Distinguished Lecture

GLOBAL ENERGY TRENDS AND THE ROLE OF GEOTHERMAL ENERGY

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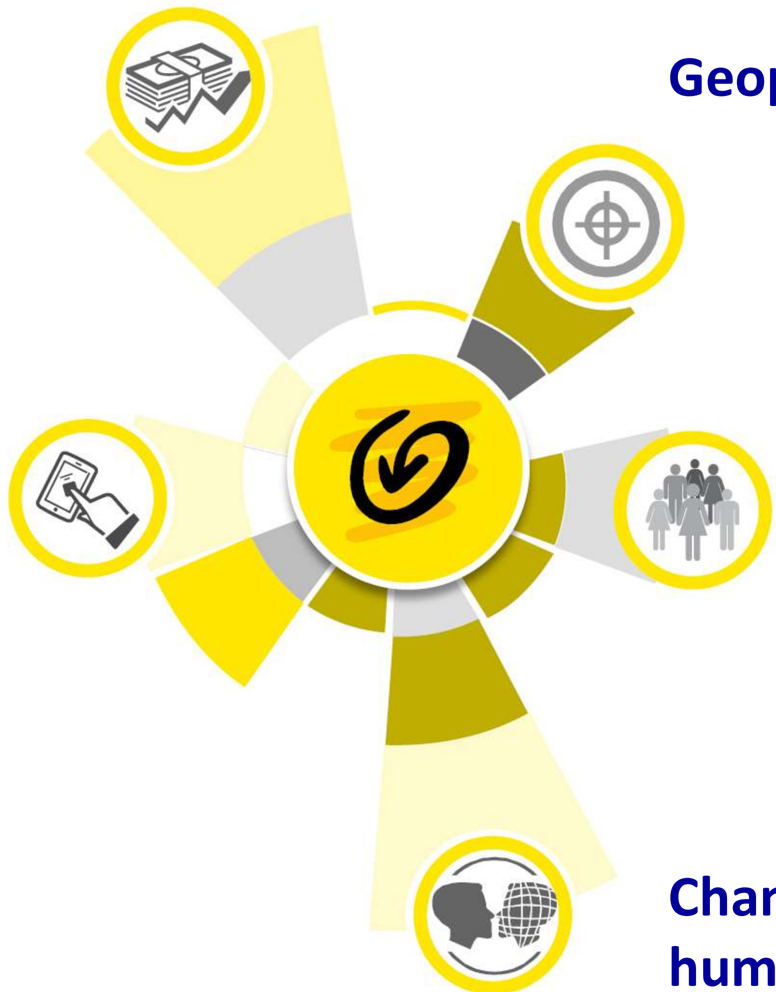
GLOBAL TRENDS IN ENERGY

Economy moves in a context conditioned by numerous factors



Geopolitical uncertainty

Technological Revolution

New social models

Changing of the human behavior

Source: EY

GLOBAL TRENDS IN ENERGY

The change of people and social models mutate the business model of companies and transform cities

Consumer ⟵  ⟶ Citizen

72% **Experience**
Millennials buy experience, not goods

150 **Constant Connection**
Times/day we check our devices

89% **Fidelity**
Change the brand if not satisfied

66% **Big Cities**
Population will live in cities in 2050

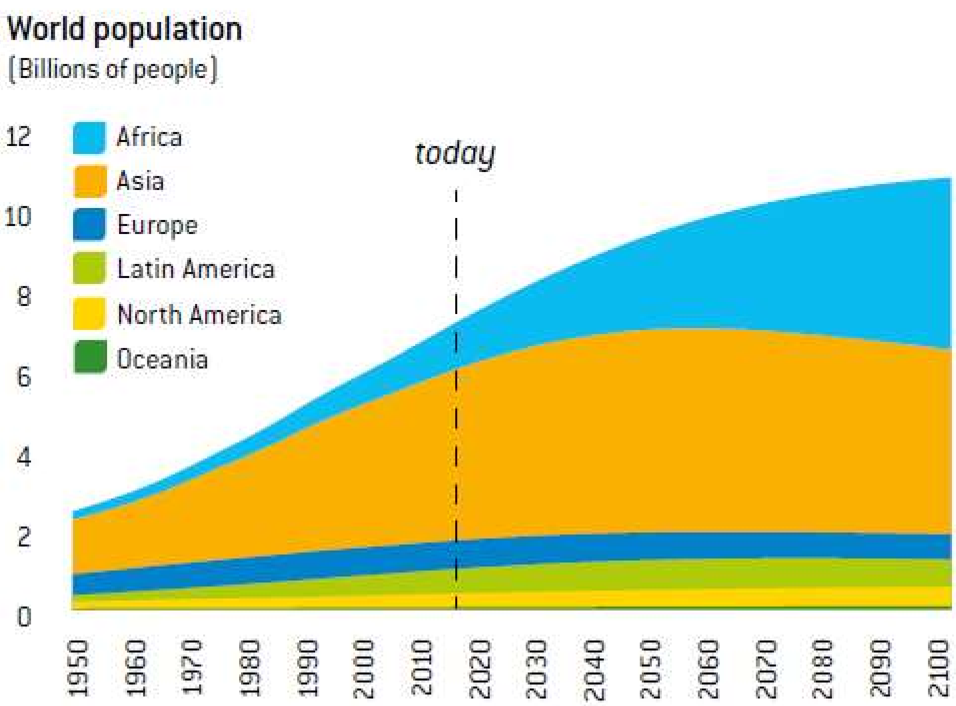
56% **Sharing**
Miles of shared vehicles in 2030

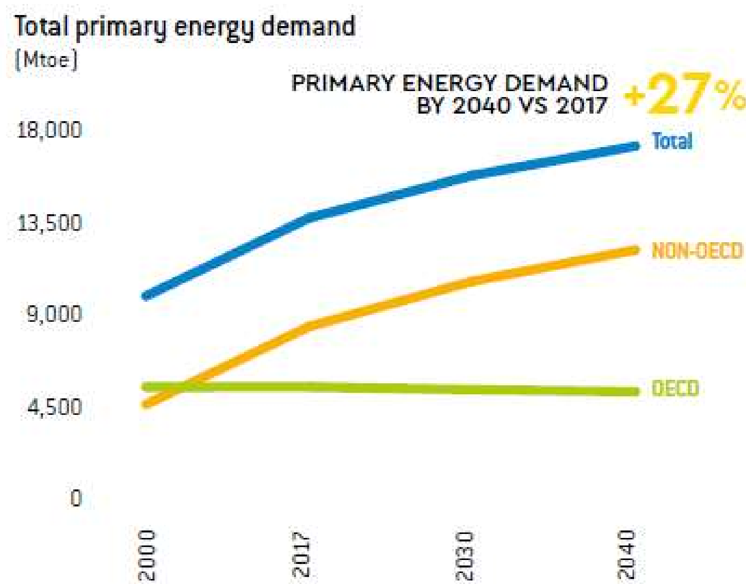
Source: EY

GLOBAL TRENDS IN ENERGY

The fundamental driver behind the increasing consumption

- By 2040 world population will exceed 9 billion people
- Global energy demand is expected to grow by 27% by 2040 compared to 2017 levels, driven mainly by non-OECD Countries (+45%)



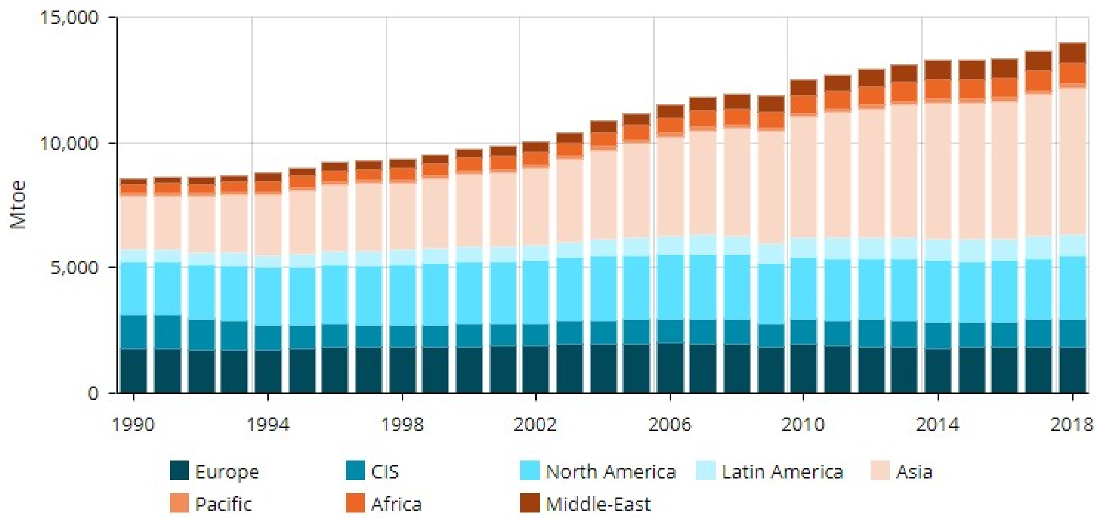


Source: UN (2017) and IEA (2018)

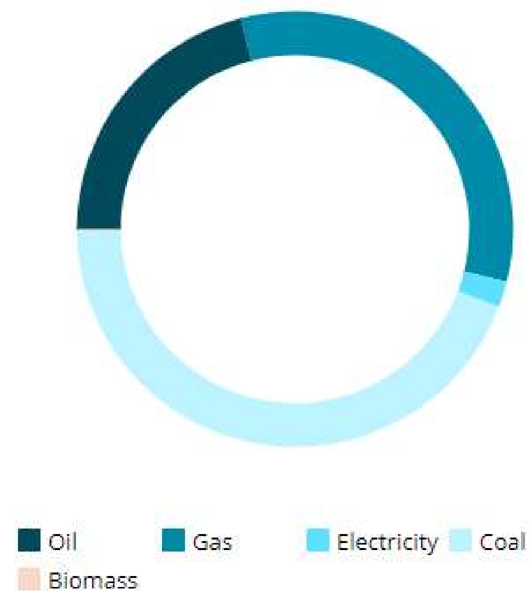
GLOBAL TRENDS IN ENERGY

Acceleration in energy consumption

Acceleration in energy consumption in 2018 (+2.3%) driven by high growth in electricity and gas demand.



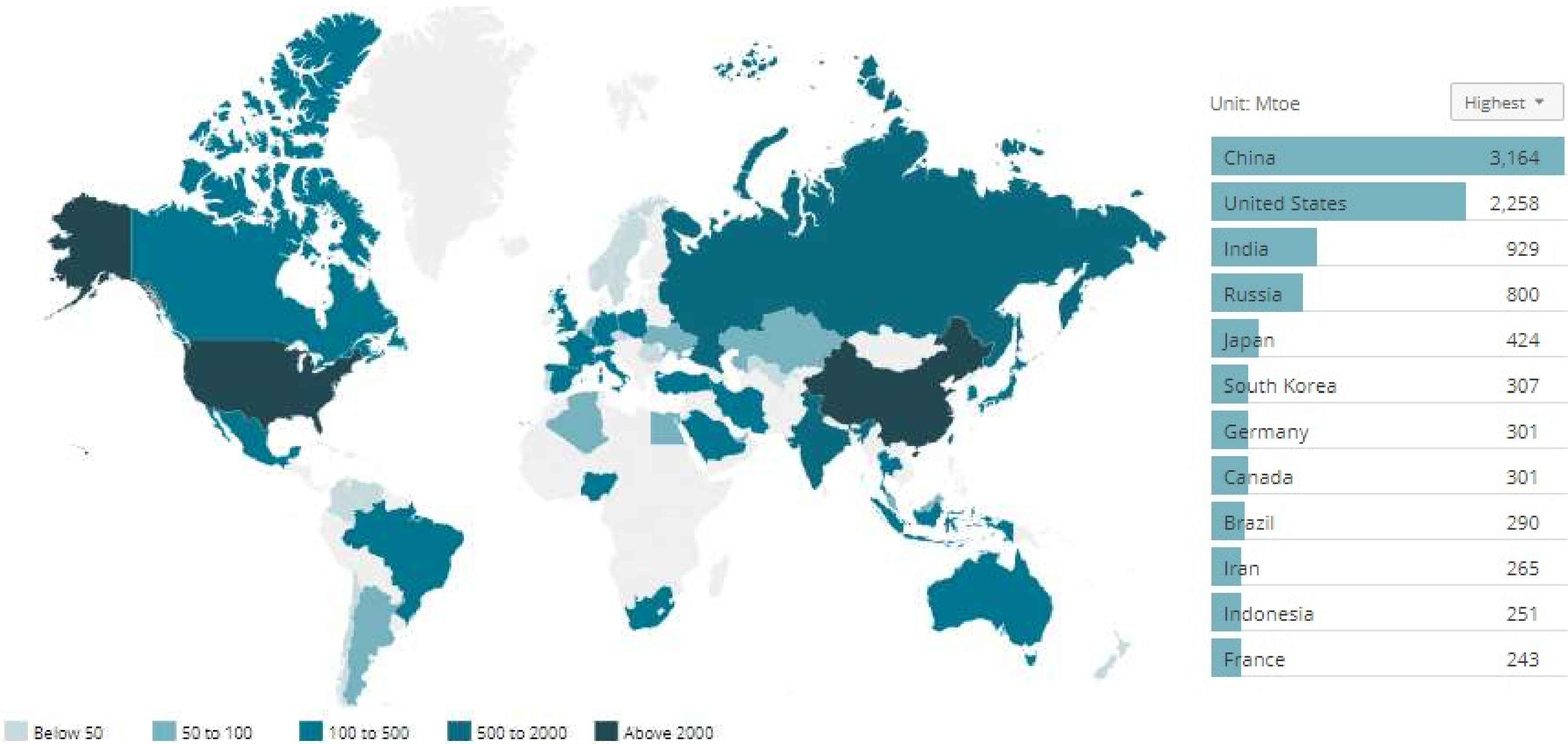
Energy consumption trend over 1990 - 2018



Breakdown by energy type (2018)

Source: Enerdata, 2019

GLOBAL TRENDS IN ENERGY



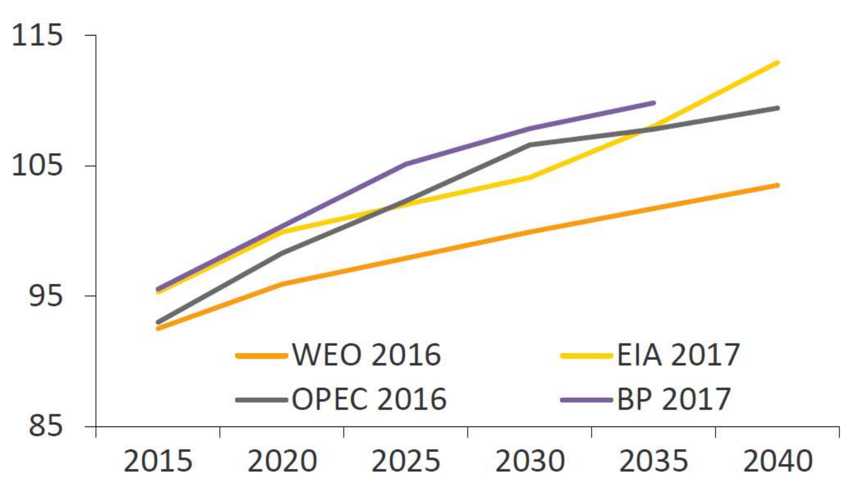
Total energy consumption by country (Mtoe) Year: 2018

Source: Enerdata, 2019

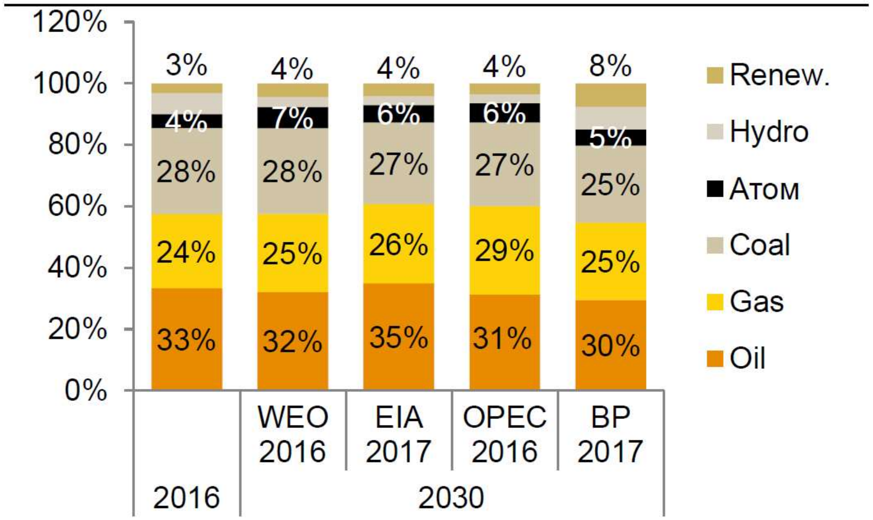
GLOBAL TRENDS IN ENERGY

Changing needs of global economy

Oil global Consumption Forecast, mmbpd liquids



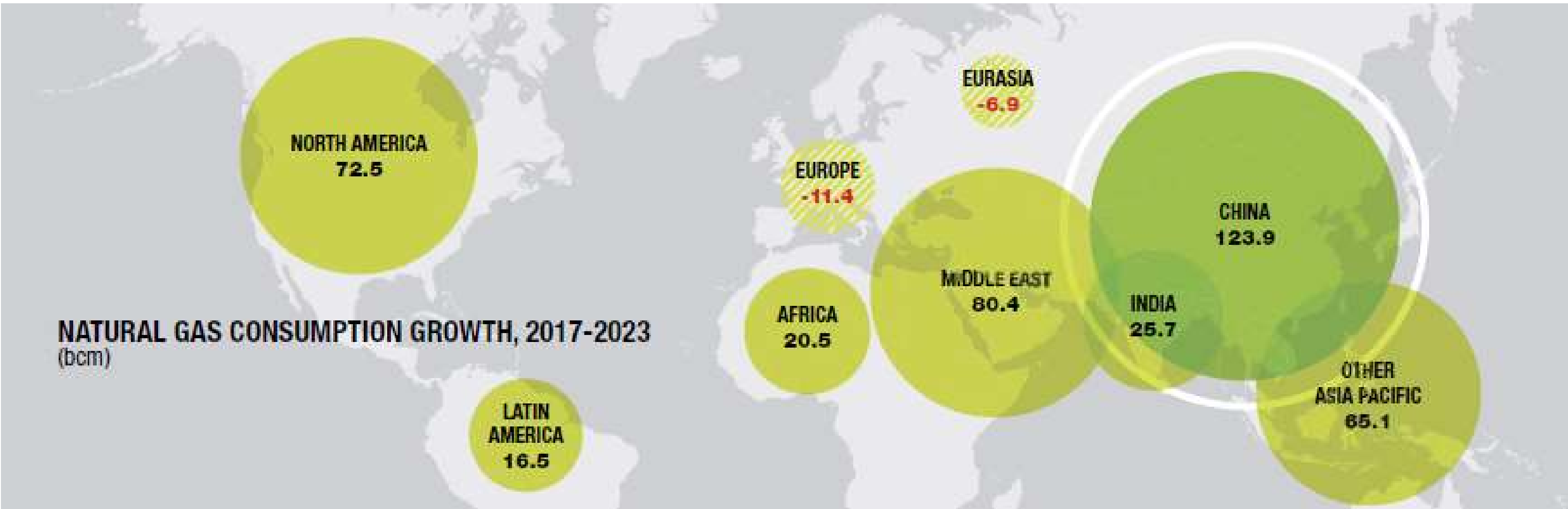
Global primary energy consumption structure

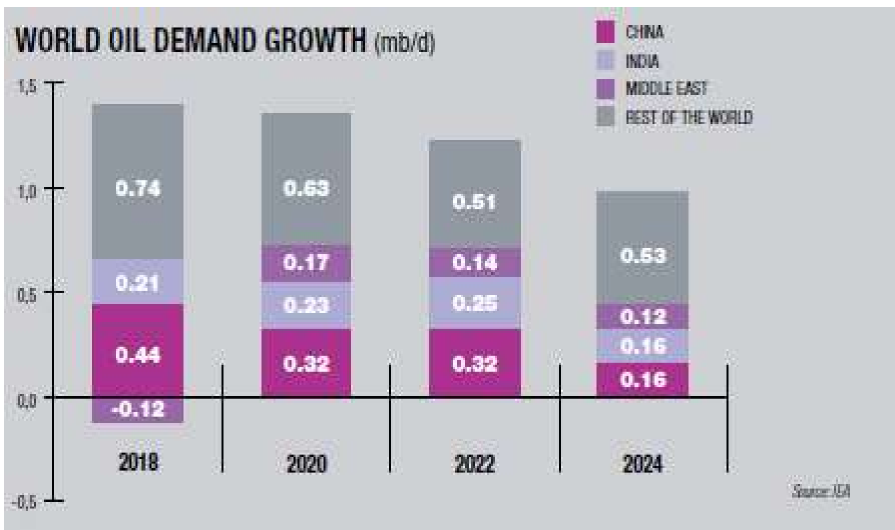


- Global oil demand will continuously grow in mid-term and long-term perspective. Yearly growth in the next 10 years will be 770 kbpd on average.
- The share of liquid hydrocarbons will remain around 30% of global primary energy consumption.

Source: Rosneft. EIA, IEA, OPEC, BP

GLOBAL TRENDS IN ENERGY





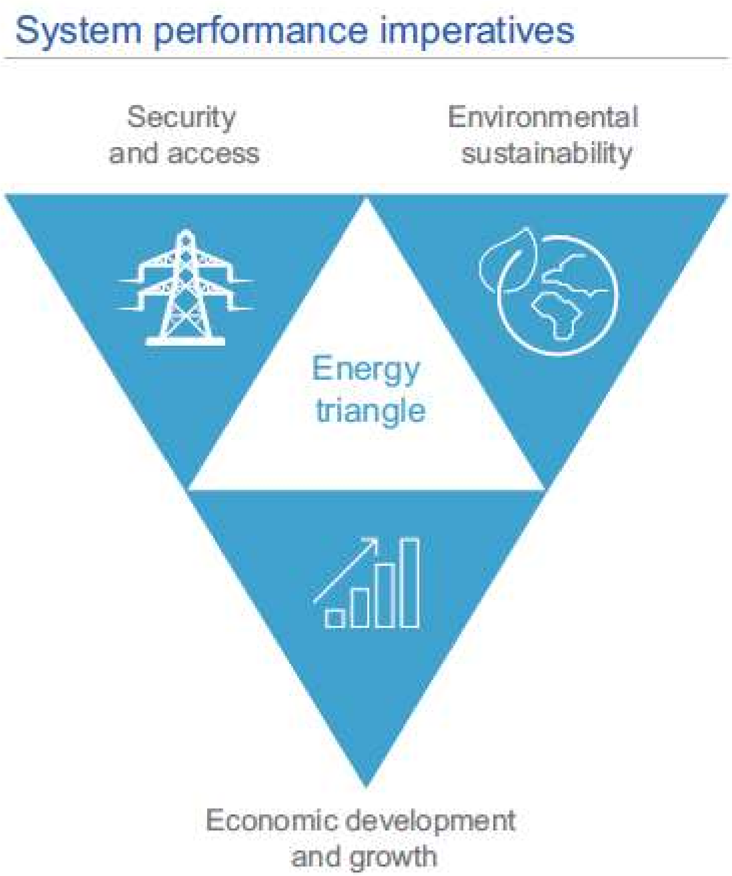
In 2017 global gas demand expanded at its fastest rate since 2010, with year-on-year growth of 4.6%, driven by higher demand and substitution from coal.

Oil demand grew 1.3% worldwide, with the United States again leading the global increase for the first time in 20 years thanks to a strong expansion in petrochemicals, rising industrial production and trucking services.

Source: International Energy Agency, 2018
World Energy, 2019

GLOBAL CHALLENGES IN ENERGY

Energy Transition



Source: World Economic Forum, 2019
IEA, 2018

According to a 2018 special report of the IPCC global anthropogenic emissions will need to **drop to net zero by 2050** to limit the global temperature increase **to less than 1.5°C** above the pre-industrial level.

The **energy** system contributes **two-thirds of global emissions** and lies at the heart of this challenge.

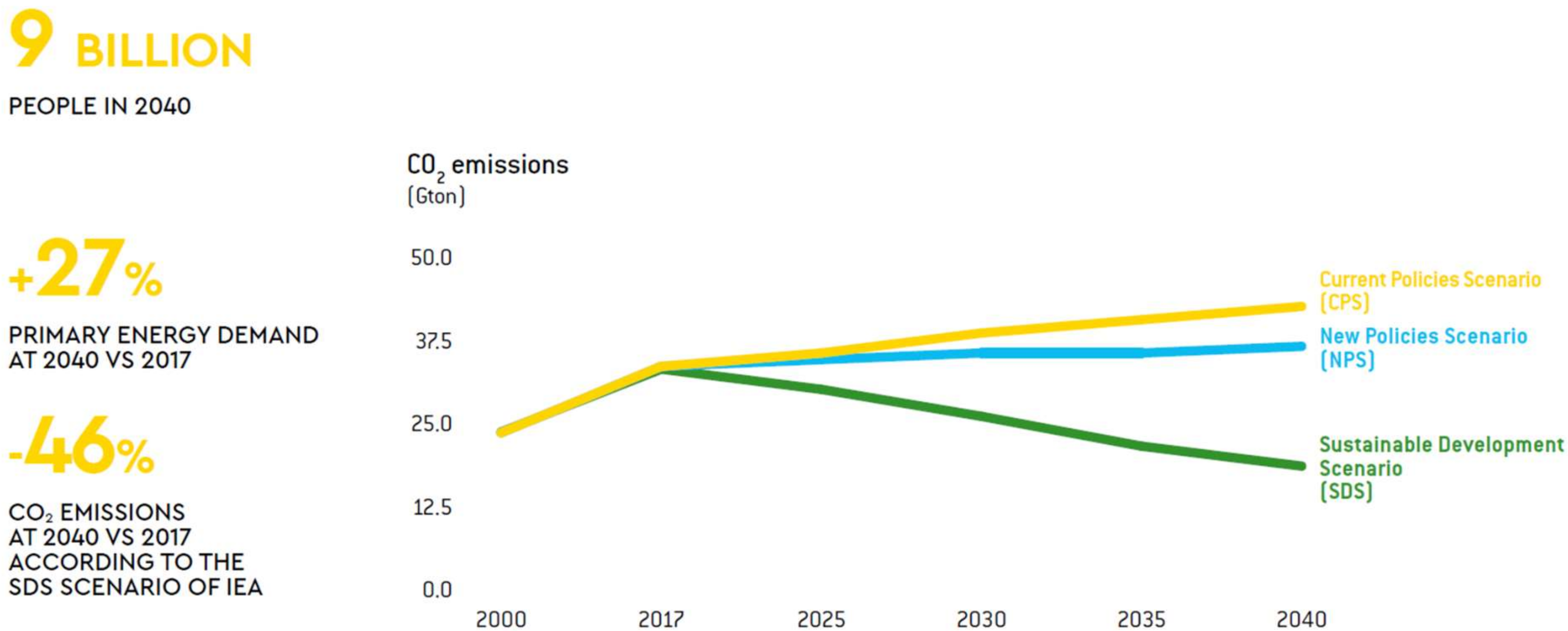
The energy system, driven by factors such as rising **demand**, technological **innovation**, **geopolitical shifts** and environmental concerns, is undergoing a pivotal **transformation**

Globally, **energy transition has slowed** and the Energy Transition Index was the lowest of the last five years

GLOBAL CHALLENGES IN ENERGY

Emissions of climate-changing gases and decarbonization

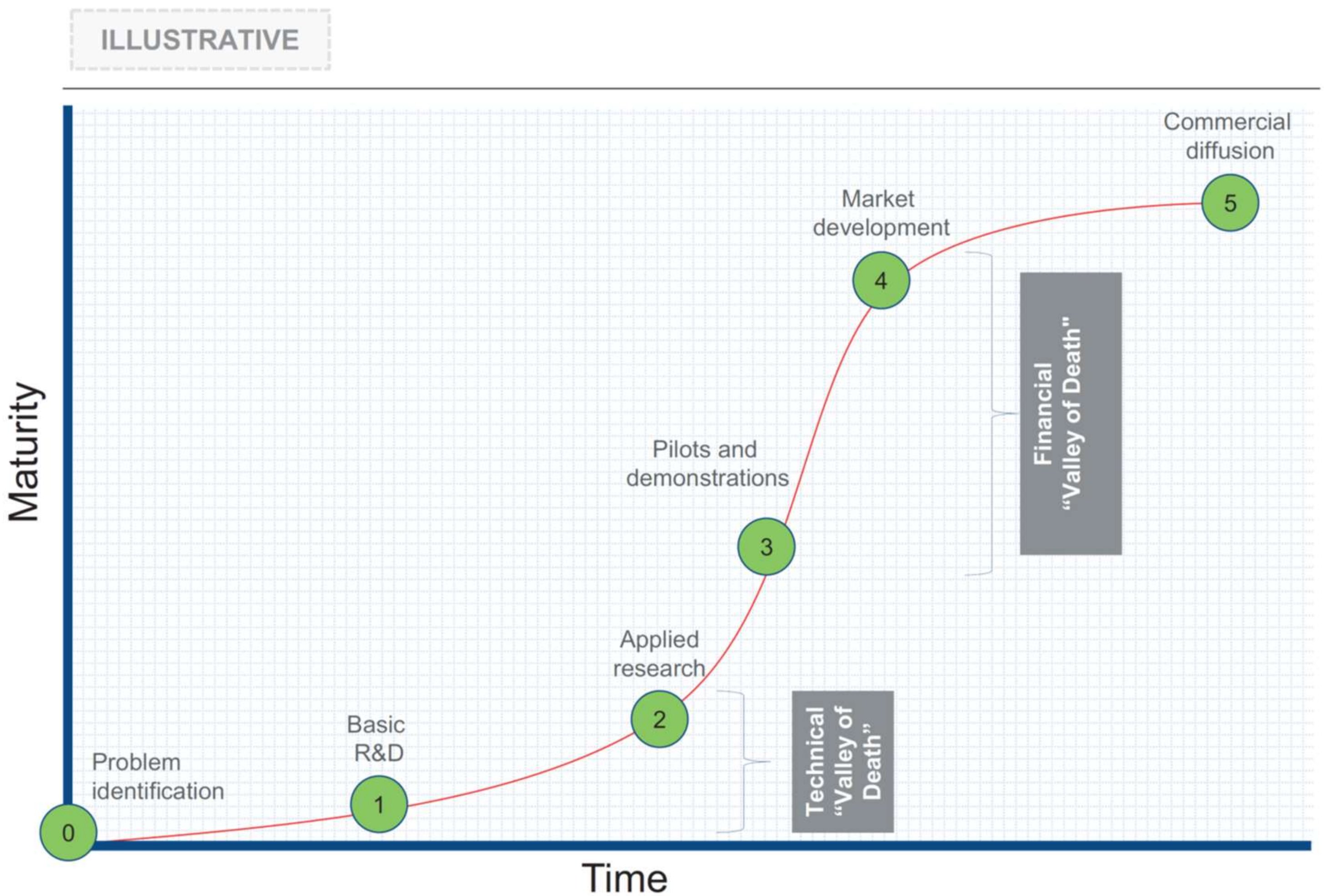
According to the IEA Sustainable Development Scenario (SDS), based on the baseline assumption of achieving the Paris target, emissions should be reduced by 46% in 2040 compared to 2017.



Source: IEA, 2018

GLOBAL CHALLENGES IN ENERGY

The stages of Innovation

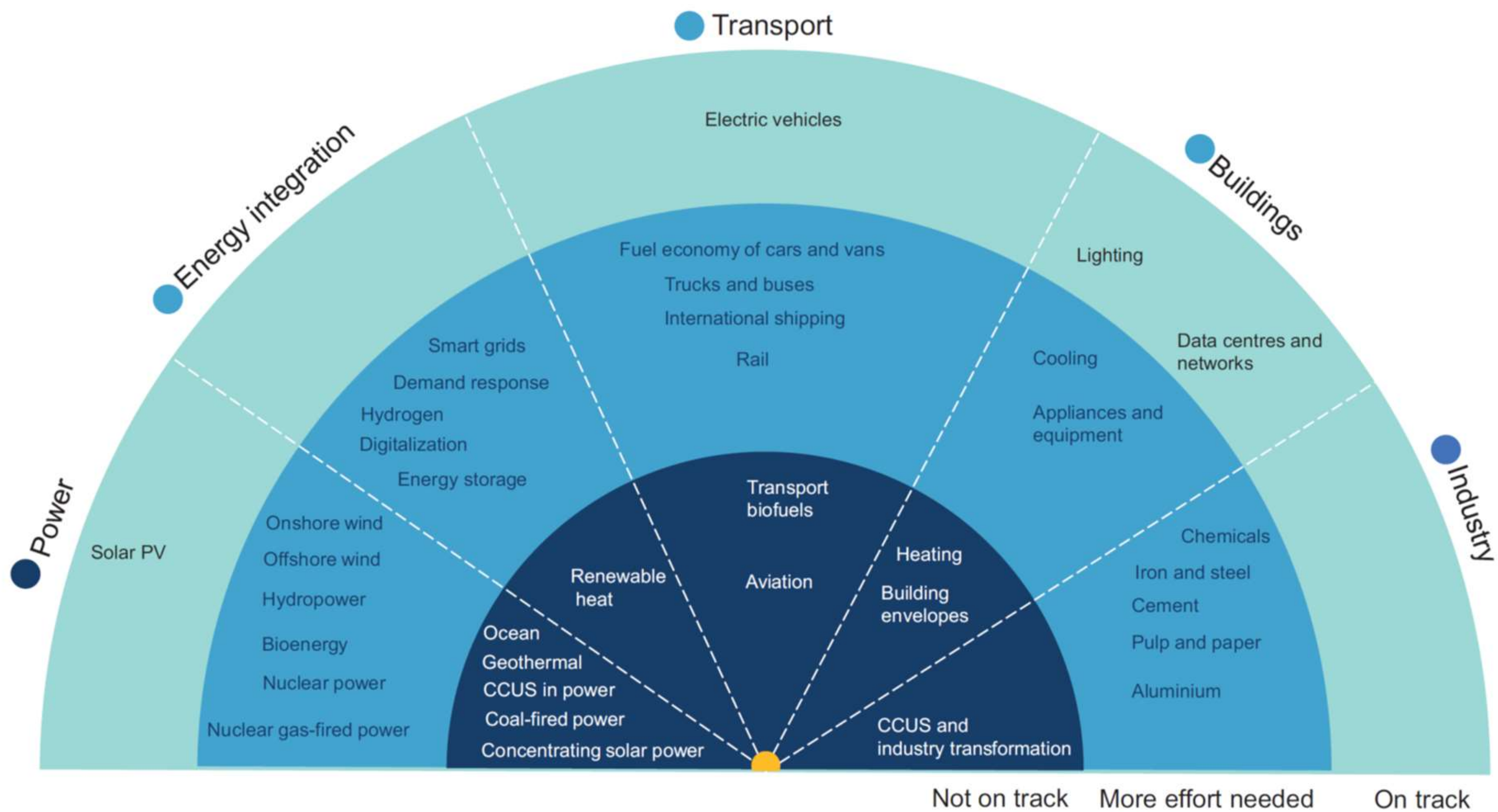


Source: World Economic Forum, 2019

GLOBAL CHALLENGES IN ENERGY

Innovation in Energy Technology

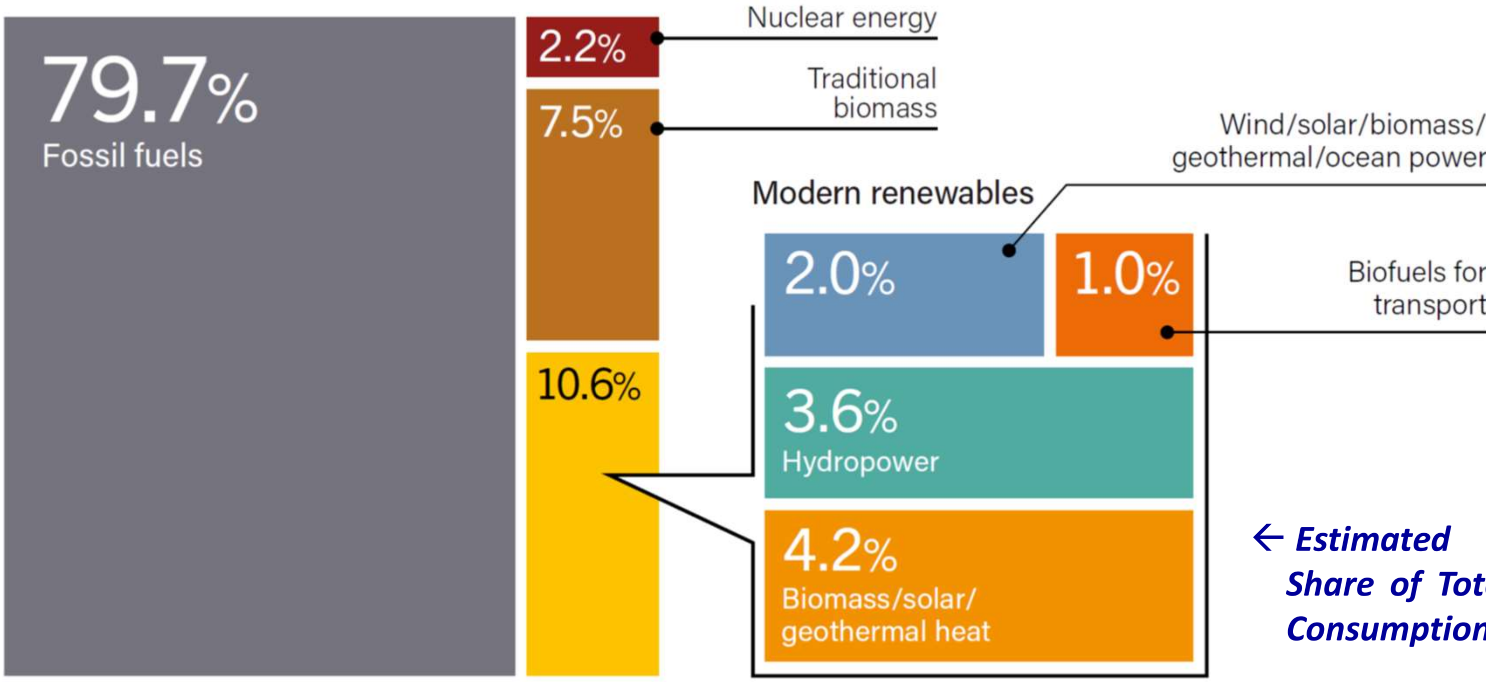
Accelerating the speed of energy transition requires breakthrough innovations to meet its Sustainable Development Scenario.



Source: IEA, 2018

GLOBAL TRENDS IN RENEWABLE ENERGY

In 2017 renewable energy accounted for an estimated 18.1% of total final energy consumption (TFEC).
Modern renewables supplied 10.6% of TFEC, with an estimated 4.4% growth in demand compared to 2016.

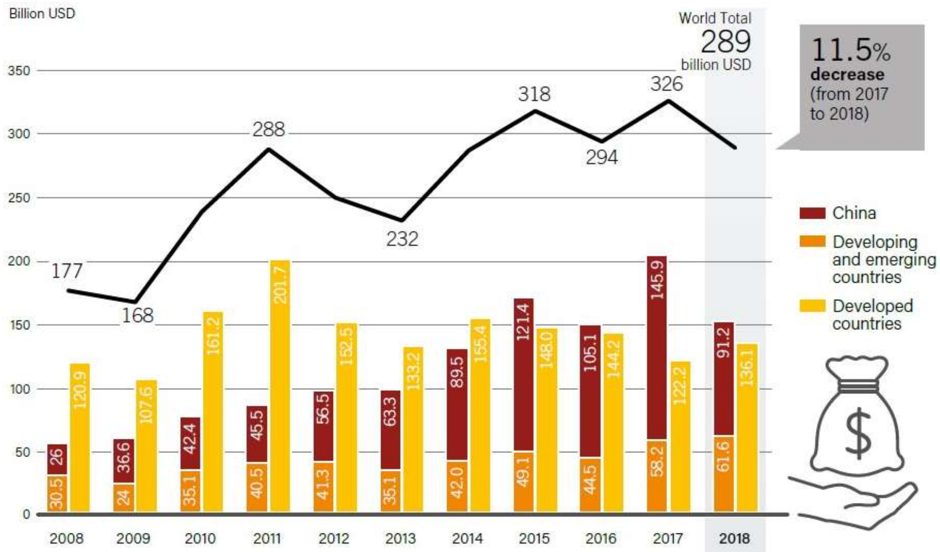


← Estimated Renewable Share of Total Final Energy Consumption, 2017

Source: Based on OECD/IEA and IEA SHC (2019)

GLOBAL TRENDS IN RENEWABLE ENERGY

Global investments in renewable energy

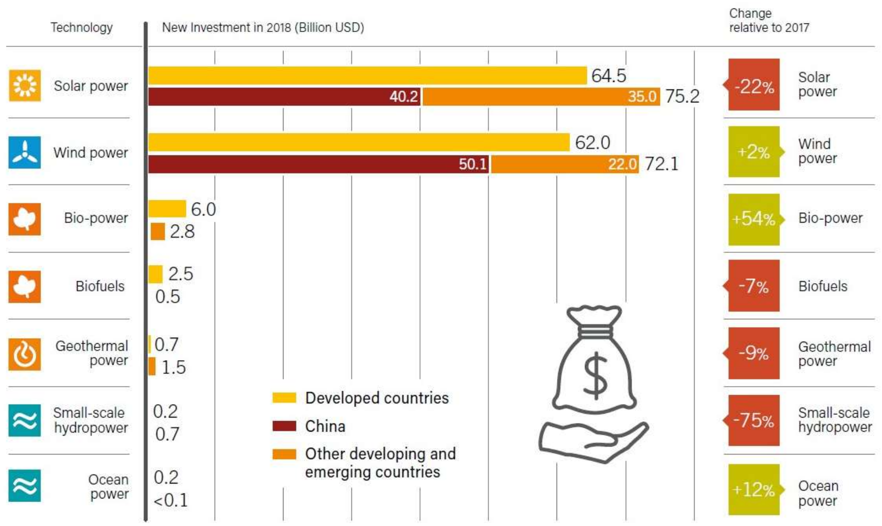


← Global New Investment in Renewable Power and Fuels in Developed, Emerging and Developing Countries, 2008-2018

Source: BNEF

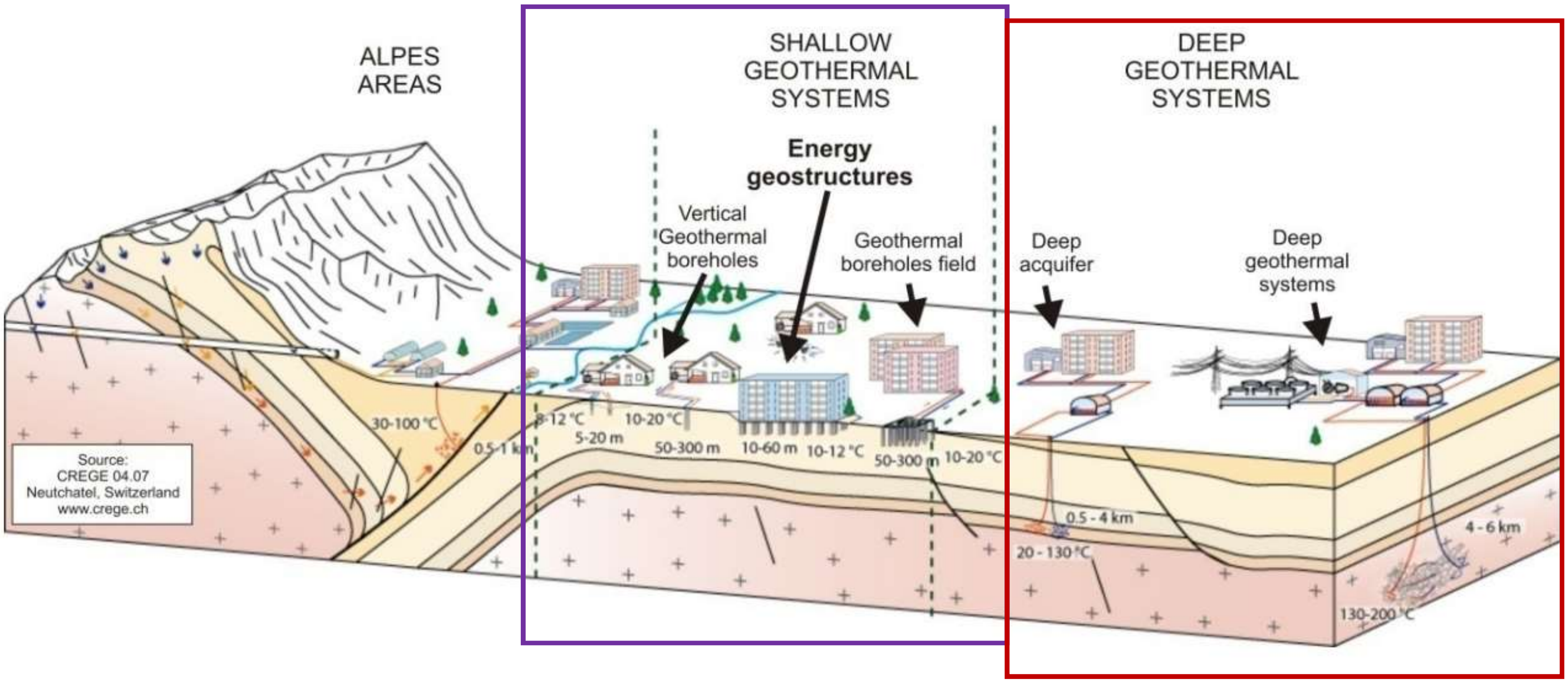
Global New Investment in Renewable Energy by Technology in Developed, Emerging and Developing Countries, 2018 →

Source: BNEF



GEOTHERMAL EXPLOITATION

LOW ENTHALPY GEOTHERMAL ENERGY



HIGH ENTHALPY GEOTHERMAL ENERGY

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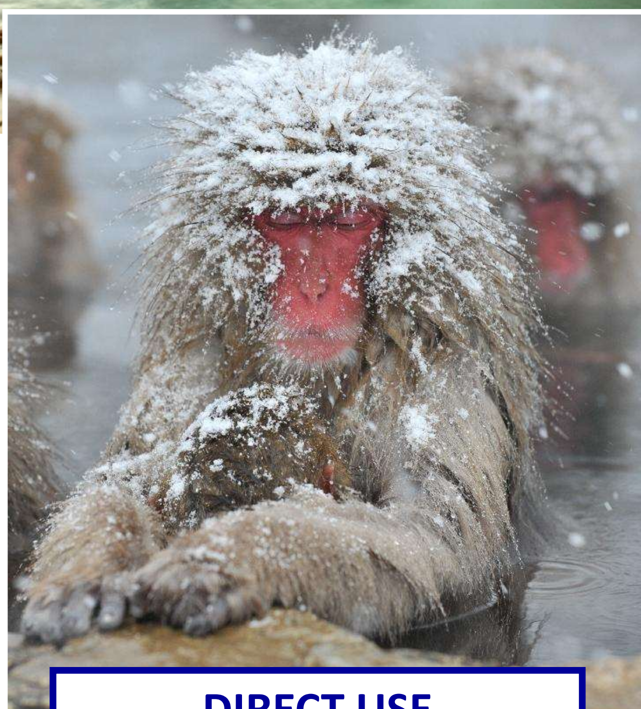
GEOTHERMAL EXPLOITATION

← Saturnia SPA (Italy)

ENERGY PRODUCTION

Larderello (Italy)

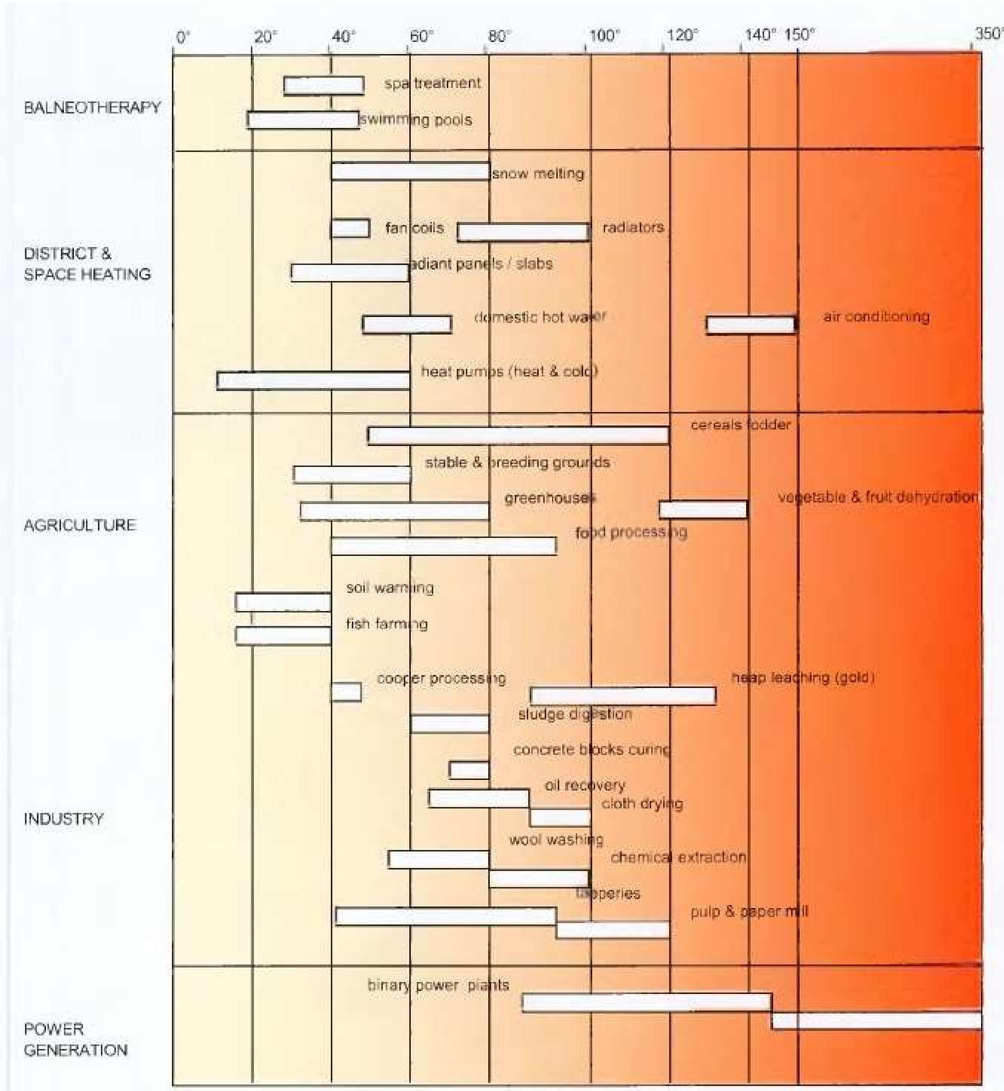


DIRECT USE

← Nagano (Japan)

GEOTHERMAL EXPLOITATION

Geothermal Industry



The major uses of geothermal resources at low - medium – high temperatures

Source: European Communities, 1999

HIGH ENTHALPY GEOTHERMAL ENERGY

Surface heat flux

Mean heat flow is 0.065 W/m^2 over continental crust and 0.101 W/m^2 over oceanic crust. This is 0.087 W/m^2 on average.

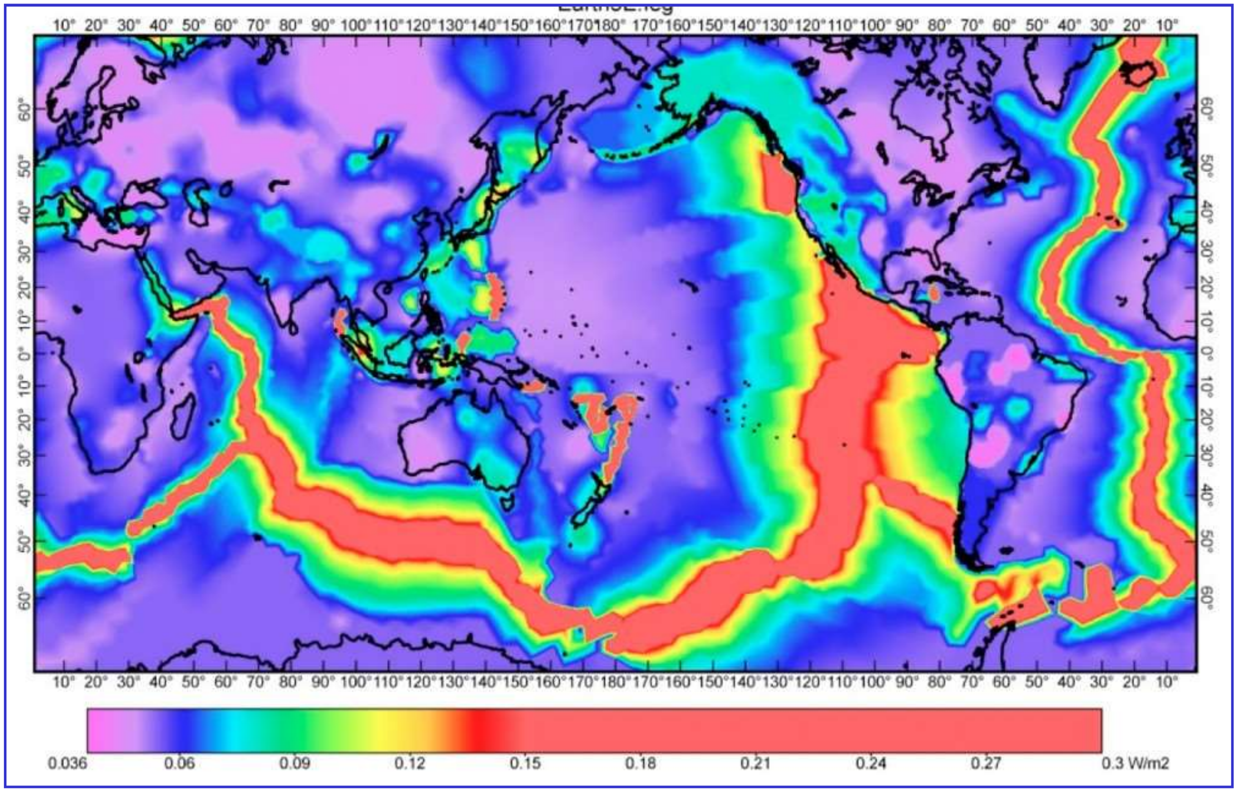
Average surface heat flux:

0.087 W/m^2

Earth surface:

*5.10*10^8 km^2*

*5.10*10^{14} m^2*



Total global surface heat flux::

4.44*10^{13} W → 44.4 TW

As a reference it corresponds approximately to 1.973 times the Three Gorges Dam Hydroelectric Plant (China) - 22.500 MW

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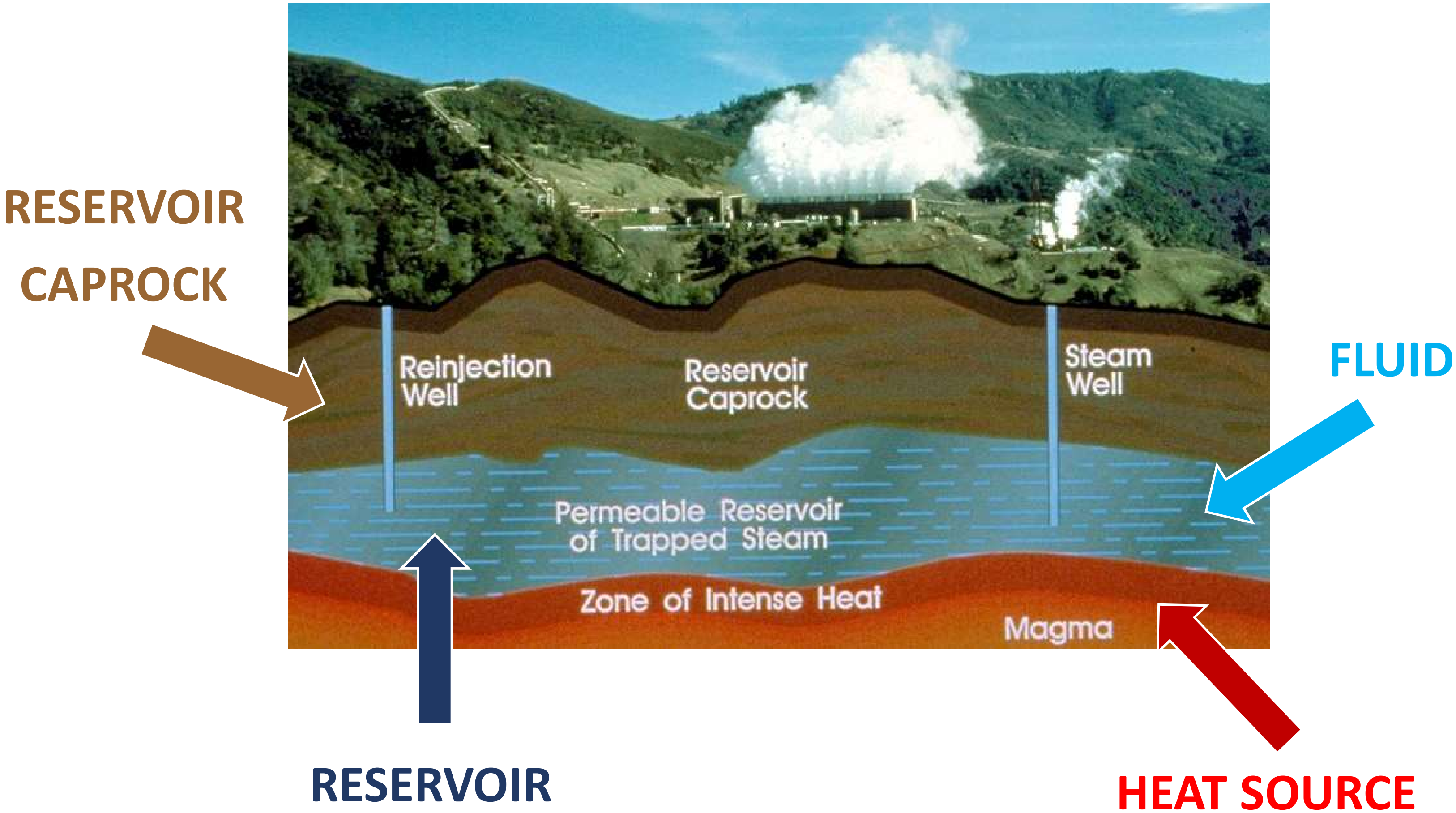
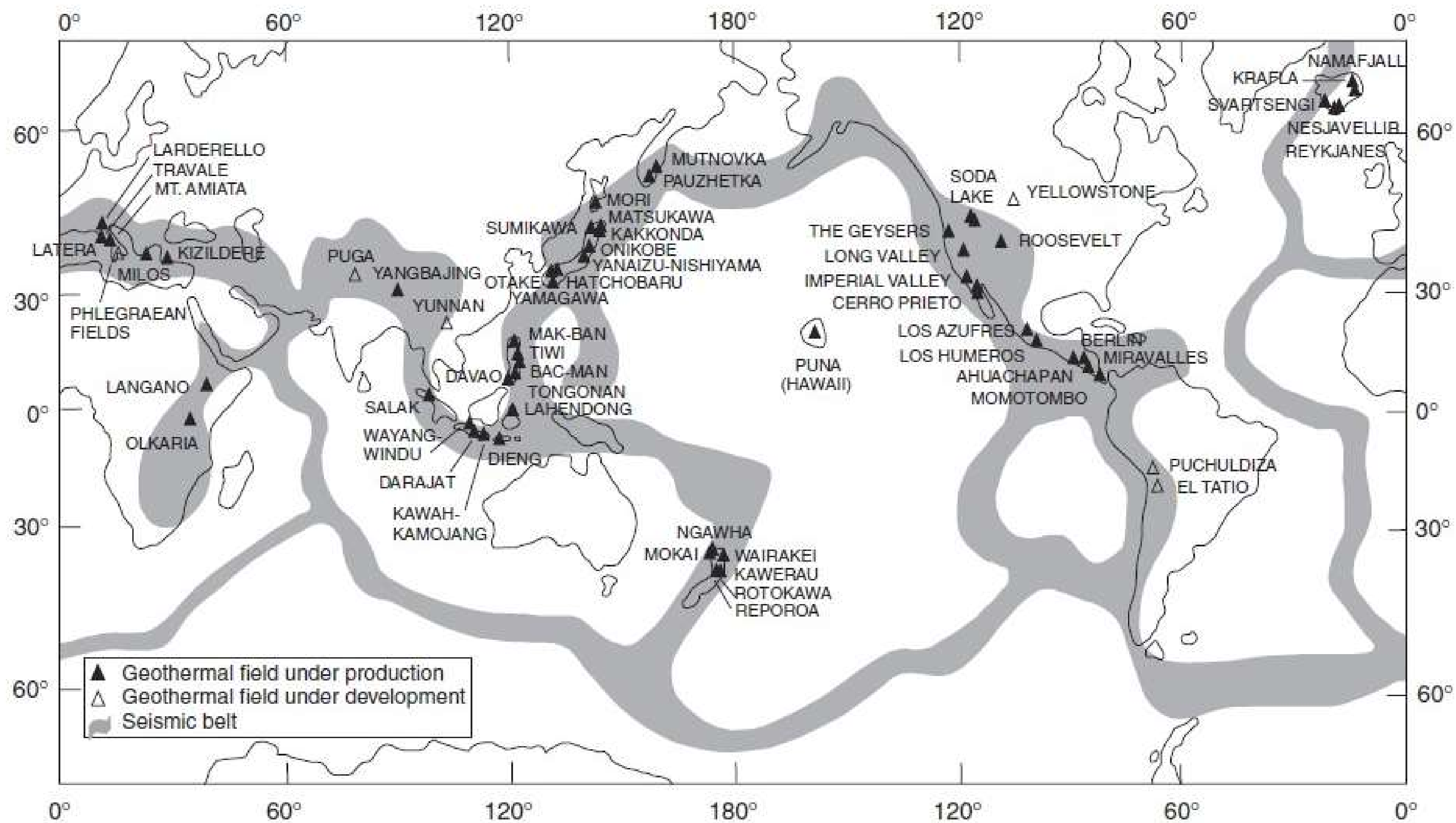
HIGH ENTHALPY GEOTHERMAL ENERGY



HIGH ENTHALPY GEOTHERMAL ENERGY

Geothermal systems

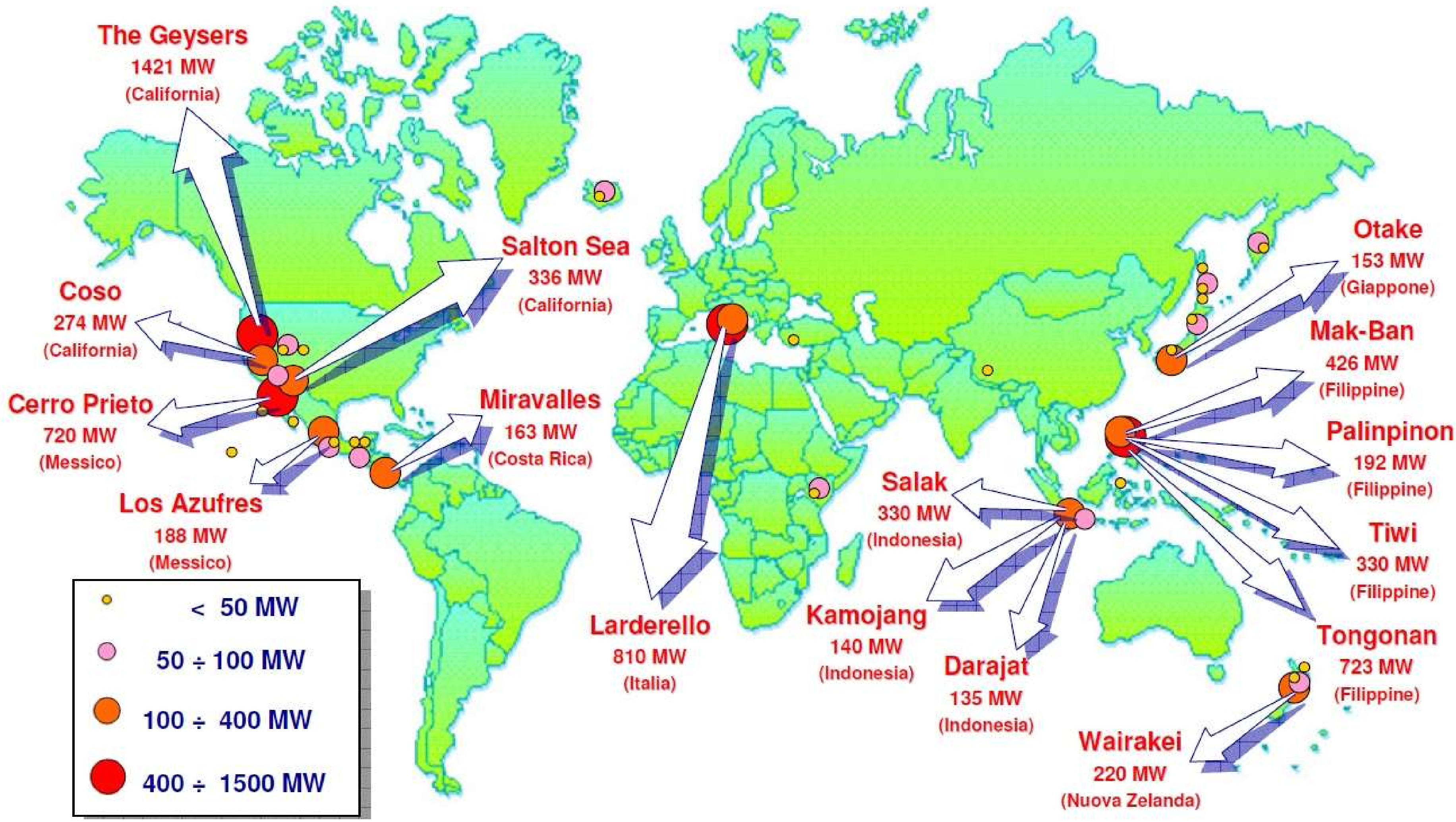


Worldwide distribution of the geothermal fields under production (filled triangles) and under development (open triangles).

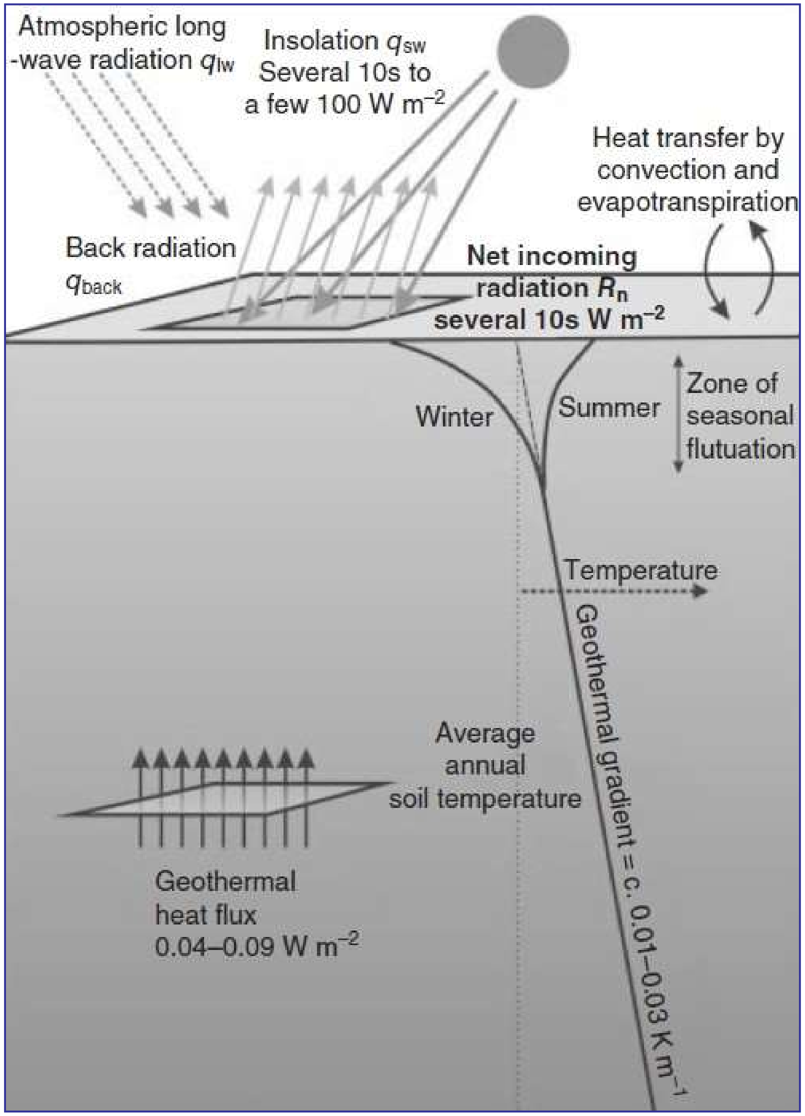
Source: Gupta and Roy, 2007

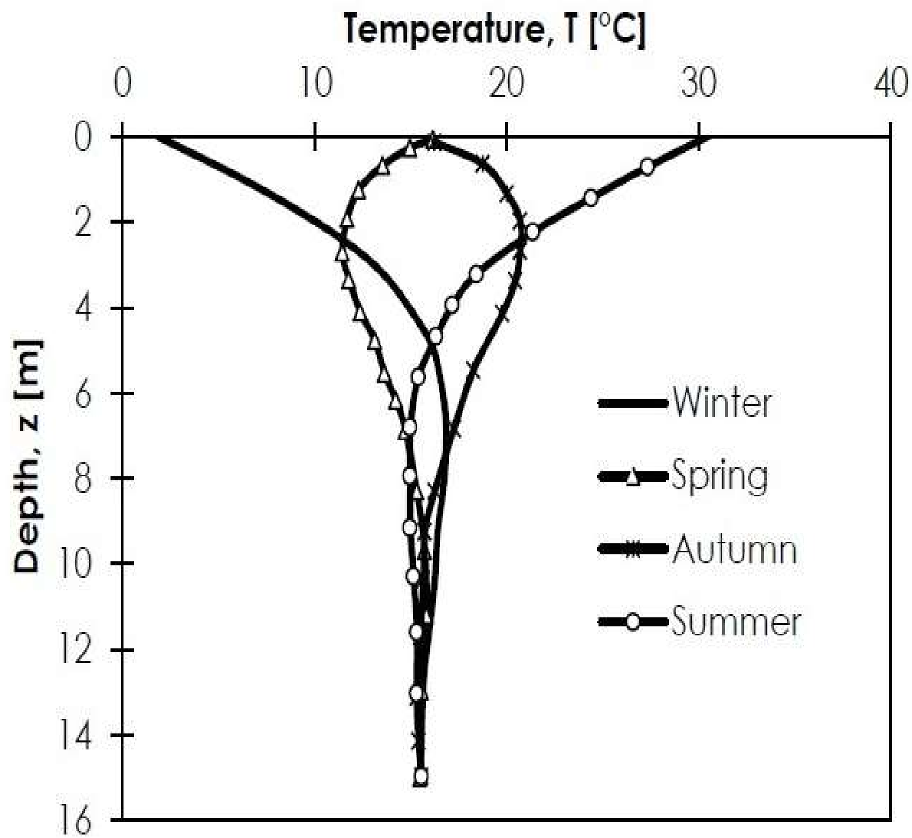
HIGH ENTHALPY GEOTHERMAL ENERGY

Geothermal systems



LOW ENTHALPY GEOTHERMAL ENERGY





Variation of temperature with depth

LOW ENTHALPY GEOTHERMAL ENERGY

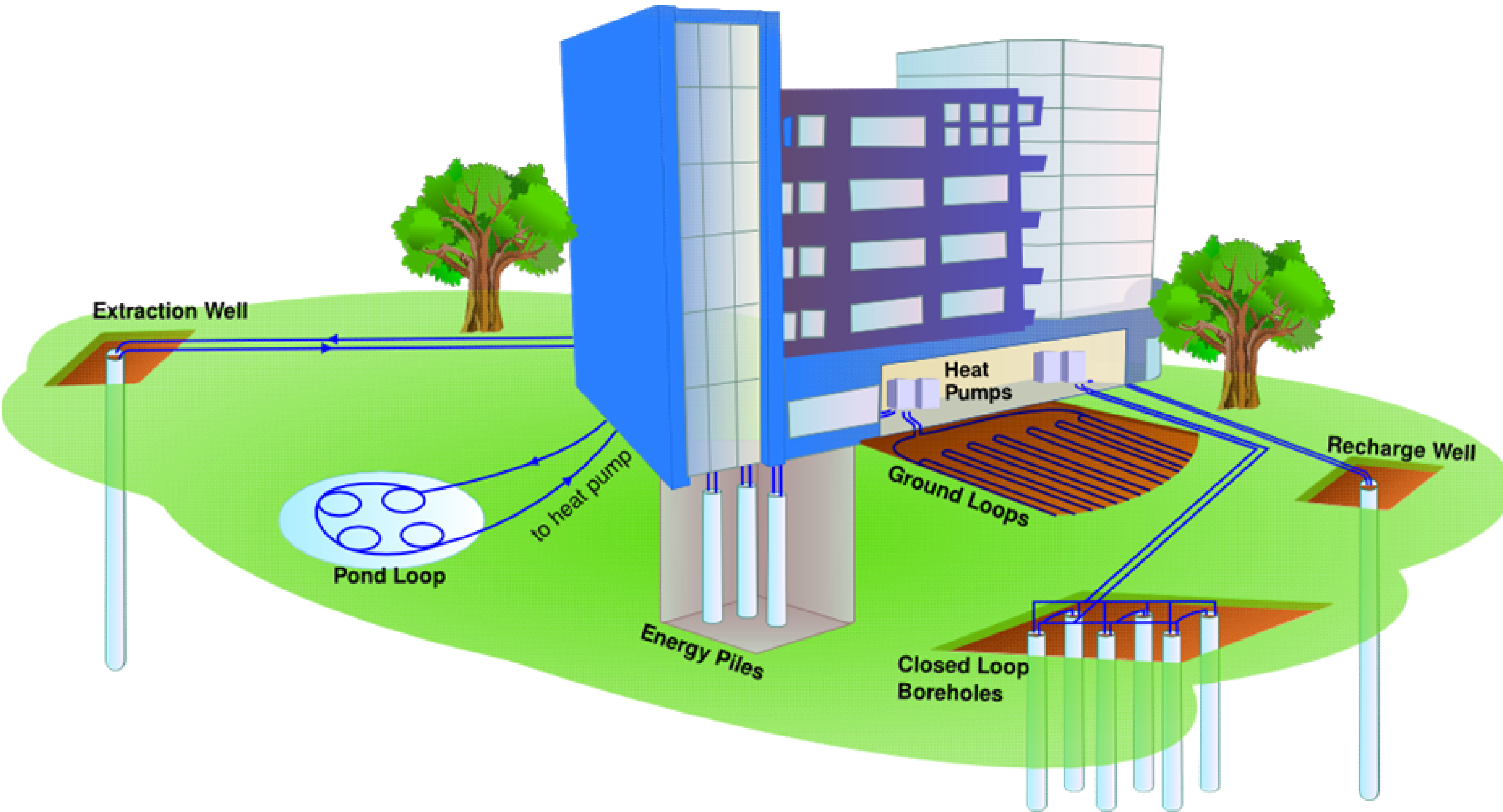
Below a few meters from the ground surface (10-15 m) the temperature is relatively constant during the year and the seasonal fluctuations are negligible.

Rocks have high volumetric specific heat capacity, the ability to **store heat**. (S_{VC} in the range 1.9 - 2.5 MJ $K^{-1}m^{-3}$).
For water, $S_{VC} \approx 4.18$ MJ $K^{-1}m^{-3}$ **is exceptionally high** and so the S_{VC} of porous rocks, soils and sediments depends strongly on their moisture content (solid particles and water stored in the pores)

The relative constancy of its temperature and the high capacity to store heat permit to couple the ground with the building by means of a **GROUND SOURCE HEAT PUMP SYSTEM (GSHP)**

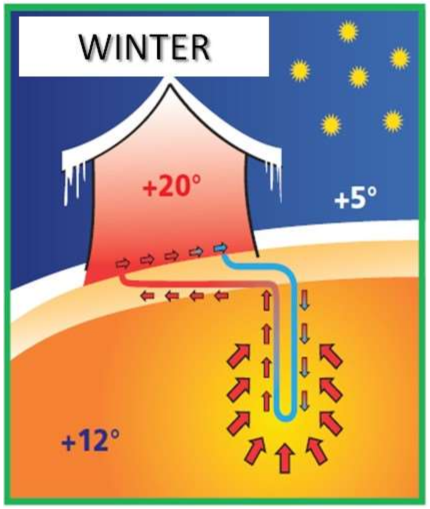
During the winter heat pumps can extract heat from a stable high-temperature source (the ground) and transfer it to a low-temperature sink (a central heating system). During the summer the cycle is reversed and the cooling is provided.

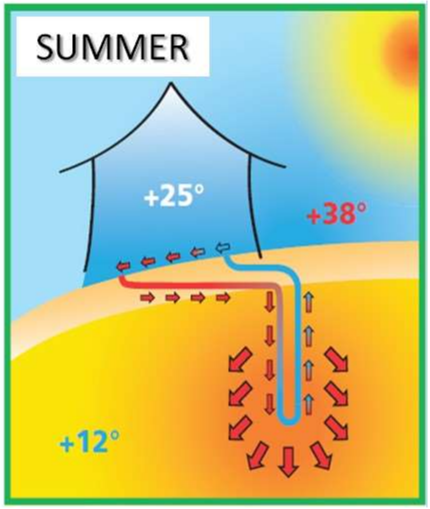
LOW ENTHALPY GEOTHERMAL ENERGY

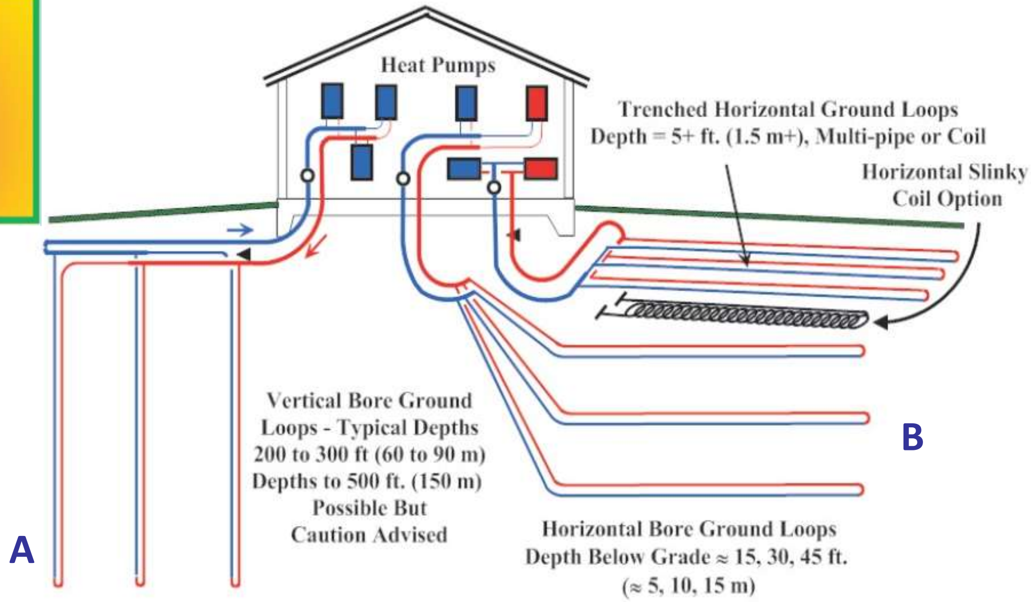


CLOSED LOOP SYSTEMS

CLOSED - LOOP SYSTEMS: does not require any water to be abstracted or re-injected at all.





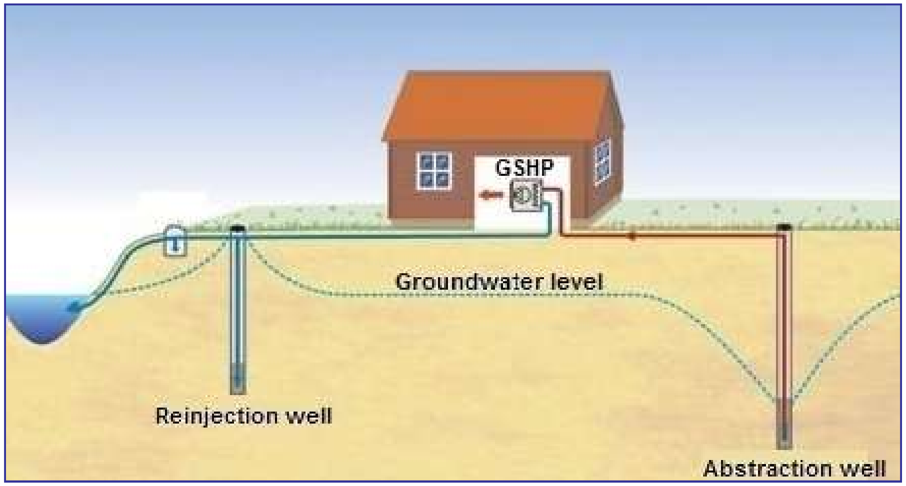


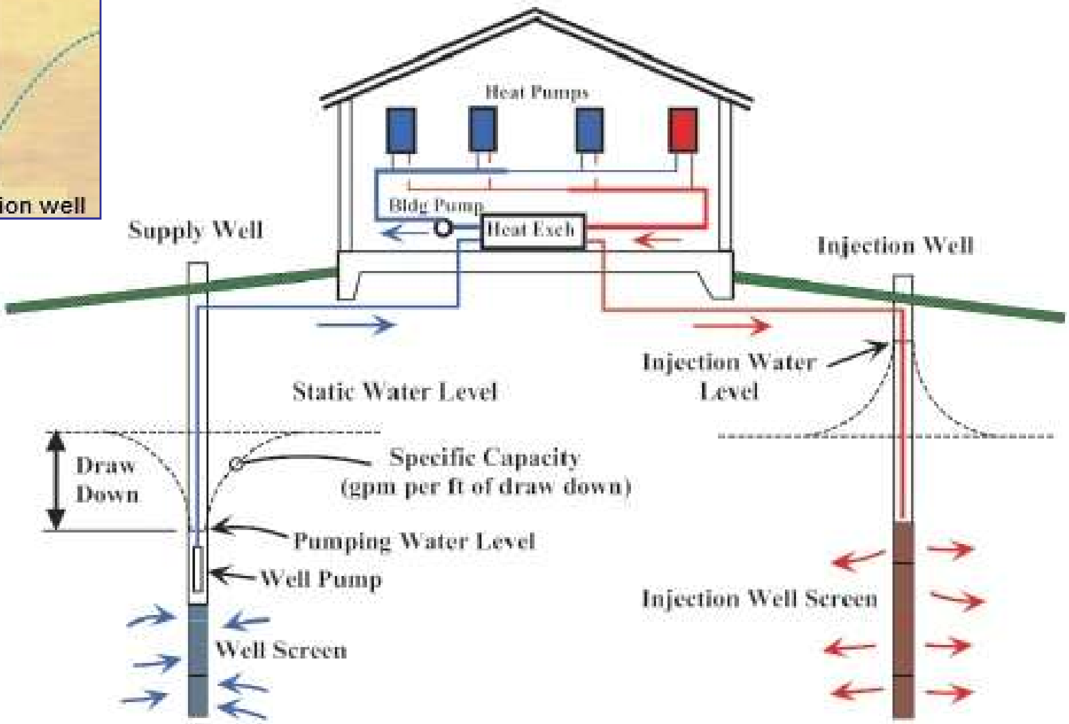
A. VERTICAL CLOSED LOOP SYSTEMS

B. HORIZONTAL CLOSED LOOP SYSTEMS

OPEN LOOP SYSTEMS

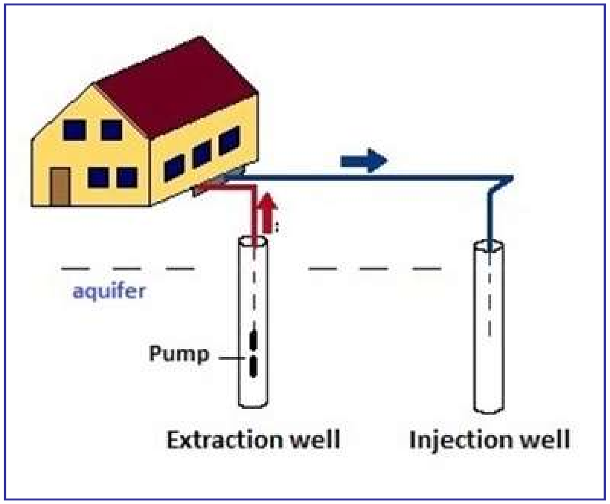
OPEN-LOOP SYSTEMS: are those where we physically abstract water from a source.





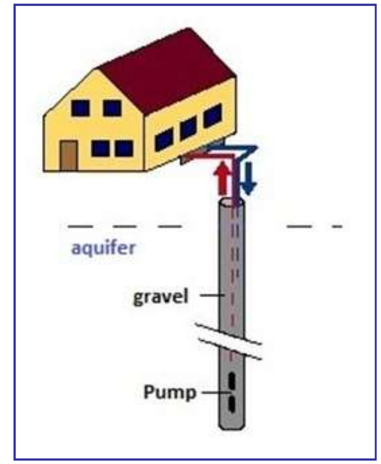
OPEN LOOP SYSTEMS

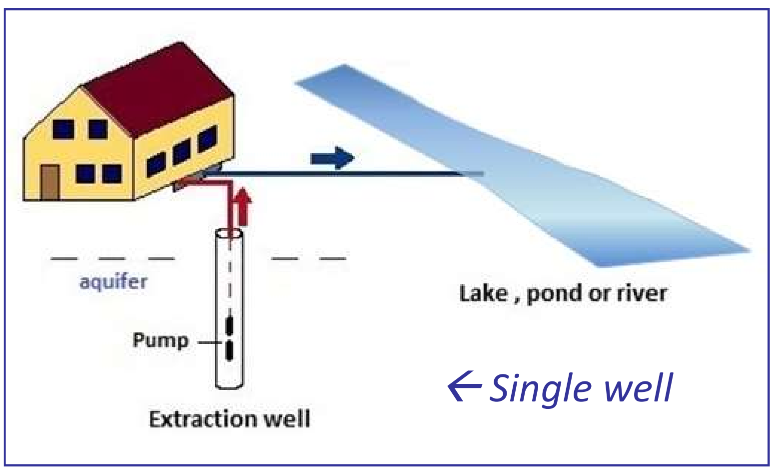
The abstracted water can be discharged in the aquifer, a river, the sea or a lake.

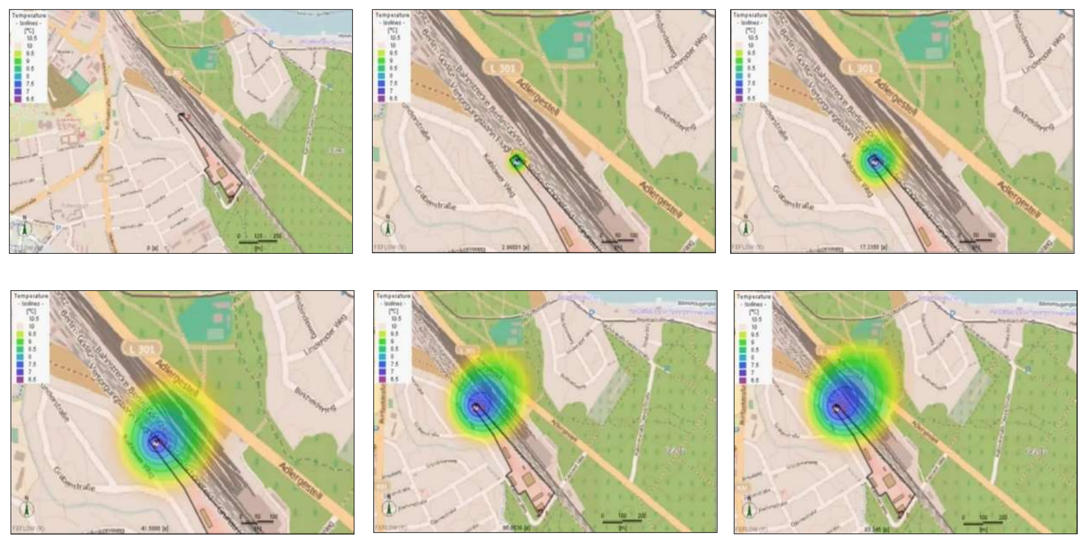


← *Well doublet system*

Standing column well →







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MAIN ADVANTAGES AND DISADVANTAGES

	ADVANTAGES	DISADVANTAGES		ADVANTAGES	DISADVANTAGES
CLOSED LOOP SYSTEMS	• No fluid exchange with the underground • Standard construction	• Large available areas required (horizontal) • Realization of multiple drilling (vertical)	HORIZONTAL	• Limited depth of excavation • Easy to build • Easy to repair • Easy to remove	• Large available areas • Low energetic performance
			VERTICAL	• Limited available areas • More stable ground temperature (increasing in energy efficiency) • May affect saturated portions in the aquifer (higher S_{vc})	• Risk of interference between overlapping aquifers • Risk of unexpected discharge in depth • Almost impossible to remove • Almost impossible to repair
OPEN LOOP SYSTEMS	• High energy efficiency • Payback in a short time	• Need of suitable aquifer • Long and complex administrative procedure	WELL DOUBLET	• Lower depth of drilling if compared to vertical closed-loop systems • Low water extraction and discharge flow when coupled with storage systems • Possibility of using surficial water and groundwater • Possibility of creating large-size systems • High energetic performance	• Environmental problems related to re-injection (thermal pollution)
			STANDING COLUMN WELL	• Need of a single well	• Possibility of creating only limited-size systems

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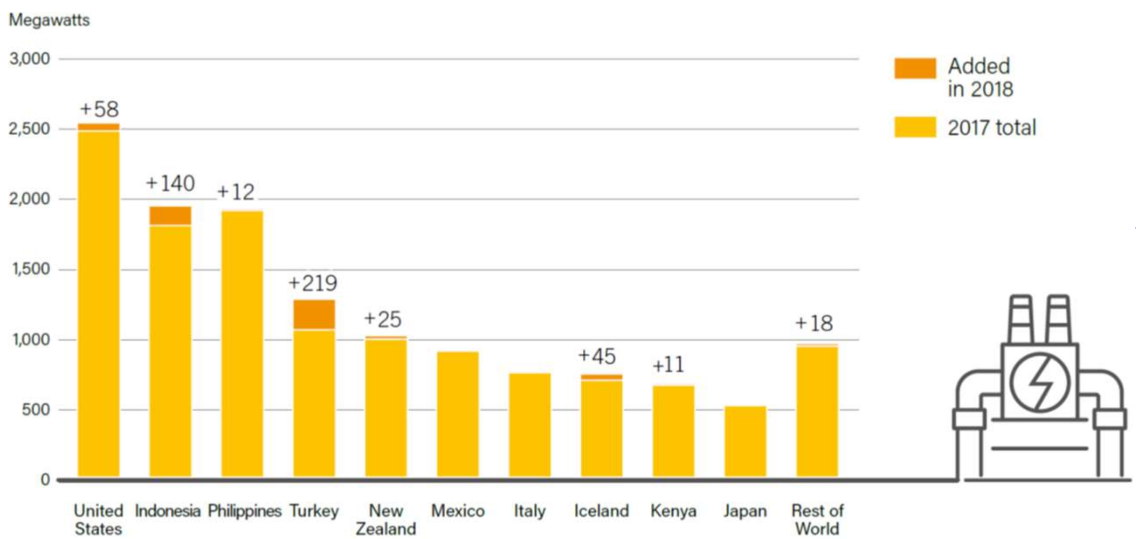
GEOTHERMAL EXPLOITATION

Energy Production

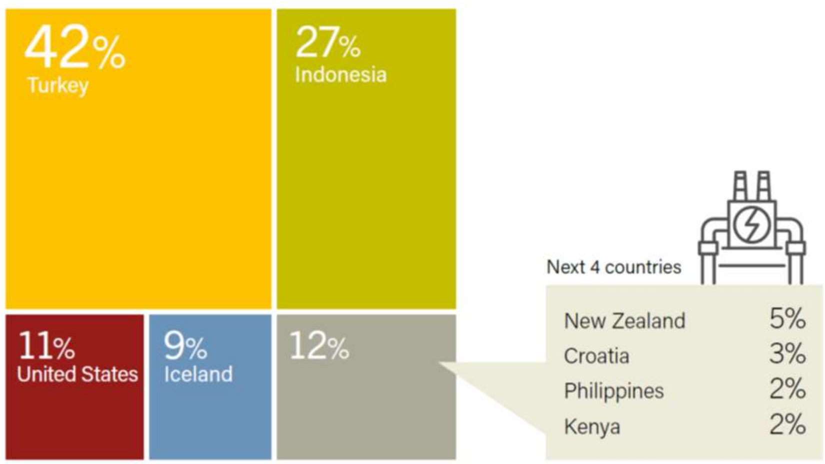


← Geothermal Power Capacity and Additions, Top 10 Countries and Rest of World, 2018

Source: REN21- Renewables, 2019

Geothermal Power Capacity Global Additions, Share by Country, 2018 →

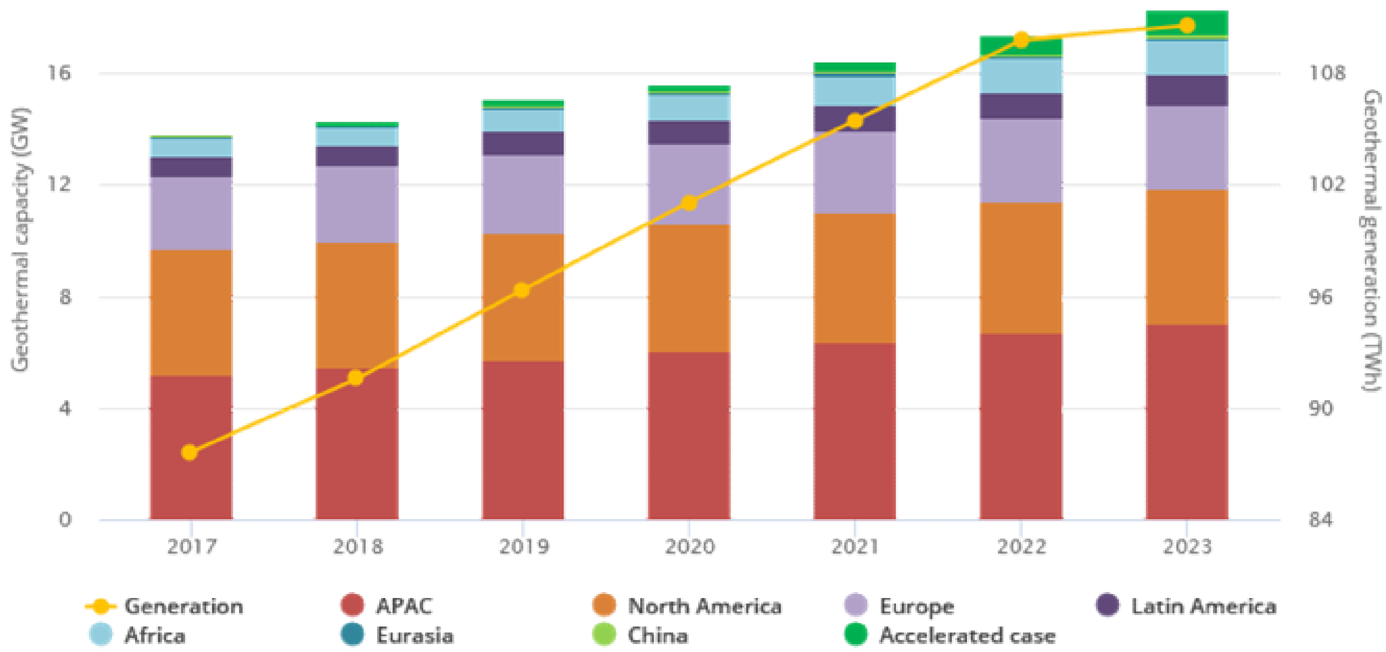
Source: REN21- Renewables, 2019



GEOTHERMAL EXPLOITATION

Energy Production

Geothermal power generation and cumulative capacity by region, 2017 – 2023



Source: IEA, 2018

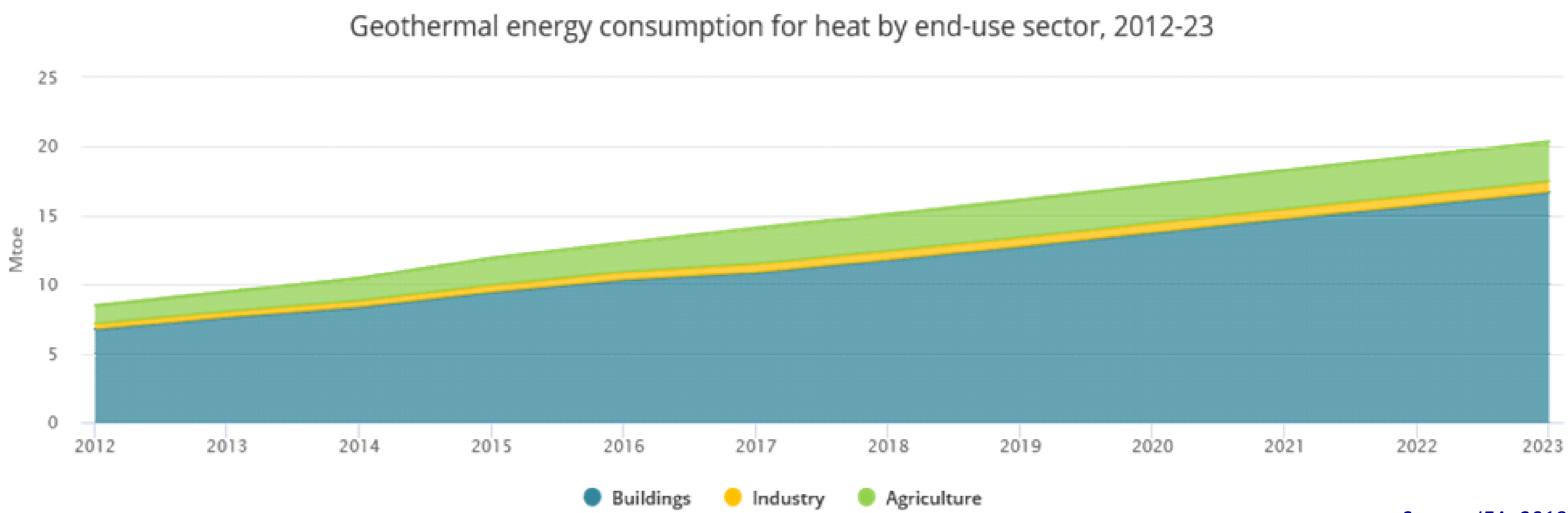
Global geothermal power capacity is expected to rise to just over 17 GW by 2023, with the biggest capacity additions expected in Indonesia, Kenya, Philippines and Turkey.

GEOTHERMAL EXPLOITATION

Direct Use

Only a limited number of countries use geothermal energy directly for heat production, with China and Turkey alone accounting for 80% of consumption in 2017.

Most geothermal heat is used for bathing (45%) and space heating (34%), agriculture (primarily for heating greenhouses).
New geothermal heat developments have focused mainly on district heating.

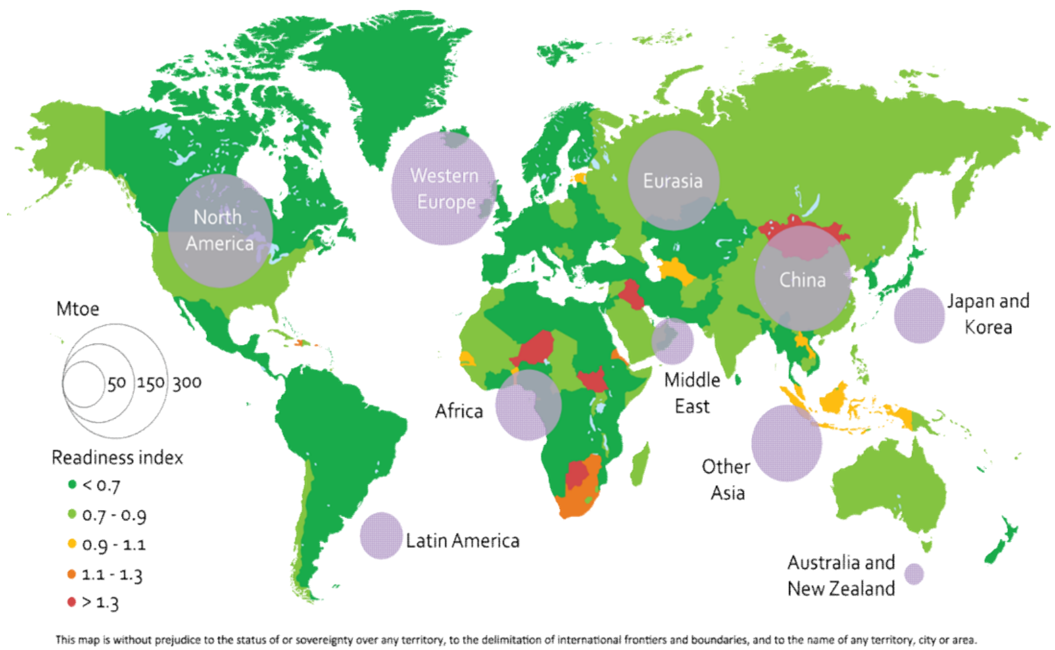


Source: IEA, 2018

GEOTHERMAL EXPLOITATION

Potentials of Heat Pumps

Heat pump readiness index relative to regional demand, 2018



Note: If the index equals 0.8, a typical heat pump would be around 20% less carbon-intensive than a condensing boiler using natural gas.

Source: IEA, 2018

Electric heat pumps still meet less than 3% of heating needs in buildings globally.

They could supply more than 90% of global space and water heating with lower CO_2 emissions than condensing gas boiler technology (which typically operates at 92-95% efficiency).

The global market for heat pumps in building applications continues to grow and is led by China, followed by Europe, Japan and the United States. In Europe, more than 1.2 million units were sold in 2018, a 12% increase from the previous year

CONCLUSIONS

1. Global **energy demand** is going to grow in the next decades. Distribution and typology of energy demand is rapidly changing. **Fossil** conventional sources consumption **will grow as well as renewables** and globally the energy transition has slowed last year

2. Among the renewables, **geothermal sources** still represent a very small contribution to the present total energy consumptions but the **massive potential** highlights their perspective to contribute in the reduction of greenhouse emissions and **support the energy transition**

3. **High enthalpy resources** are related to the geothermal anomalies and therefore are very **site-specific**. However, the vast potential of these sources is still **unexplored**, especially for the direct uses

4. **Low-enthalpy geothermal resources** represent a very promising technology to provide cooling and heating needs for buildings especially in the polluted urban areas. The required suitable ground conditions **are usually very common** and not site-specific. This element hugely strength the potential of implementation of these **not expensive and high efficient technologies**. In particular they can represent an economic and environmental sustainable option for the **growing urbanization** worldwide

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Thank you

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