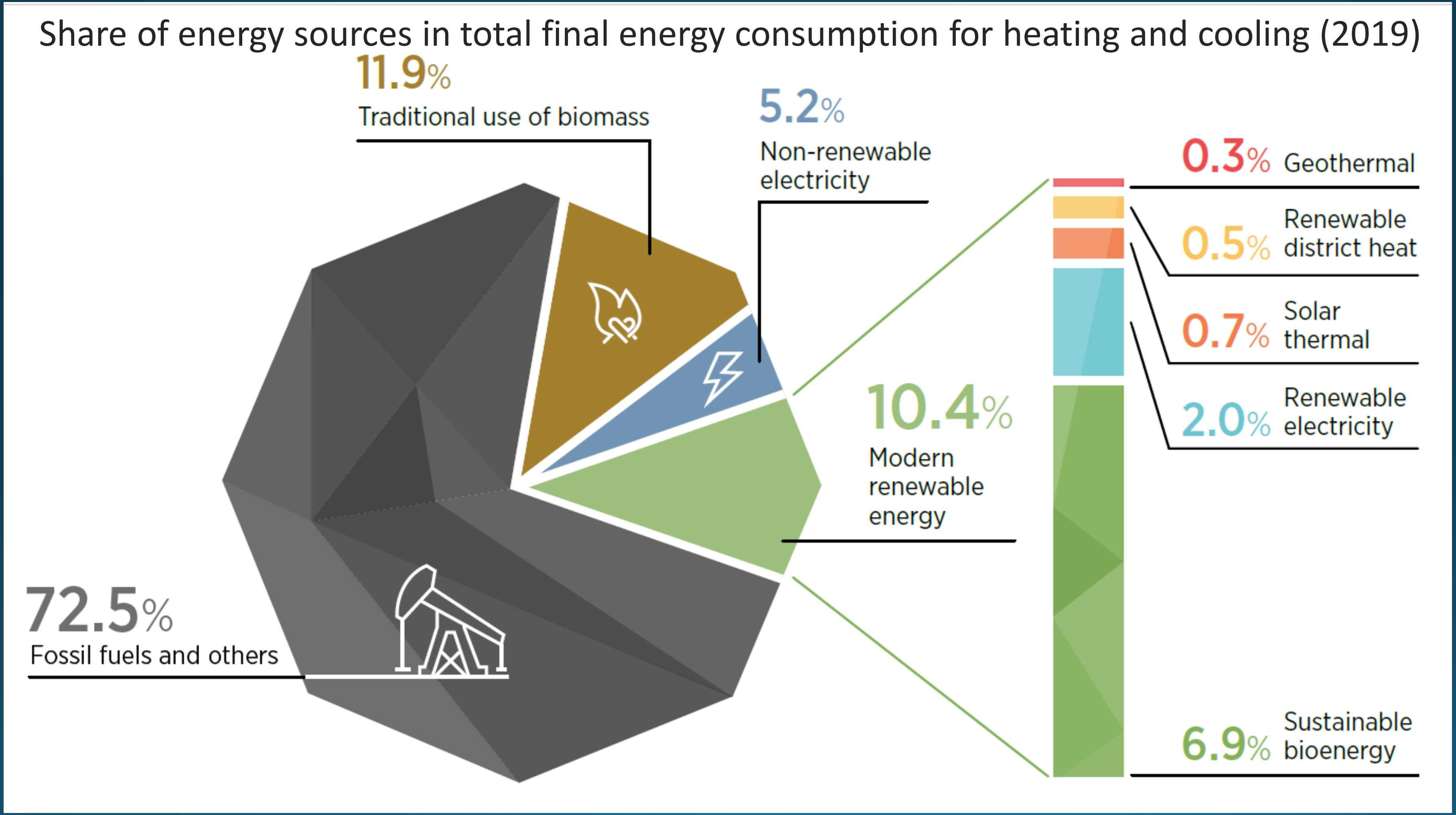
Renewable heating and cooling include direct renewables such as:

- bioenergy,
- geothermal,
- solar thermal heat,
- renewable district heating

Energy used for purposes of heating and cooling accounts for around 50% of total final energy consumption. Of this, around half is consumed in industrial processes, while another 46% is used in residential and commercial buildings – for space and Domestic Hot Water (DHW).

Renewable Energy

Heating & Cooling

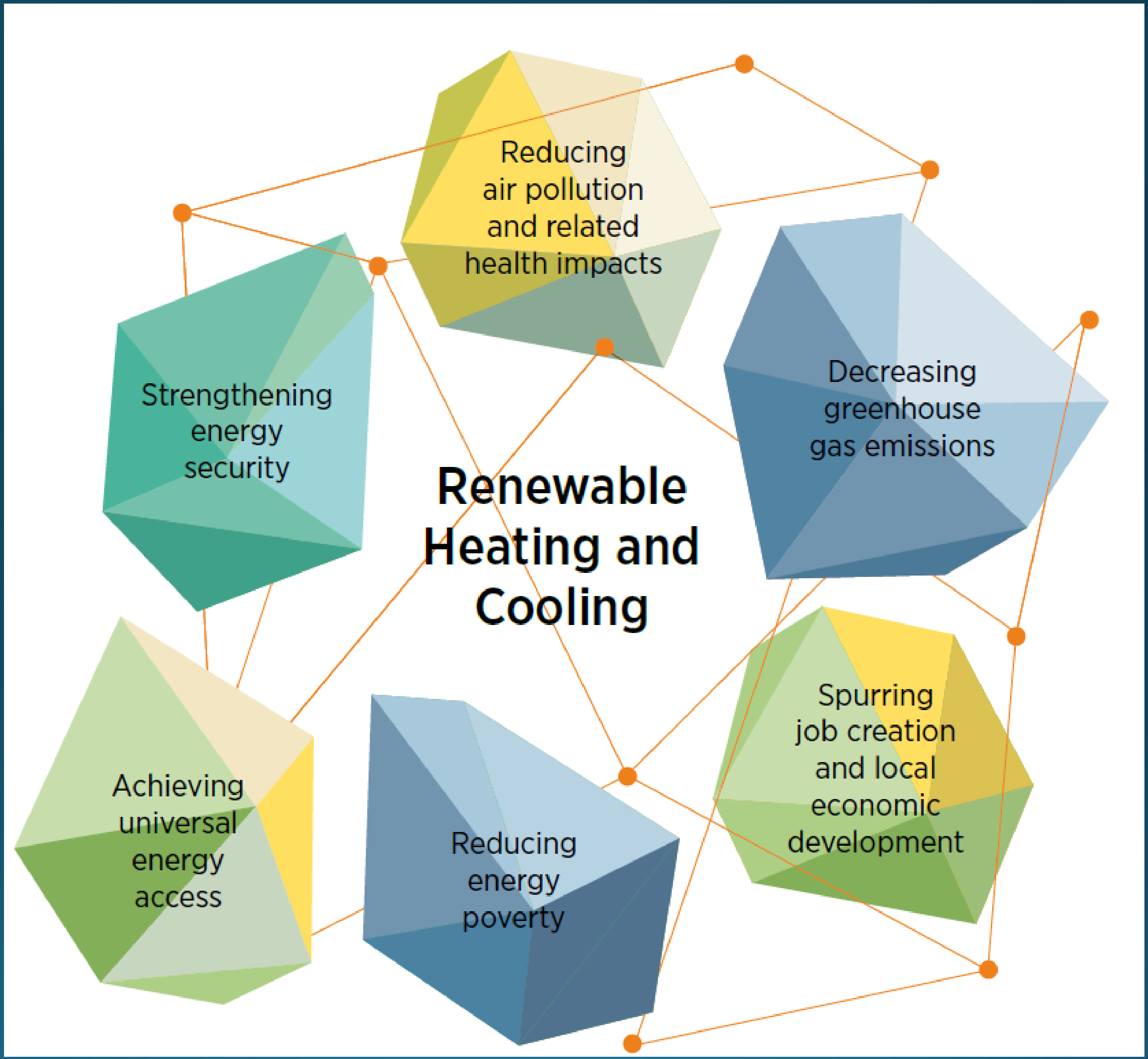


Source: www.irena.org

Renewable Energy

Heating & Cooling

Benefits of deploying renewable heating and cooling



Source: www.irena.org

Barriers of Renewable Heating & Cooling

Political and institutional barriers

- Lack of political commitment, including to universal access to energy
- Weak institutional structures (heat markets are complex, fragmented and not well understood)
- Inadequate data and statistics on types and amounts of energy required to meet heating and cooling needs
- Little awareness among decision makers of impact about the effects on the climate and the environment of using fossil fuels for heating and cooling
- Policy frameworks built around a fossil fuel-based energy system

Economic and financial barriers

Playing field with fossil fuels is still not level, owing to:

- Externalities not accounted for
- Persistent fossil fuel subsidies in many parts of the world

High upfront costs, including:

- Capital costs
- Cost of and access to finance
- Unbalanced tax burden

Other

Weak supply chains, including:

- Infrastructure and renewable fuels
- Shortages of trained personnel
- Lack of economies of scale

Consumer inertia and behaviour, resulting from:

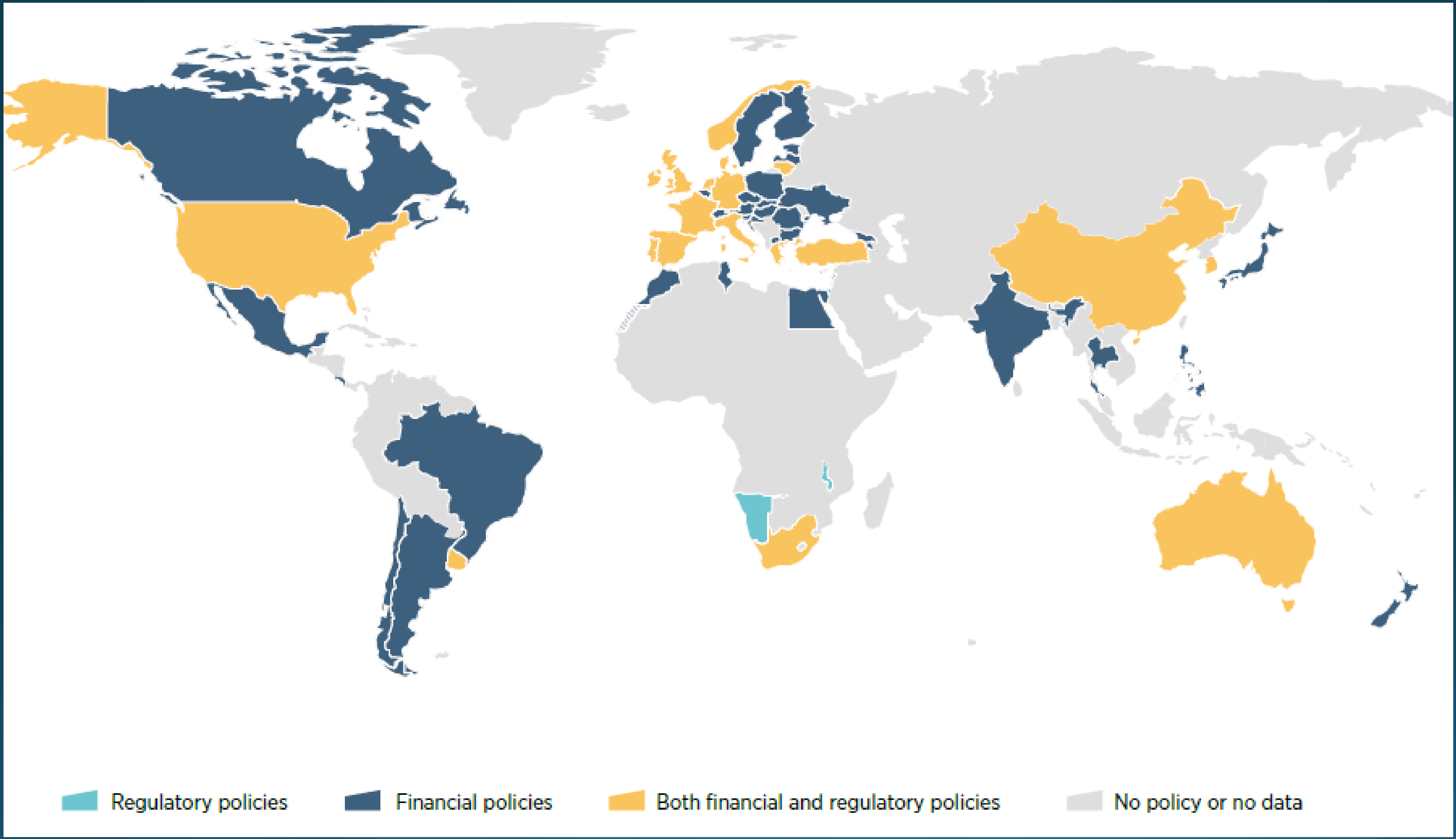
- Lack of awareness about potential and benefits
- Distressed purchase
- Disruption and "hassle costs"
- Split incentives

Technical barriers, including:

- Building suitability
- Industrial heat requirements
- Reliability of technology

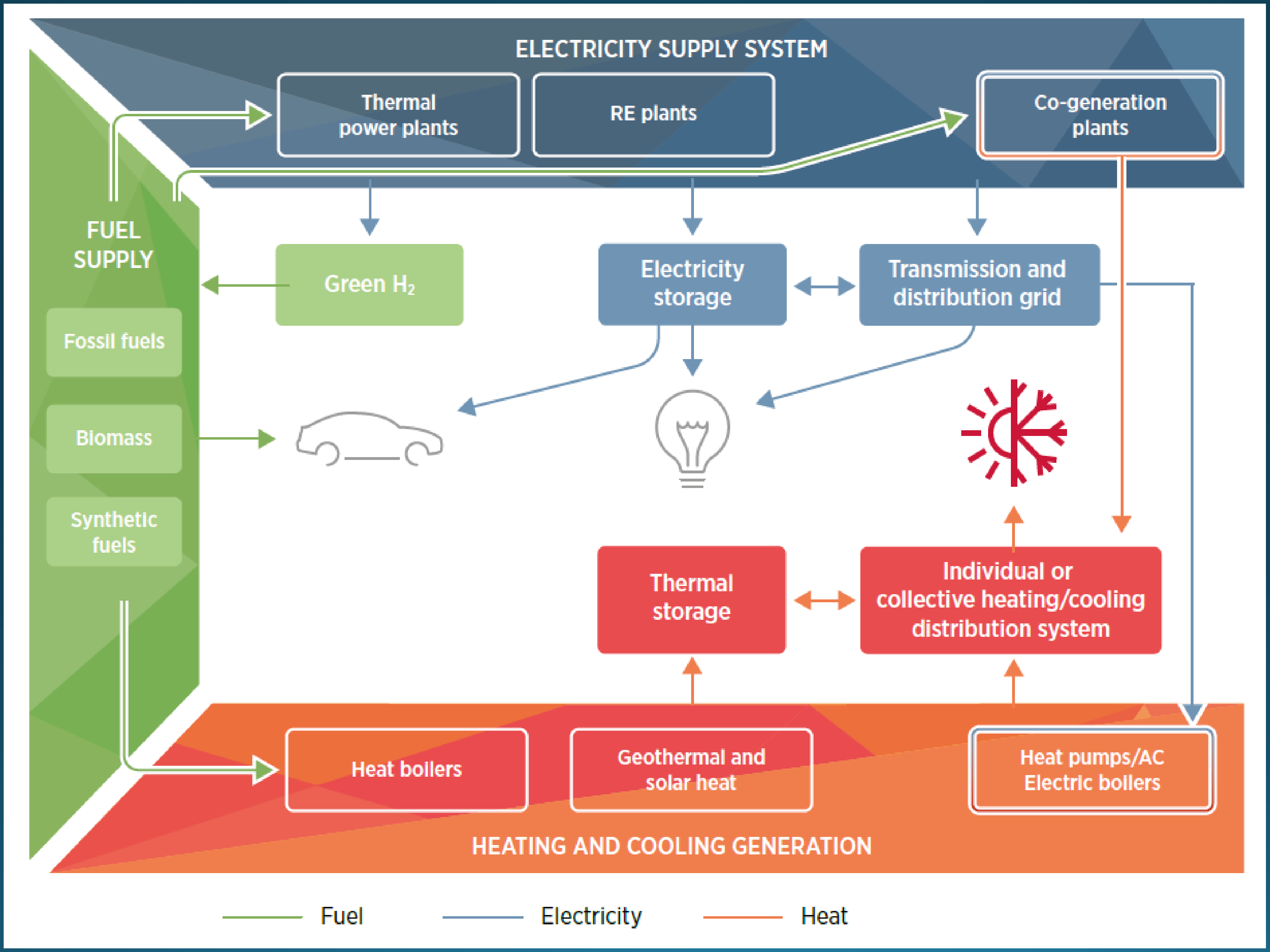
Source: www.irena.org

Policies for Renewable Heating & Cooling



Source: www.irena.org

Coupling power with heating and cooling



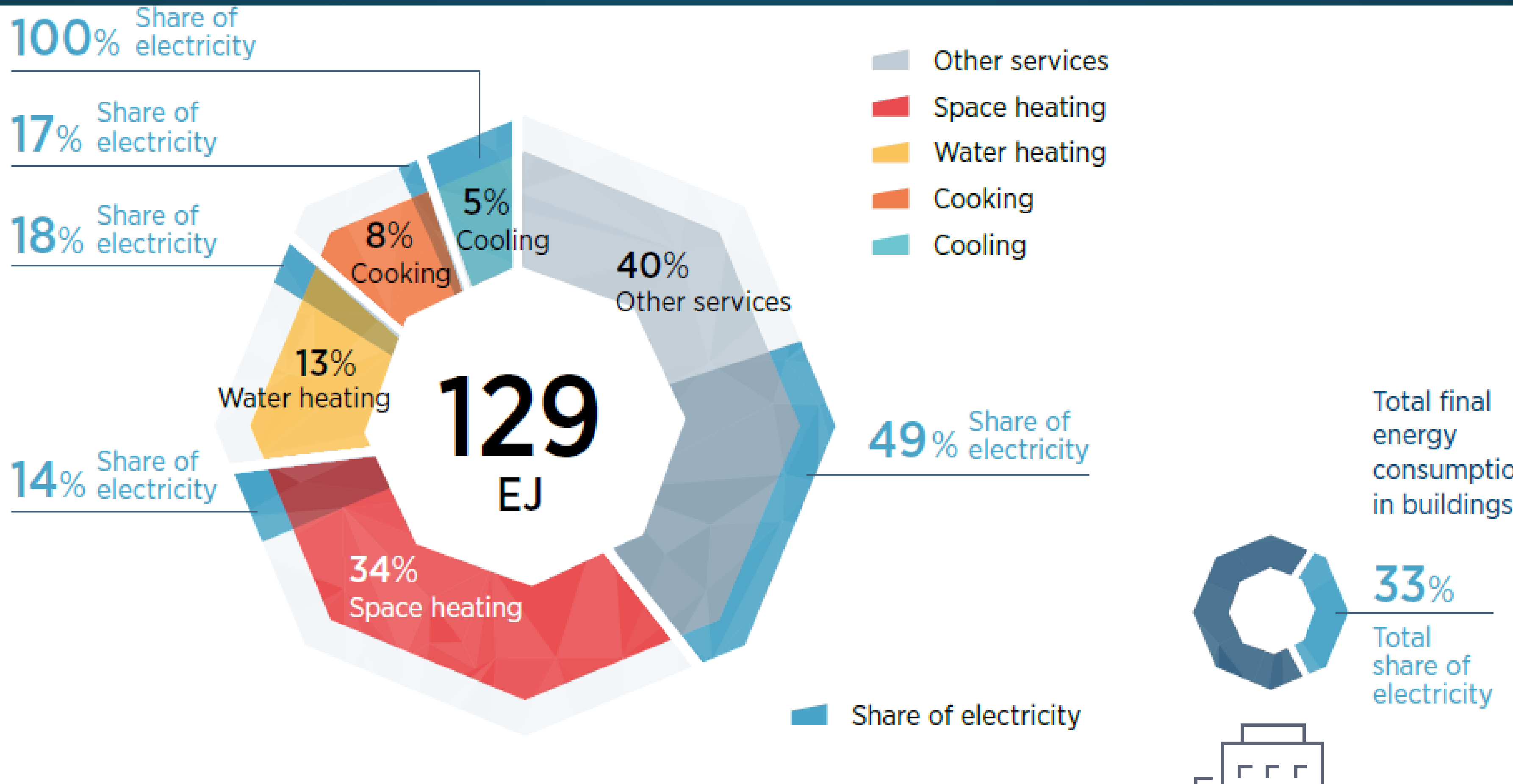
Source: www.irena.org

More incentives needed…

In China, government subsidies encouraged the uptake of decentralised electric heat pumps as part of a strategy to eliminate coal-fired boilers. Eligible buyers could receive subsidies of USD 42 to 84 (CNY 300 to 600), around 10% of the total retail price, depending on the rated heating capacity and efficiency. As a result, over half million air-source heat pumps for water heating were sold in 2018 (CHPA, 2019;Zhao, Gao and Song, 2017).

Germany’s Market Incentive Programme offers grants for small-scale renewable heat systems. The overall programme, which also includes low-interest loans for industry and district heating, offers EUR 300 million per year in grants and loans. More than 1.8 million systems were funded between 2000 and 2020, about 100 000 units per year (BMWI, 2020). However, in comparison, more than 600.000 fossil fuel boilers (oil or gas) were sold in 2019 alone. Indeed, in Germany, heat pumps and biomass boilers made up just 15% of the annual boiler market (BDH, 2020).

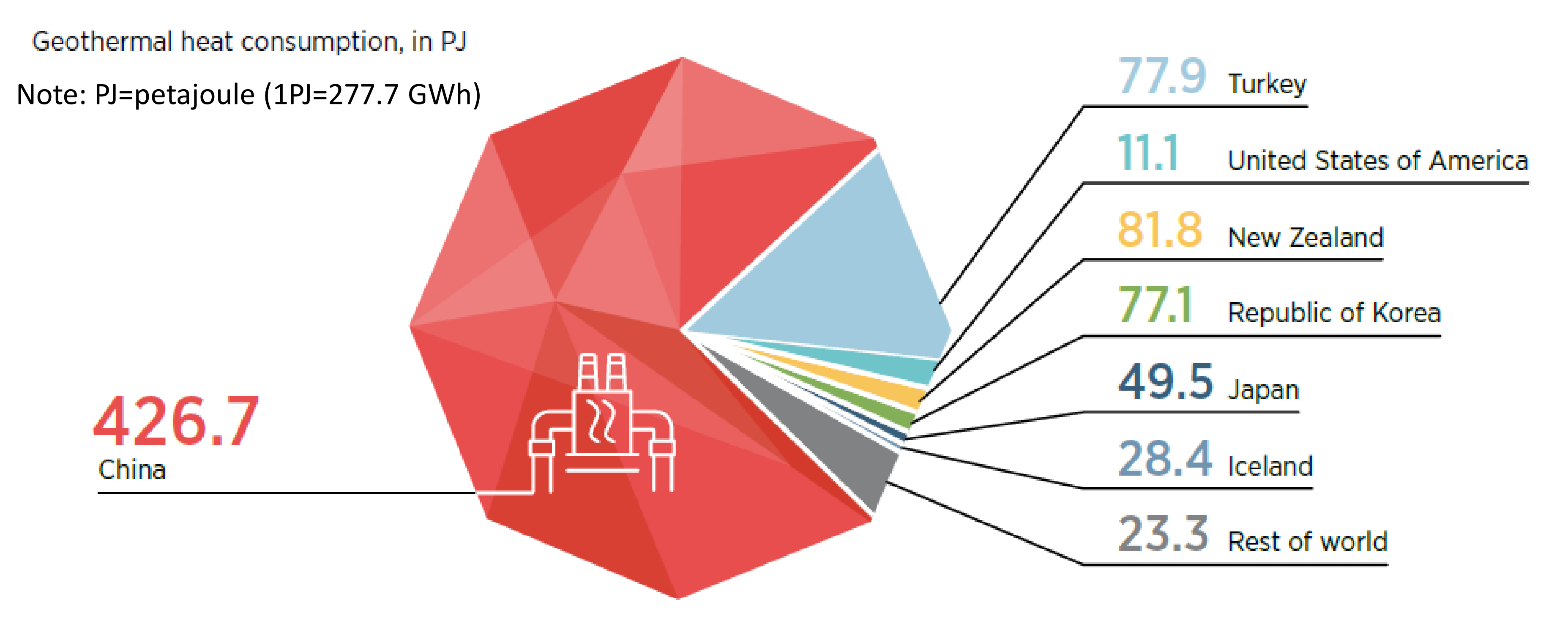
Buildings: massive energy consumption



Source: IEA, 2020b.

EJ (Exajoule) is a unit of energy equal to 1.0E+18 **joules**

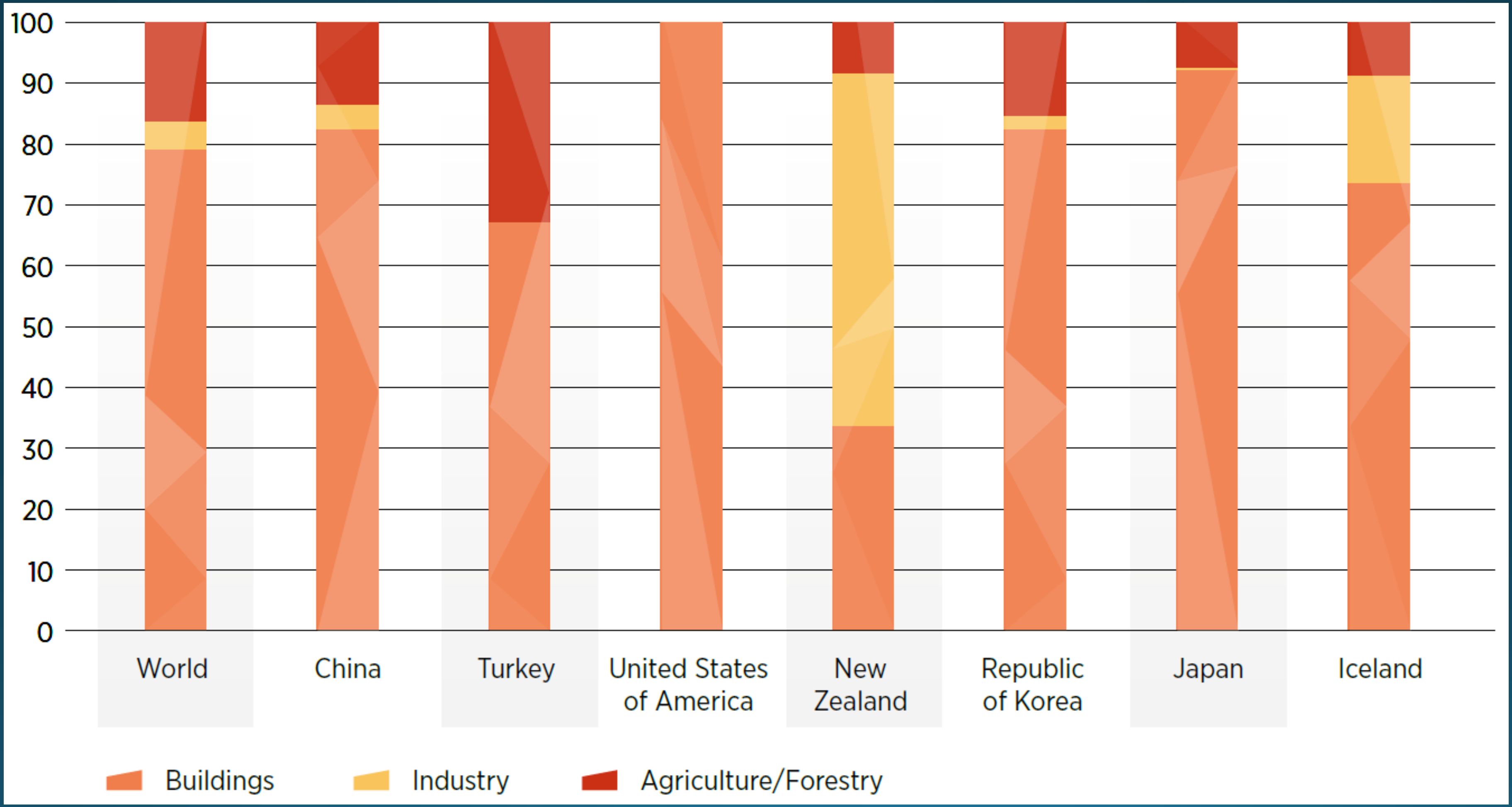
Geothermal heat consumption



Source: www.irena.org

Geothermal distribution (heat consumption %) by sector

Geothermal energy consumption varies depending on resource availability and structure of the economy



Source: www.irena.org

Barriers to Geothermal Heat

- High upfront investment cost
- Risks related to the evaluation of geothermal resources
- Securing funding for surface exploration and drilling operations
- Inadequate policy and regulatory frameworks
- Shortage of a qualified workforce
- Transporting geothermal heat for long distances from geothermal wells may not be economically viable.
- Distance (need to find nearby direct-users for the thermal energy)
- Administrative constraints (issuance of licences)
- Different countries – different regulations for performing environmental & social impact assessments.

How to overcome barriers to the direct use of Geothermal Heat

Targeted barriers	Policies	Examples	Comments
Low investor confidence owing to uncertainty about long-term market development	Roadmap and action plans	**China**'s action plans for renewables-based heating	Credibility depends on consistency of the policy system.
Technical barriers related to geothermal applications	Research, development and demonstration	**Switzerland**'s support for research and development to advance its programme on geothermal energy for industrial use	Demonstration projects, by their very nature, entail uncertainty about costs and the proper functioning of technologies.
Lack of demand stemming partly from the lack of public awareness of available options and benefits	Public campaigns, information-sharing activities	Public campaigns on geothermal energy in the **United States**	Campaigns can be more effective when they showcase the results of successful demonstration projects.

Source: www.irena.org

How to overcome barriers to the direct use of Geothermal Heat

Targeted barriers	Policies	Examples	Comments
Lack of demand stemming partly from the lack of public awareness of available options and benefits	Public campaigns, information-sharing activities	Public campaigns on geothermal energy in the **United States**	Campaigns can be more effective when they showcase the results of successful demonstration projects.
Lack of information on geothermal resources	Data collection and sharing	The **European Union**'s geothermal data platform	Synergies with mining industries offer potential benefits.
Risks related to the exploration of geothermal resources	Risk insurance funds or loans	Risk insurance for drilling in the **Netherlands**	Feasibility depends on competing budget requirements.
High operational costs	Heating tariffs	The **United Kingdom**'s renewable heating incentives for non-domestic uses	Payment per kilojoule requires a specific metering device for heat uses. Policy attention is needed to avoid inefficient consumption.

Source: www.irena.org

How to overcome barriers & boost productivity using Geothermal Heat

Targeted barriers	Policies	Examples	Comments
High upfront costs to purchase and install technologies; difficulty accessing finance	Tax incentives (tax and duty exemptions)	Tax exemptions for companies in the Olkaria geothermal area in **Kenya**	Effectiveness depends on clear and specific regulations to avoid competing technologies and fuels from benefitting.
Technologies may process more than the average smallholder farmer can produce	Farmers' collectives	The Geothermal Development Company in **Kenya**	The desire and ability to create farmers' collectives are country specific.
	Early-stage assessment of productive use activities	Olkaria's geothermal feasibility study	Effectiveness depends on community engagement during the planning phases.
Dependence on multiple variables (*e.g.* farmers' experience, crop quality, market access) to ensure success of productive use activities	Integrated resource management plans	**Kenya**'s integrated geothermal energy and rural development plans	Effectiveness depends on interministerial co-ordination and implementation.

Geothermal grain dryer in Menengai, Nakuru (Kenya), cut their drying costs by at least 50%

Source: www.irena.org

Geothermal Heat district heating (DH) & cooling

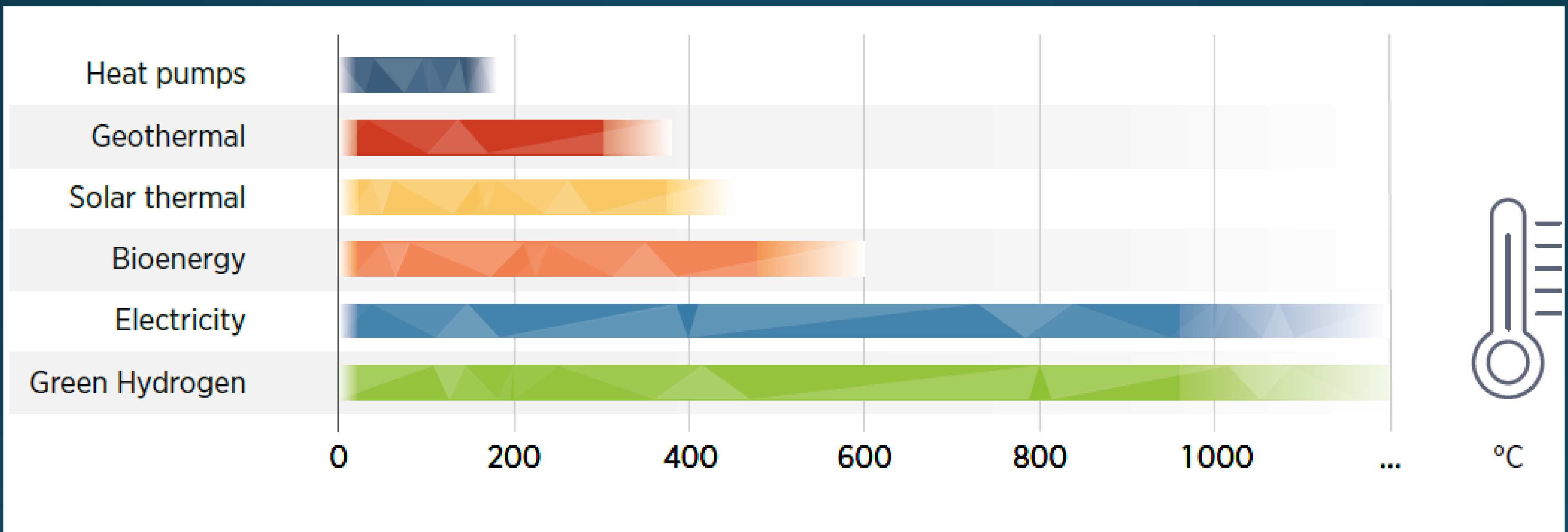
Denmark, Germany, Iceland, Norway and Sweden all offer financial incentives for investment in DH infrastructure.

The German CHP Act of 2016 offers subsidies for district heating based on the length and diameter of the pipe, up to an annual maximum of EUR 1.5 billion.

The subsidy programme has led to significant investment in new and existing district heating systems.

Germany's capital investments in refurbishing existing pipes are aimed chiefly at permitting the use of hot water instead of steam in Dortmund, Hamburg, Leipzig and Munich, among other cities. The use of hot water reduces energy losses and allows for lower operating temperatures. In Munich, this process is expected to increase the share of geothermal heat and help meet the city's goal of 100% renewable district heating by 2040.

Working temperatures for various renewable heat technologies



Source: Adapted from IEA

Case studies
Arnhem Netherlands – 96 small houses
Solar PV & ASHP

Location	Arnhem, the Netherlands
Number of houses	96
Number of households	400
Installation/Commissioning	2015
Expected lifetime	20 years
Investment costs	€10,000 to 12,000€ (energy module)
Investment support	Sustainable energy investment subsidy scheme (ISDE)
Operation support	Energy performance fee
Type of heat pump	Air-to-water, 8kW (max)
Coefficient of performance	>3
Yearly energy output (per heat pump)	12.8 MWh
Space heating	Wall radiators, hydronic distribution system, 40°C
Domestic hot water (per house)	185-litre storage system, 53°C to 58°C

Case studies
Drammen Norway– District Heating System

The world's largest zero carbon 90°C district heat pump to provide heat for Drammen, a Norwegian city of 64,000 people. The heat source for the heat pump is sea water. The installed heat pumps cover 85% of the Drammen district heating heat demand. The heat supplied is modulated from 2 MW during summer to 13.2 MW in winter with a peak up to 15 MW using gas boilers. Even with such a large temperature difference between the sea water as heat source and the district heating water loop, the heat pump installation can deliver a pretty constant COP all over the year of 3.05 for the water at 90°C. There is an estimated saving of 2,690,000 € per year.

	Summer	Winter
Heating Capacity	2 MW	13.2 MW
Heat source	Sea water cooling from 8°C to 4°C	
Heat sink- Water loop temperature	60 °C to 80°C	60°C to 90°C
COP	2.80	3.05

Source: https://www.star-ref.co.uk/sectors/district-heating/

Case studies

V&A Museum of Design, Dundee – Heat Pumps - boreholes

The heat pumps provide direct renewable energy for the museum, with 800,000 kWh a year of heating and 500,000 kWh a year of cooling for an 8,000m² building. Thirty 200 metre deep boreholes allow heat pumps to draw heat from the ground to provide heating in winter. In summer the heat pumps transfer excess heat from the building down to the borehole field: this not only provides efficient cooling, it also stores heat in the ground for the winter when it will be recycled back to the museum to provide heating. This building is run by the sun.

Source: https://www.gshp.org.uk/GSHP_Case_Studies.html

Case studies
Rotokawa Geothermal Power Station, New Zealand

It provides about 34 MW of electricity, source steam.

The steam is hot (230°C) and high pressure (26 bar) and is used to power the main steam turbine producing 16 MW.
Secondary to the main 16 MW steam turbine there are four binary turbines (total 17.5MW) which generate enough electricity for about 18.000 homes.

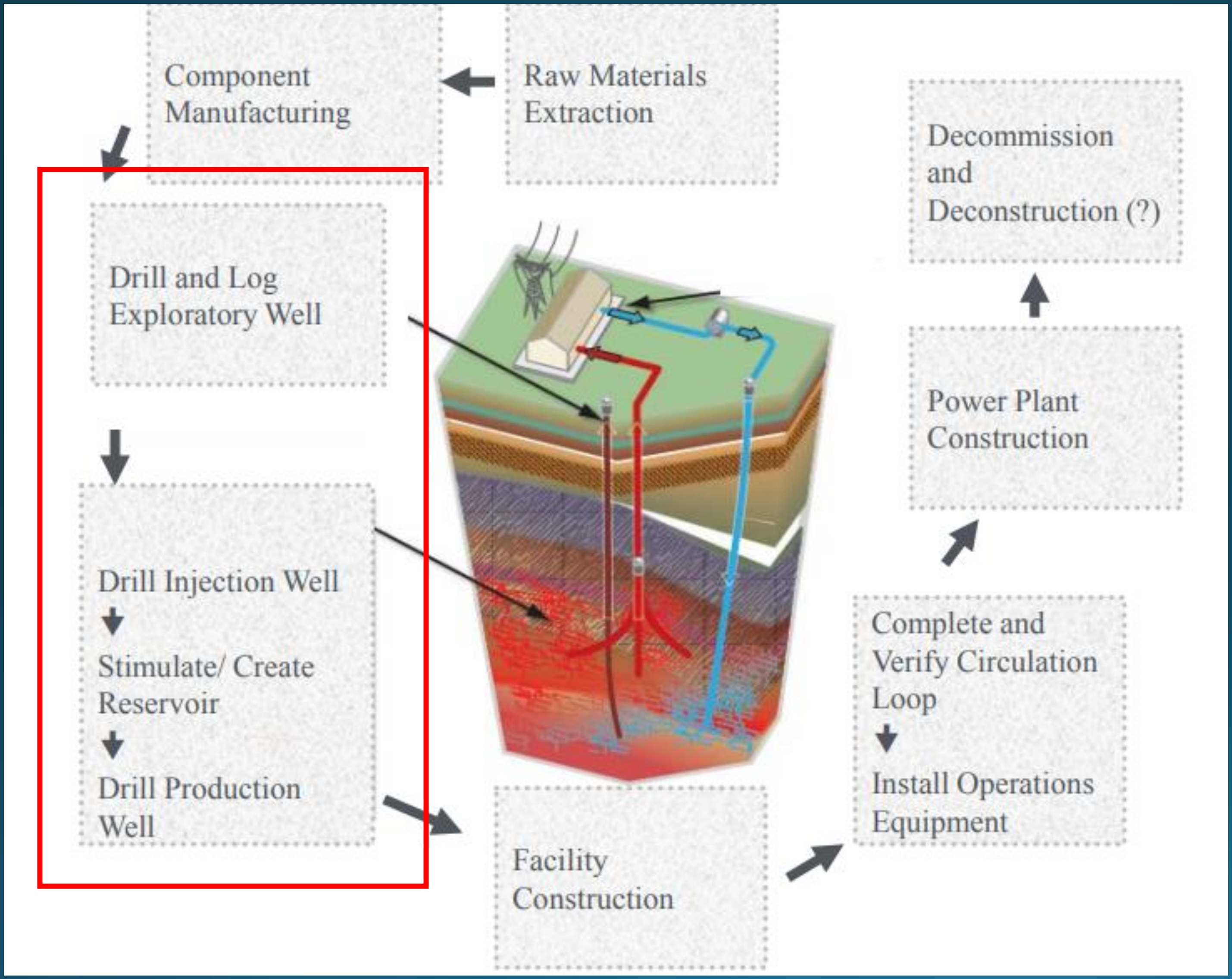
Source: https://www.gns.cri.nz/Home/Learning/Science-Topics/Earth-Energy/Case-Studies

Case studies
Seawater used for district cooling in Stockholm, Sweden.

- Cools over 600 buildings in central Stockholm (offices, hospitals and universities)
- 204 km distribution network
- 242 MW capacity which results in 408 GWh per annum output.
- Two sea water inlets feed the cooling plant, located 4 km from the city; one on the sea bed at 20 m depth and one at the surface.
- The cool water is pumped 4 km to central Stockholm then through the city's distribution network.

Source: https://www.gns.cri.nz/Home/Learning/Science-Topics/Earth-Energy/Case-Studies

Life cycle analysis for Geothermal Technologies



Temperature of the resource

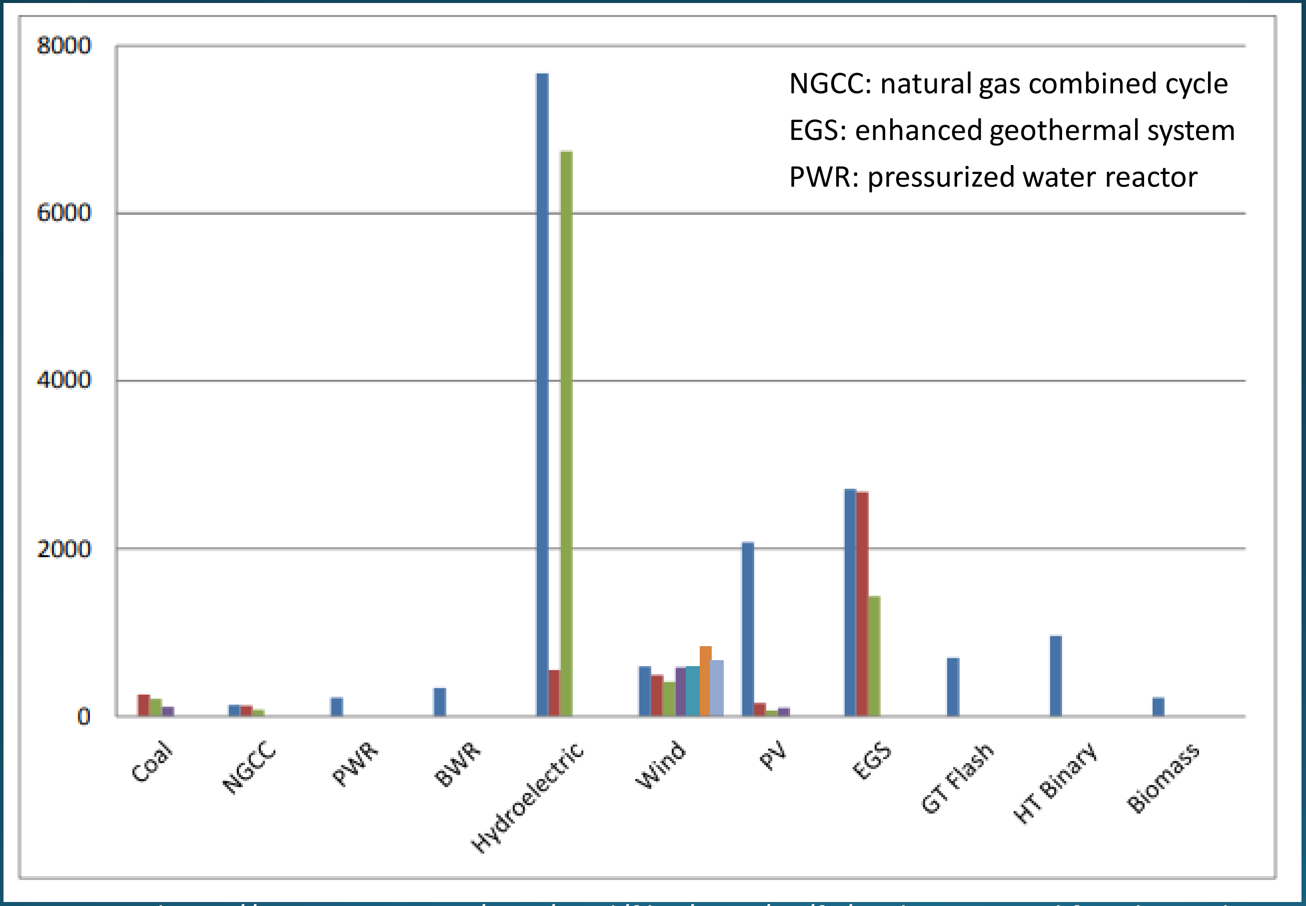
Well depth

Flow rate

Source:https://www.energy.gov/sites/prod/files/2014/02/f7/analysis_wang_lifecycle_analysis.pdf

Life cycle analysis for Geothermal Technologies

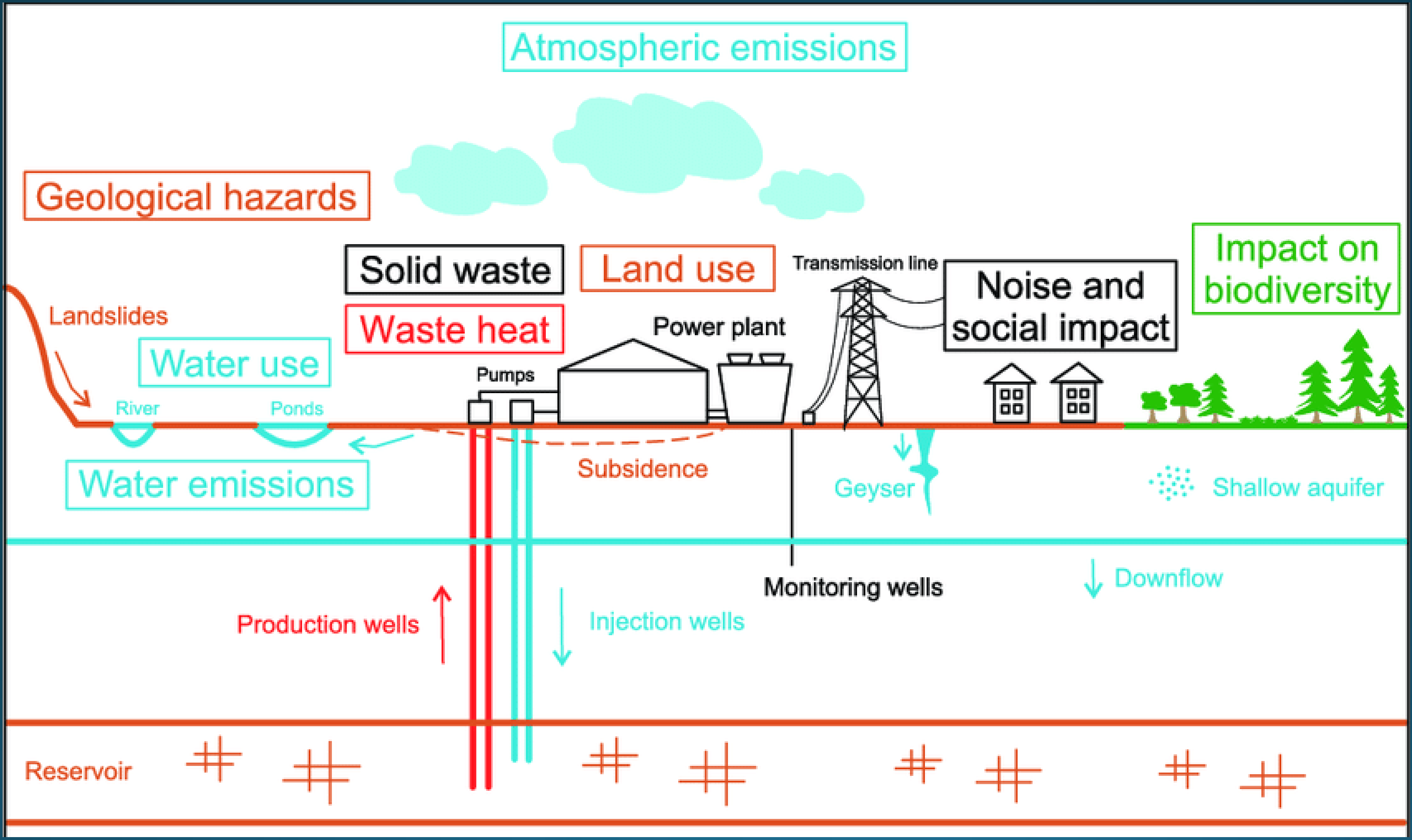
Plant Material Intensity. Total compositional mass (Steel use in tonnes/MW)



Source: https://www.energy.gov/sites/prod/files/2014/02/f7/analysis_wang_lifecycle_analysis.pdf

The provided quantities of structural steel, concrete, various sizes of pipes and wire and equipment were converted to weights of concrete, steel, copper, aluminium.

Life cycle analysis for Geothermal Technologies
Environmental effects



Source:https://www.researchgate.net/publication/257099959_Review_on_life_cycle_environmental_effects_of_geothermal_power_generation/figures?lo=1