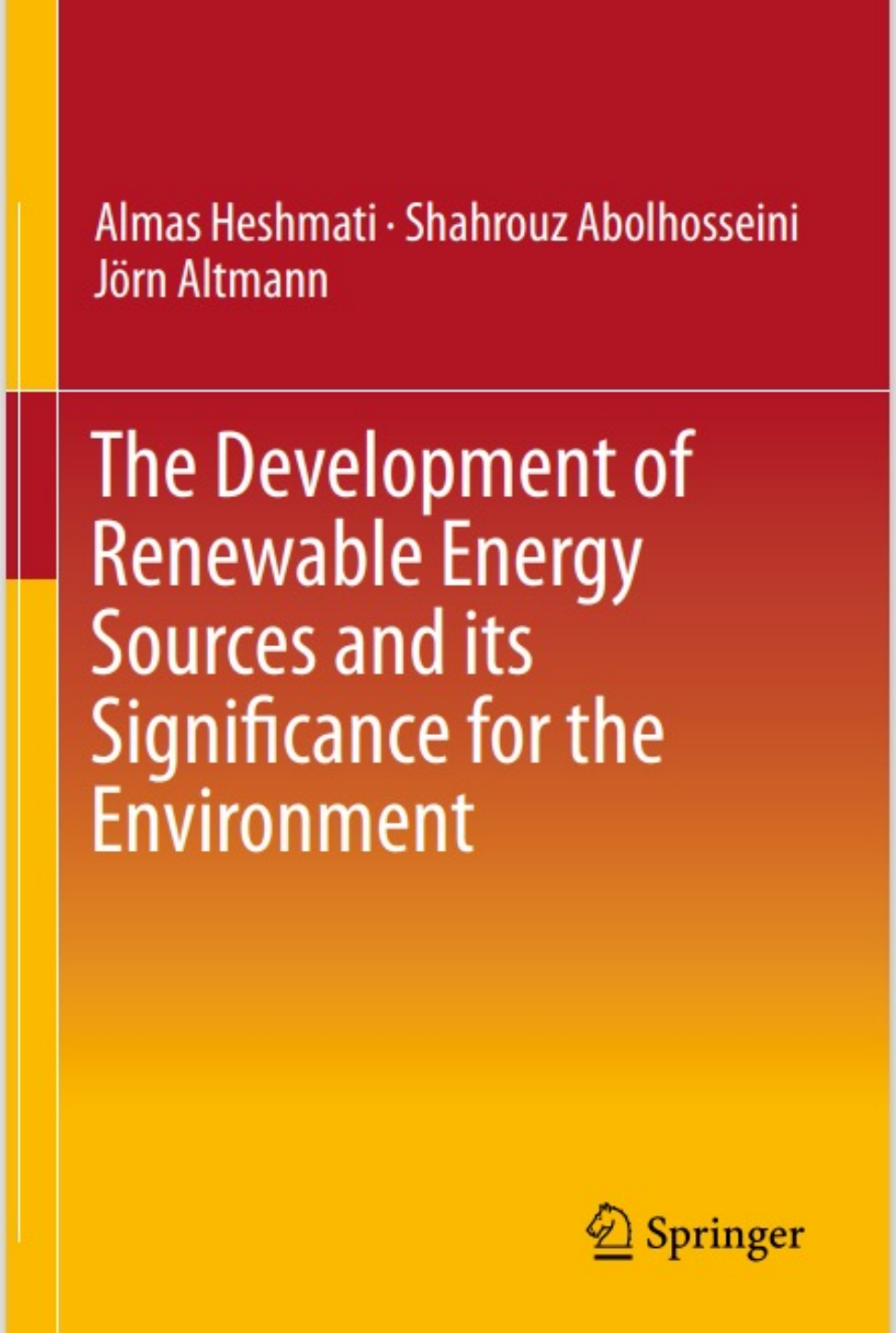
University of Piraeus
Department of European and International Studies

Renewable Energy Sources (RES) in Global Politics

Alternative Renewable Energy Production Technologies

Nikoletta Kontoulis (PhD Candidate)
nicole.kontoulis@gmail.com
Piraeus, 2023



Presentation Outline

Alternative Renewable Energy Production Technologies

Renewable Energy Production Technologies

- ✓ Hydropower
- ✓ Wind Power
- ✓ Solar Power
- ✓ Geothermal Power
- ✓ Other Renewable Power

Energy Efficiency Technologies

- ✓ Electric Vehicles
- ✓ Combined Heat and Power
- ✓ Virtual Power Plants
- ✓ Smart Meter

Introduction

The importance of alternative energy sources is underlined by climate change issues triggered through the excessive use of fossil fuels.

The three drivers for stimulating renewable energy deployment are:

- ✓energy security
- ✓economic impacts
- ✓carbon dioxide emission reductions

These drivers should stimulate two changes in a large number of countries:

1. The output of renewable energy production is expected to grow.
2. The cost of renewable energy production is expected to go down such that it becomes competitive with the production costs of other existing energy production types.

Introduction

Transforming the energy sector and replacing conventional energy with renewable energy is an evolutionary process associated with technological change and market formation.

There are two concepts of clean energy technologies:

1. **Energy supply technologies**

   Are used for generating electricity from RES (e.g., wind and solar power).

2. **Energy efficiency technologies**

   Are used to enhance energy efficiency. Examples are:

   (a) combined heat and power plants (CHP)

   (b) virtual power plants (VPP)

   (c) smart meters for metering the consumption accurately

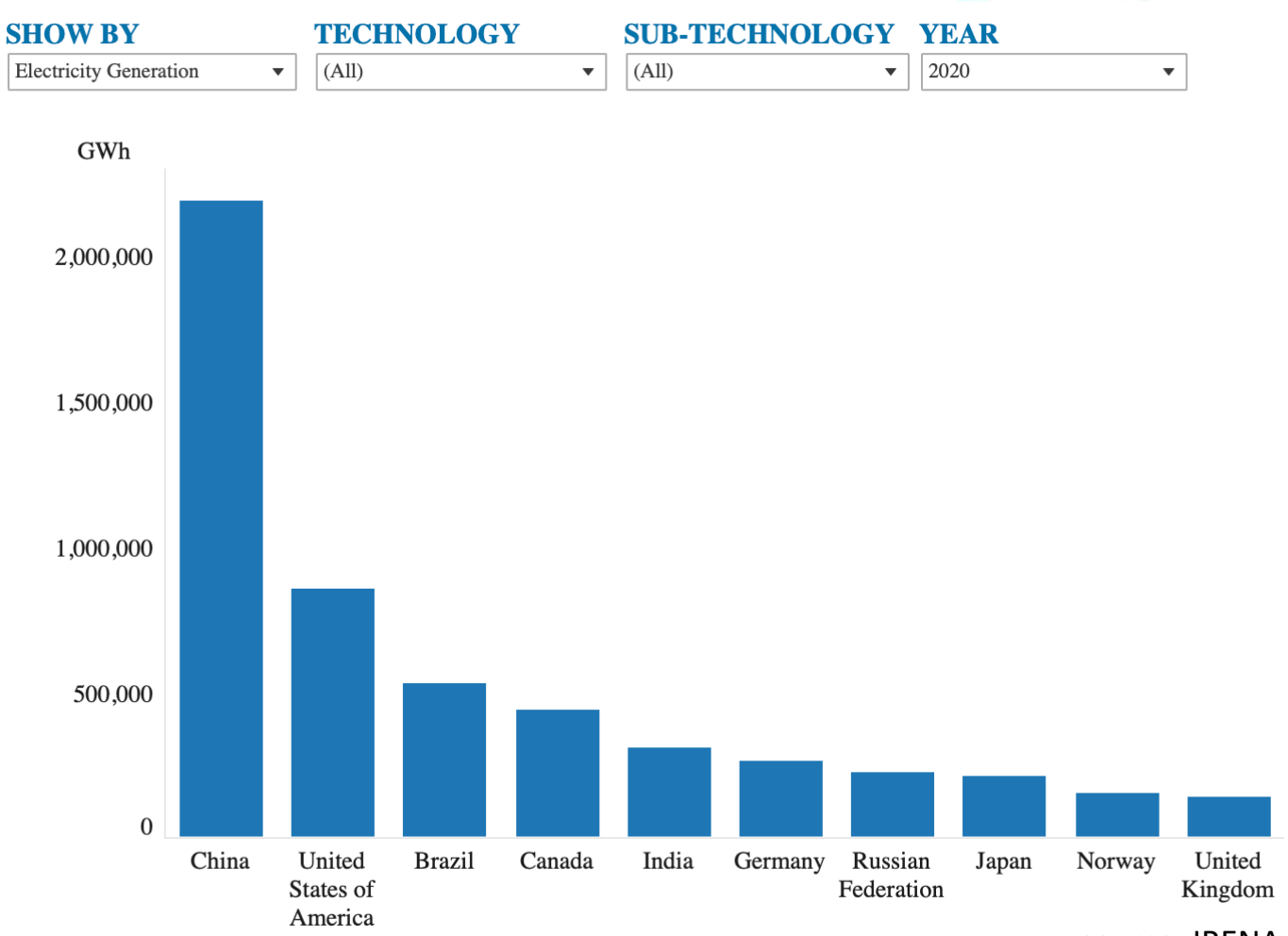
Renewable Energy Production Technologies

Renewable Energy Supply Technologies

Renewable energy supply is increasing continuously.

A large amount of investment has been made during the recent years, and advanced technologies have enabled countries to produce renewable energy more cost effectively.

It is forecast that the number of countries producing over 100 MW renewable energy will increase significantly.



source: IRENA

Renewable Energy Supply Technologies

These technologies may be incompatible compared with conventional fuels in view of unit production cost.

When they could be compatible?

If we consider their associated externalities such as **environmental** and **social effects**.

✓Economies of scale could play a key role in reducing the unit production cost.

Transmission and **distribution** costs and technologies do not differ much between the two main types of energies.

Renewable Energy Supply Technologies

Hydropower Technologies

Is the largest renewable energy source for power generation globally.

Hydroelectricity generation has increased strongly over the past 50 years.

- 1950: 340 TWh (1/3 of the global demand)
- 1975: 1,500 TWh
- 2005: 2,994 TWh

Hydropower development is difficult due to its large initial investment (high capital cost despite its low operational cost) and the environmental concerns it raises.

- It creates some problems for local residents because of relocation of large populations.
- The environment is influenced by hydropower construction because of large engineering works

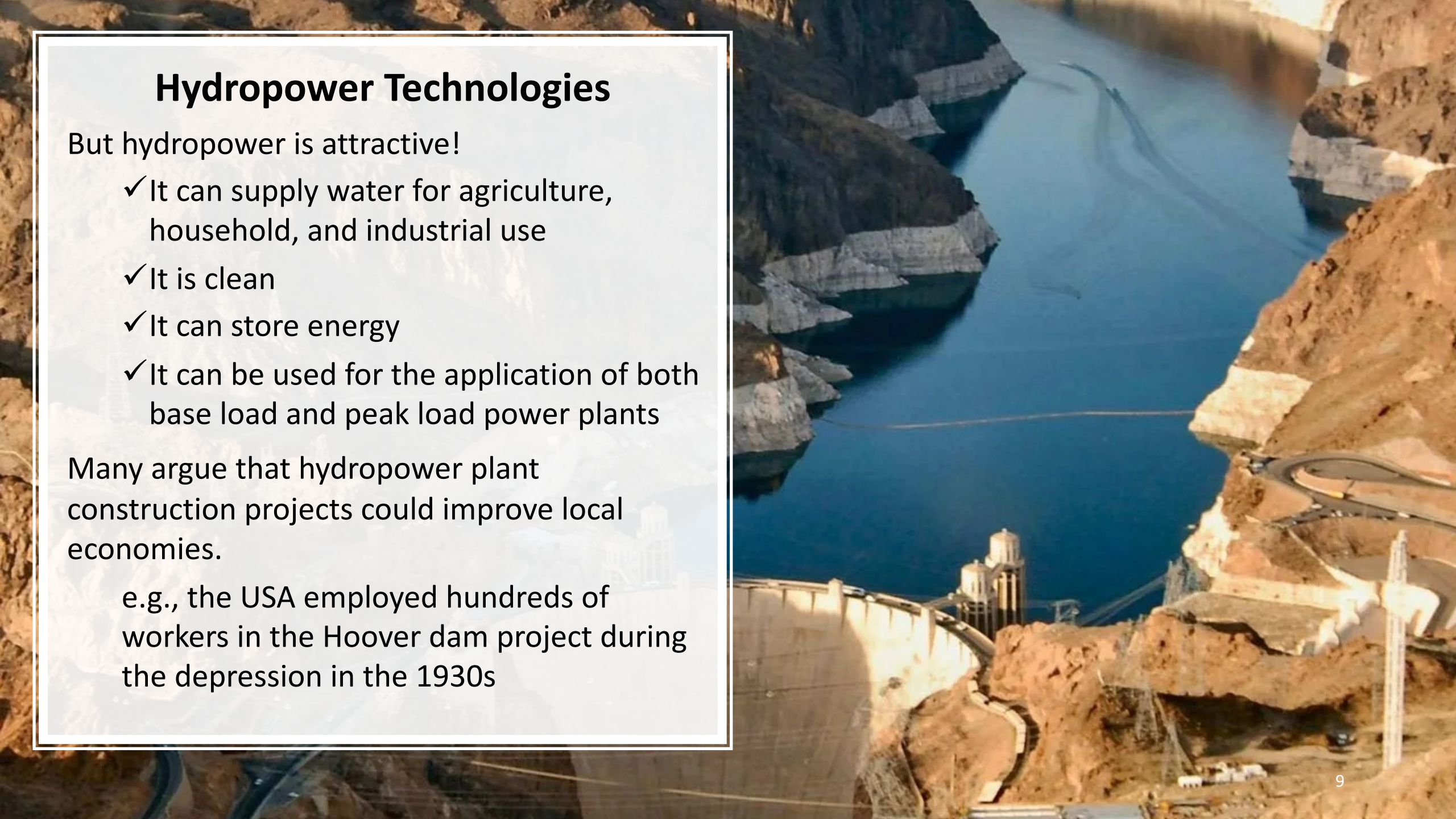
Hydropower Technologies

But hydropower is attractive!

- ✓It can supply water for agriculture, household, and industrial use
- ✓It is clean
- ✓It can store energy
- ✓It can be used for the application of both base load and peak load power plants

Many argue that hydropower plant construction projects could improve local economies.

e.g., the USA employed hundreds of workers in the Hoover dam project during the depression in the 1930s



Itaipu (Parana River)
The largest worldwide capacity hydropower plant

Renewable Energy Supply Technologies
Hydropower Technologies

In 2021 global hydropower generation **decreased** by 0.4%.

- The drop in generation was caused by persistent droughts in hydropower-rich countries (Brazil, the U.S., Turkey, China, India and Canada), leading to lower than usual hydro capacity utilization.

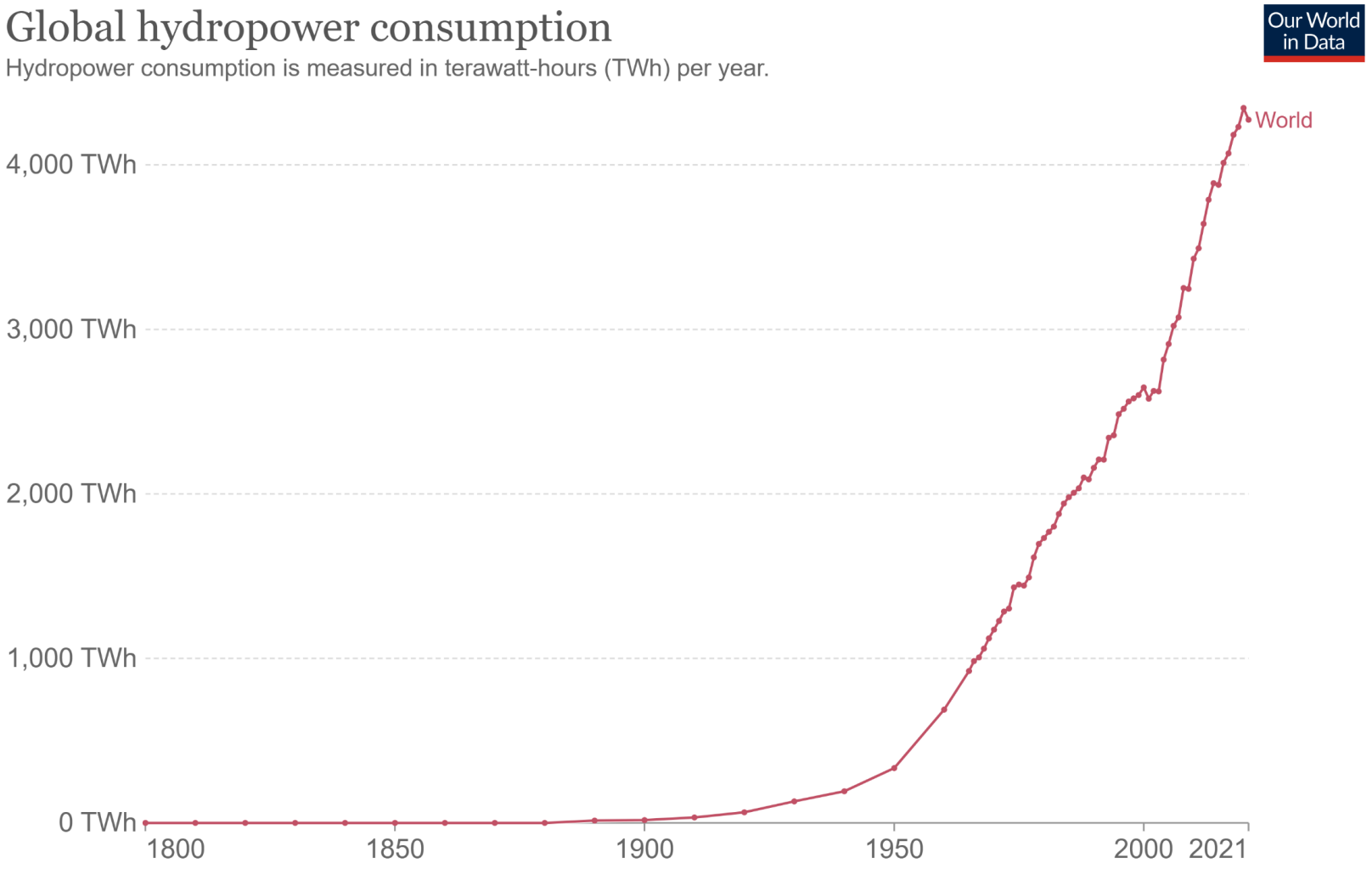
Capacity additions in 2021 reached 35 GW (50% higher than the average of the previous five years).

- However, severe droughts continue in 2022, which can result in continuation of below average generation.

China was responsible for 66% of the capacity growth, thanks to the commissioning of several large-scale projects.

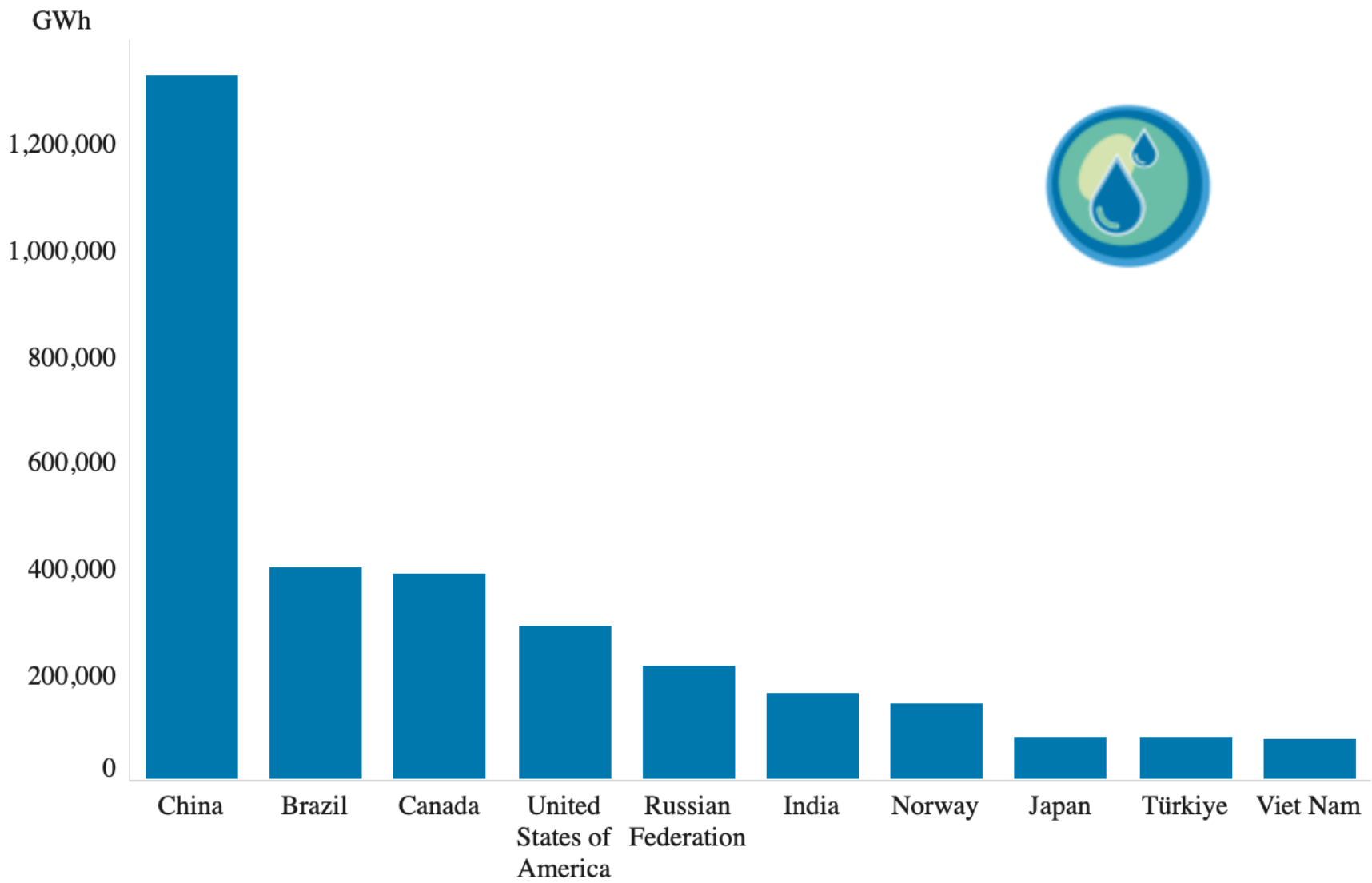
Global hydropower consumption

Hydropower consumption is measured in terawatt-hours (TWh) per year.

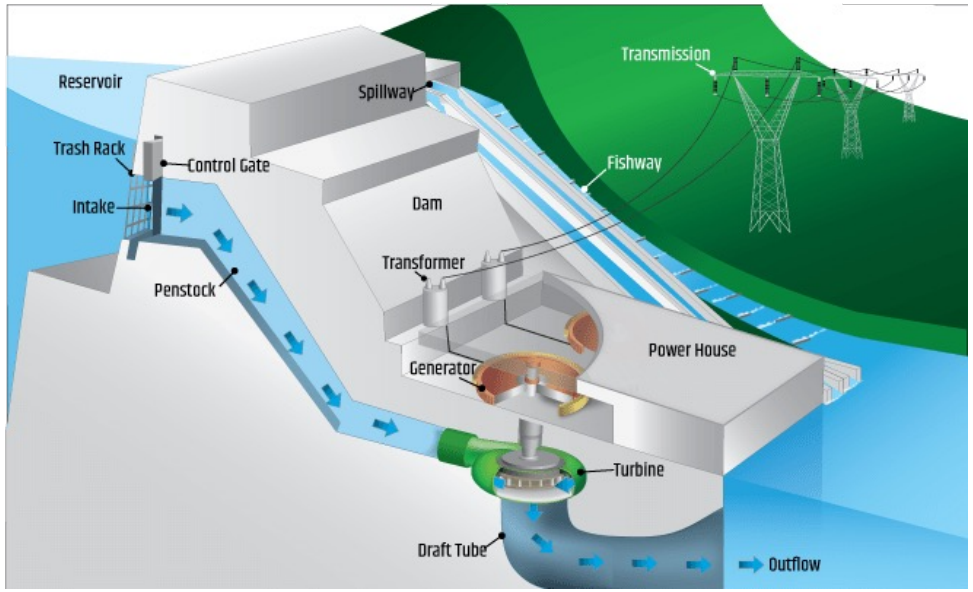


Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy
OurWorldInData.org/renewable-energy • CC BY

SHOW BY	TECHNOLOGY	SUB-TECHNOLOGY	YEAR
Electricity Generation	Hydropower (excl. Pumpe…	(All)	2020



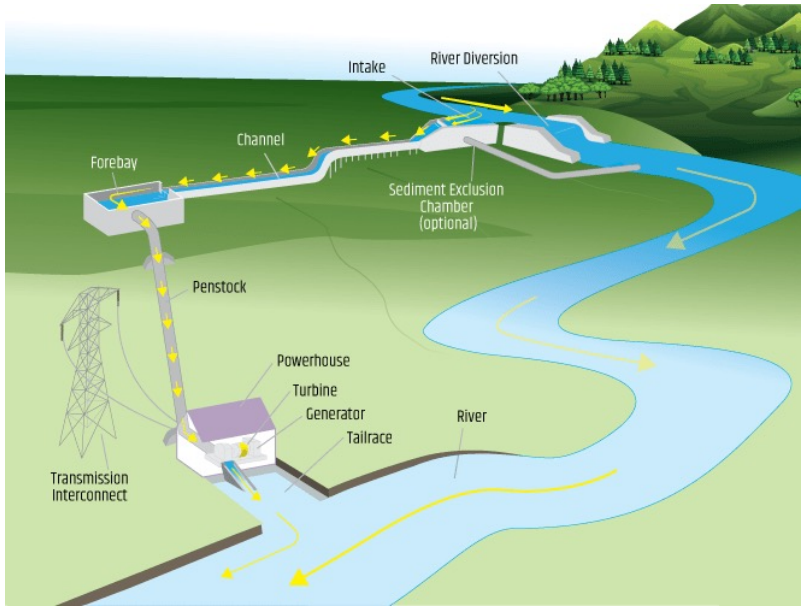
Three kinds of hydropower generation plants



1. Run-of-the-river

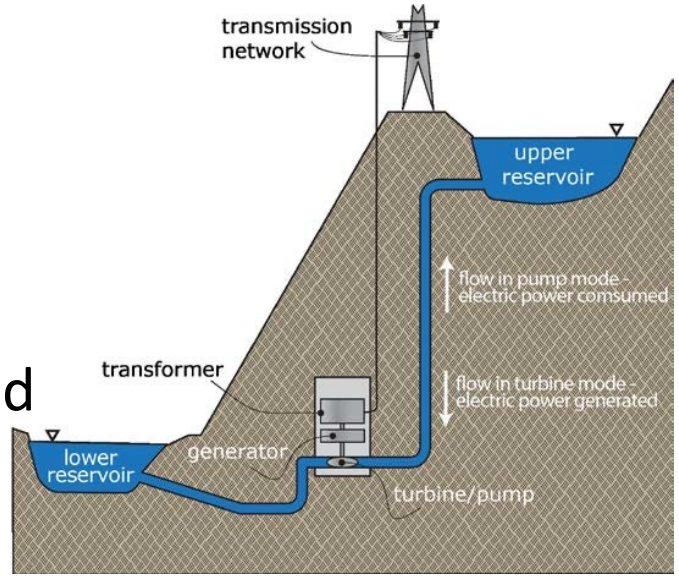
(Small-scale hydropower stations)

The power is generated by the flow of a river



2. Reservoir

The power is generated by releasing stored water



3. Pumped storage

Stored water is backed to the reservoir in order to be pumped again

Renewable Energy Supply Technologies

Wind Power Technologies

Wind turbines can generate as much electricity as conventional power plants.

Wind energy has made its most significant contribution in China (62GW), the USA (47GW), and Germany (29GW).

The trend shows that wind capacity installation has increased continuously during the last two decades.

- ✓The IEA estimates that global capacity will increase from 238 GW in 2011 to almost 1,100 GW in 2035 (80 % of which will be constituted of onshore wind turbines).
- ✓Offshore wind capacity is growing quickly and is expected to increase from 4 GW in 2011 to 175 GW by 2035 due to governmental support.

Renewable Energy Supply Technologies

Wind Power Technologies

In 2021 wind electricity generation increased by a record 273 TWh (up 17%).

This was 55% higher growth than that achieved in 2020 and was the highest among all renewable power technologies.

Such rapid development was possible thanks to an unprecedented increase in wind capacity additions, which reached 113 GW in 2020, compared with just 59 GW in 2019.

Renewable Energy Supply Technologies

Wind Power Technologies

China was responsible for almost 70% of wind generation growth in 2021, followed by the USA at 14% and Brazil at 7%.

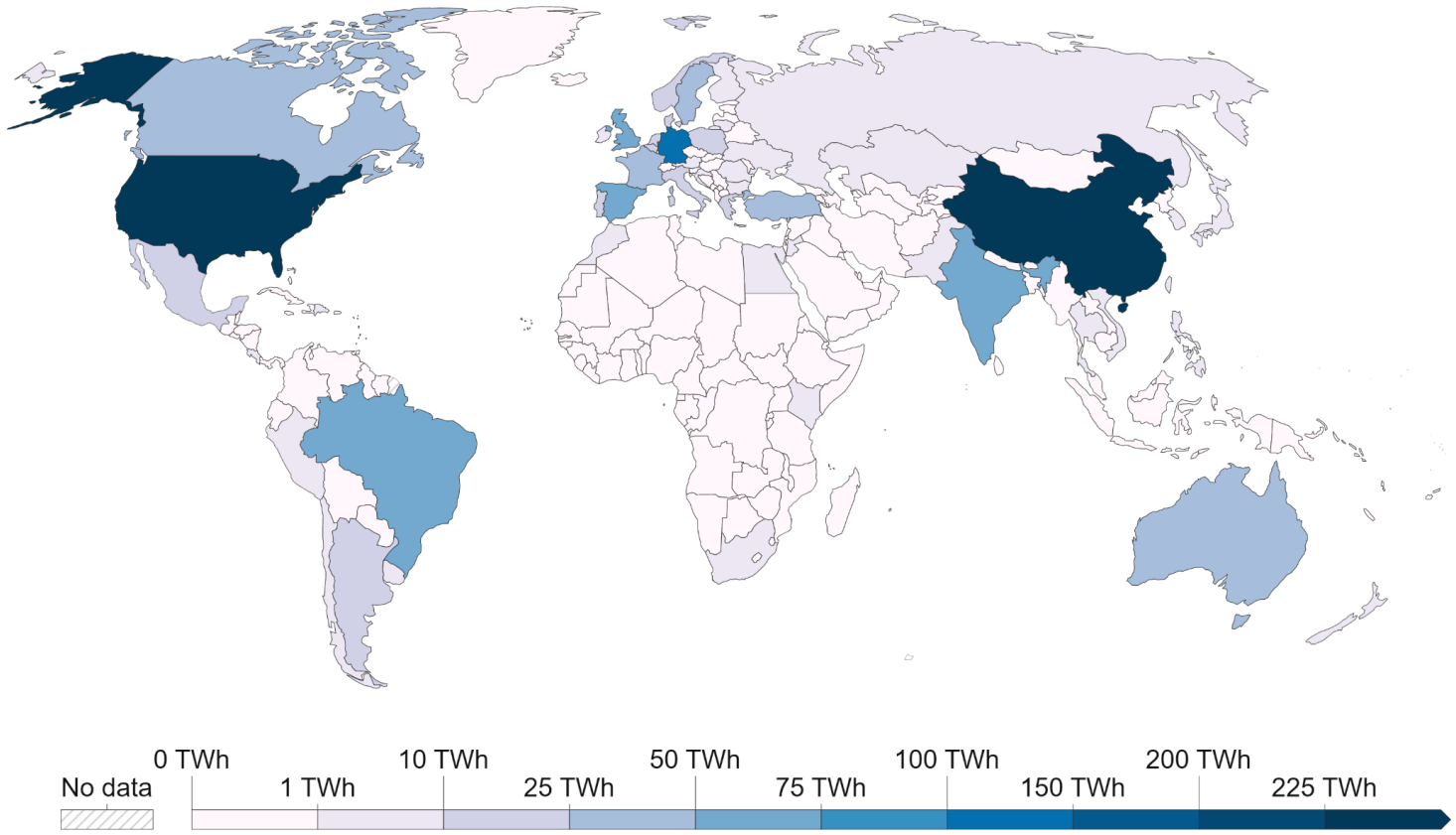
The EU, despite near-record capacity growth in 2020 and 2021, saw wind power generation fall by 3% in 2021 due to unusually long periods of low wind conditions.

Globally, record generation growth was possible thanks to a 90% increase in capacity growth in 2020, which reached 113 GW, driven by policy deadlines in China and the USA.

In 2021 however, wind additions decreased by 1/3 in China and by a 1/4 in the USA, partially offset by faster growth in other parts of the world, resulting in overall capacity growth reaching 94 GW.

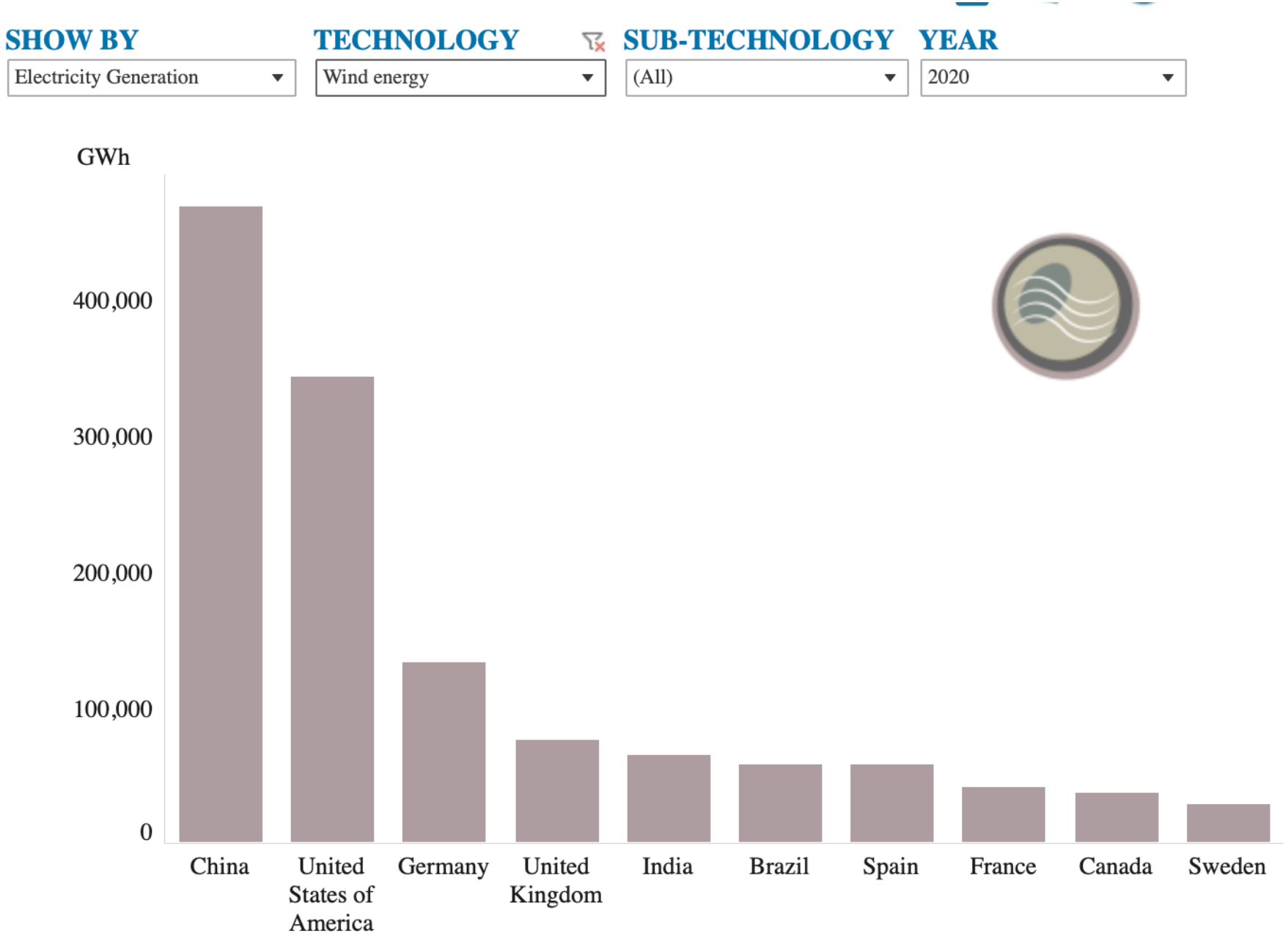
Wind power generation, 2021

Annual electricity generation from wind is measured in terawatt-hours (TWh) per year. This includes both onshore and offshore wind sources.



Source: Our World in Data based on BP Statistical Review of World Energy (2022); Our World in Data based on Ember's Yearly Electricity Data (2022); Our World in Data based on Ember's European Electricity Review (2022)

OurWorldInData.org/renewable-energy • CC BY


SHOW BY
Electricity Generation
TECHNOLOGY
Wind energy
SUB-TECHNOLOGY
(All)
YEAR
2020
GWh
400,000
300,000
200,000
100,000
0
China
United States of America
Germany
United Kingdom
India
Brazil
Spain
France
Canada
Sweden

Renewable Energy Supply Technologies

Solar Power Technologies

During the last few decades, researchers have investigated the economic feasibility of solar power for residential, commercial, and industrial consumption.

Industrial countries like Japan and Germany are looking for alternative sources of energy such as solar power due to the limited availability of natural primary energy sources.

In the early 1990s, Japan started taking advantage of large-scale electricity generation by solar photovoltaics, followed by Germany.

> Currently, both countries, with multibillion-dollar industries in solar power, have taken the lead in the manufacturing and production of solar power technologies.

In view of its industrial requirements, China has developed an extensive solar power capacity and has decreased the cost of solar power generation by taking advantage of cheap labor and government subsidies.

Renewable Energy Supply Technologies

Solar Power Technologies

Cost reduction of power generated through conventional solar PV technologies, advancement and high efficiency in concentrated solar power technologies in the USA has resulted in more reduction in the cost of electricity in solar power industry.

Negative effects caused by solar technologies:

- ✓Visual impact on buildings' aesthetics
- ✓Routine and accidental release of chemicals
- ✓Use of land
- ✓Impact of large PV systems on ecosystems
- ✓Construction activities for solar thermal energy

Renewable Energy Supply Technologies

Solar Power Technologies

Like wind energy, solar energy depends on weather conditions.

Variations in the weather such as clouds and pollution could affect solar power generation.

There is a major difference between wind and solar power because solar energy is available just during daylight hours.

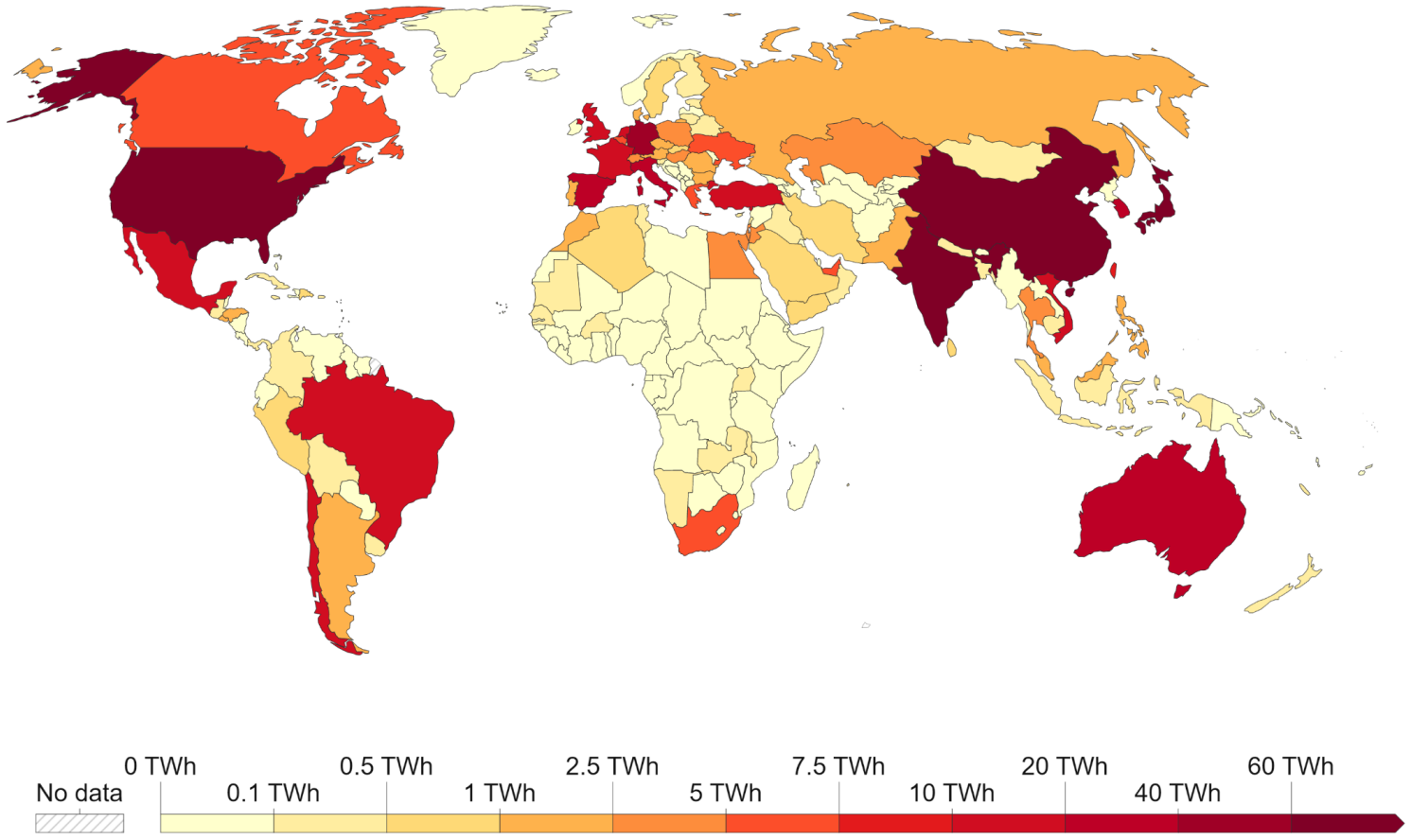
Therefore, solar power generation varies by season, location, and time of the day.

An advantage of photovoltaic technology compared to other technologies is the opportunity to integrate a PV collector into the building by turning external walls, windows, and roofs into a PV collector.

Solar power generation, 2021

Electricity generation from solar, measured in terawatt-hours (TWh) per year.

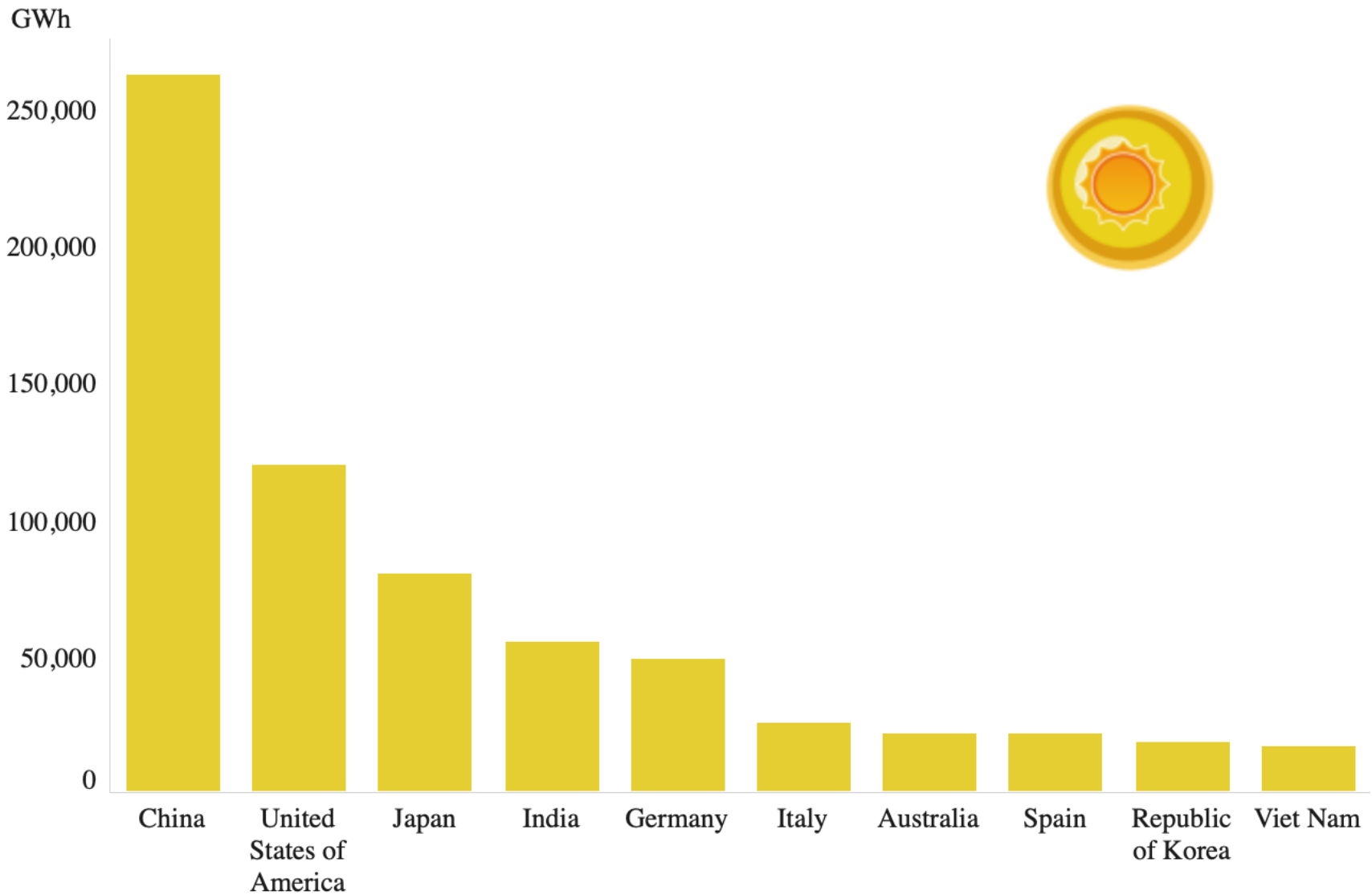
Our World in Data



Source: Our World in Data based on BP Statistical Review of World Energy & Ember

OurWorldInData.org/renewable-energy • CC BY

SHOW BY	TECHNOLOGY	SUB-TECHNOLOGY	YEAR
Electricity Generation	Solar energy	(All)	2020



Renewable Energy Supply Technologies

Solar Power Technologies

Solar PV generation increased by a record 179 TWh (up 22%) in 2021 to exceed 1 000 TWh.

It demonstrated the second largest absolute generation growth of all renewable technologies in 2021, after wind.

Solar PV is becoming the lowest-cost option for new electricity generation in most of the world, which is expected to propel investment in the coming years.

As with wind power, the main subject of research is life-cycle and market analysis of PV systems and GHG emissions as well as reliability, supply capability, technology innovation, grid parity, and economic incentives.

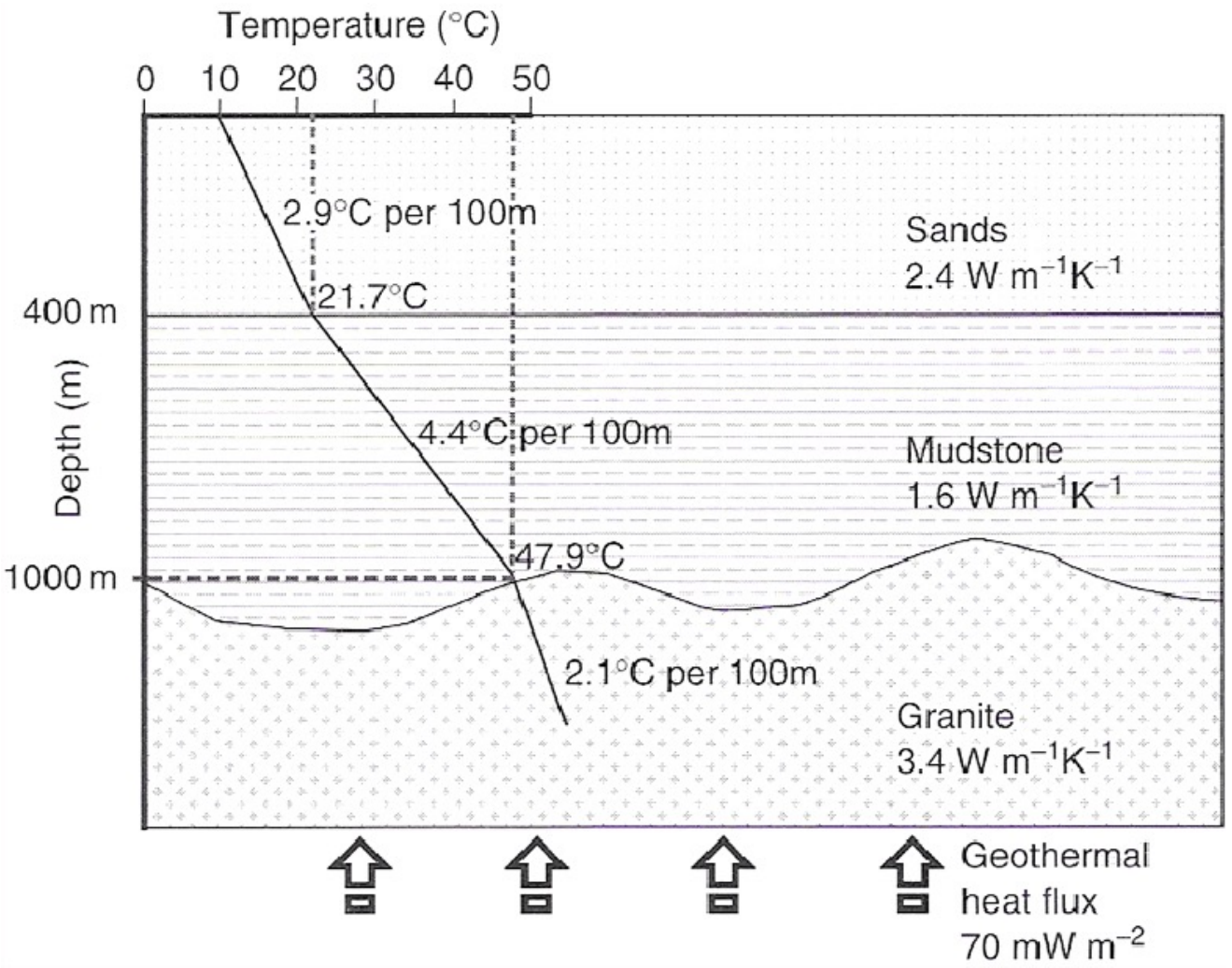
Renewable Energy Supply Technologies
Geothermal Power Technologies

While geothermal energy is available worldwide, there is an important factor called geothermal gradient to indicate a region as a favored place for deploying such energy.

It measures the rate of increasing temperature when the depth in the Earth increasing.

e.g., the geothermal gradient average in France is 4 ^{o}C/100 m with a broad variation from 10 ^{o}C/100 m in the Alsace region to 2 ^{o}C/100 m in the Pyrenees.

In Iceland and volcanic regions, 30 ^{o}C/100 m may be reached.



Renewable Energy Supply Technologies

Geothermal Power Technologies

Geothermal gradient is not the only dominant factor to measure the accessibility of geothermal energy.

Permeability of the rocks, which determines the rate of flowing heat to the surface, is considered another important measurement in deploying geothermal energy.

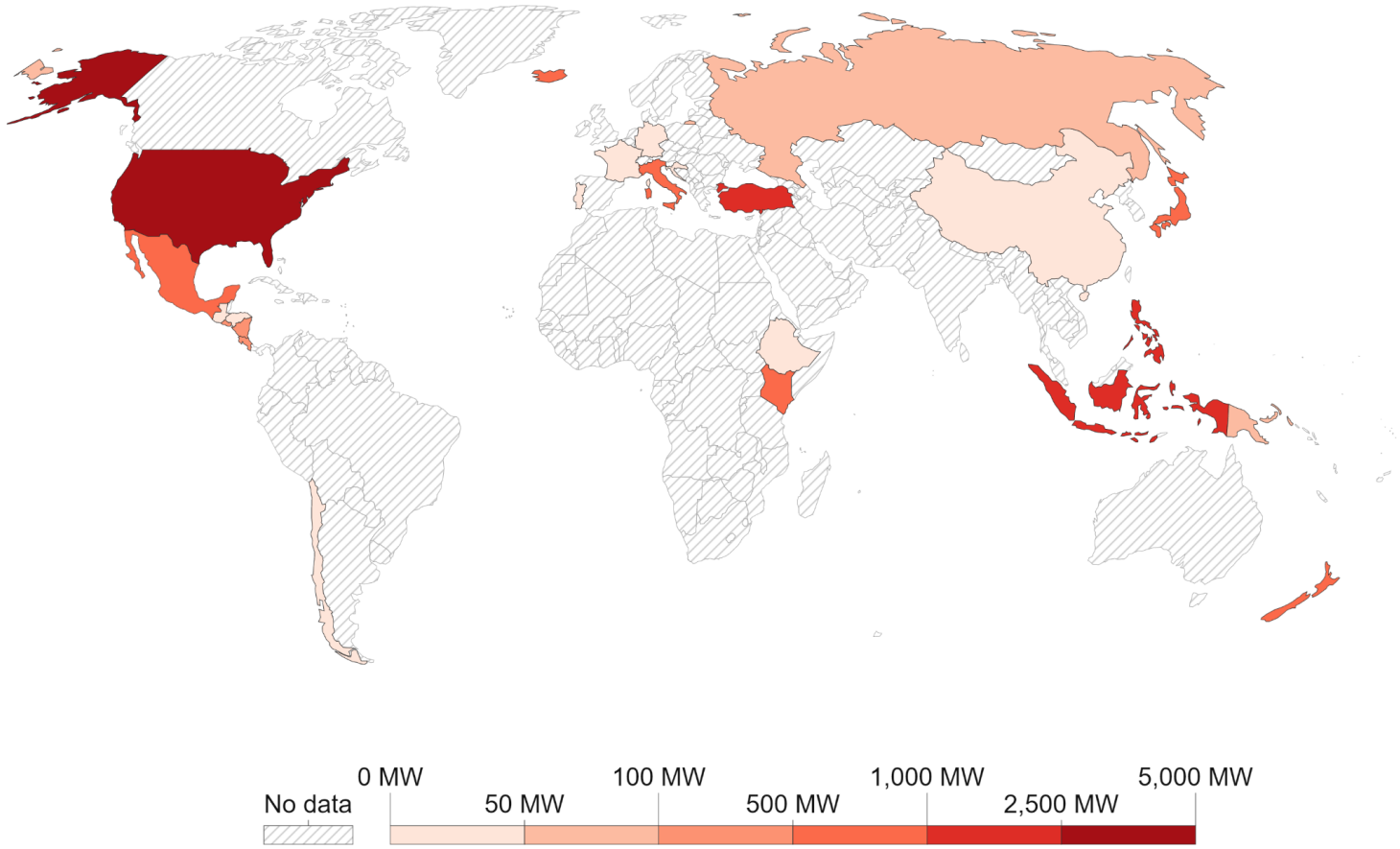
Geothermal has a big advantage compared to wind and solar energy

Availability of 24h through the year!

Installed geothermal energy capacity, 2020

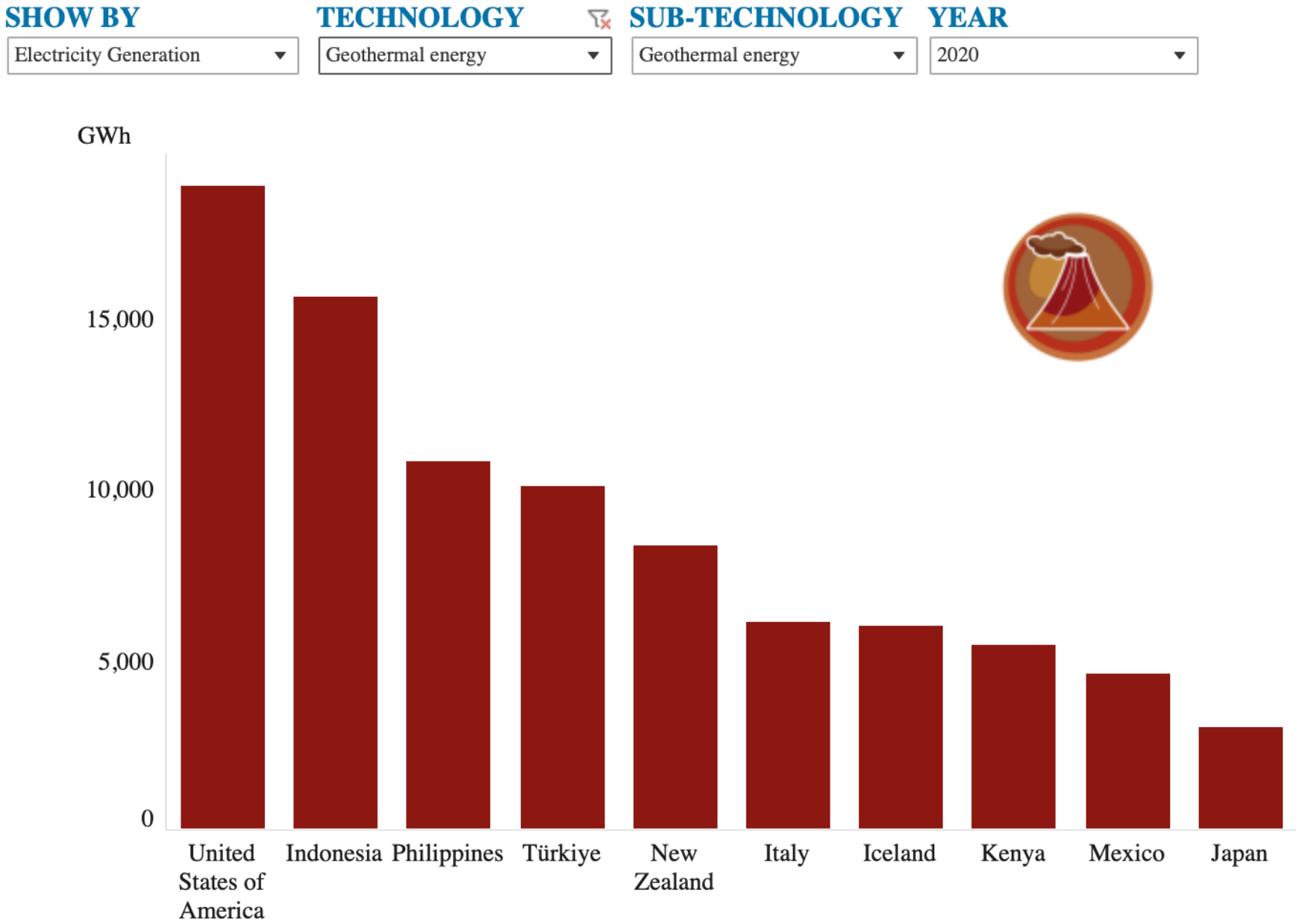
Cumulative installed capacity of geothermal energy, measured in megawatts.

Our World in Data



Source: Statistical Review of World Energy - BP (2021)

OurWorldInData.org/renewable-energy • CC BY


SHOW BY
Electricity Generation
TECHNOLOGY
Geothermal energy
SUB-TECHNOLOGY
Geothermal energy
YEAR
2020
GWh
15,000
10,000
5,000
0
United States of America
Indonesia
Philippines
Türkiye
New Zealand
Italy
Iceland
Kenya
Mexico
Japan

Renewable Energy Supply Technologies
Other Renewable Power Technologies

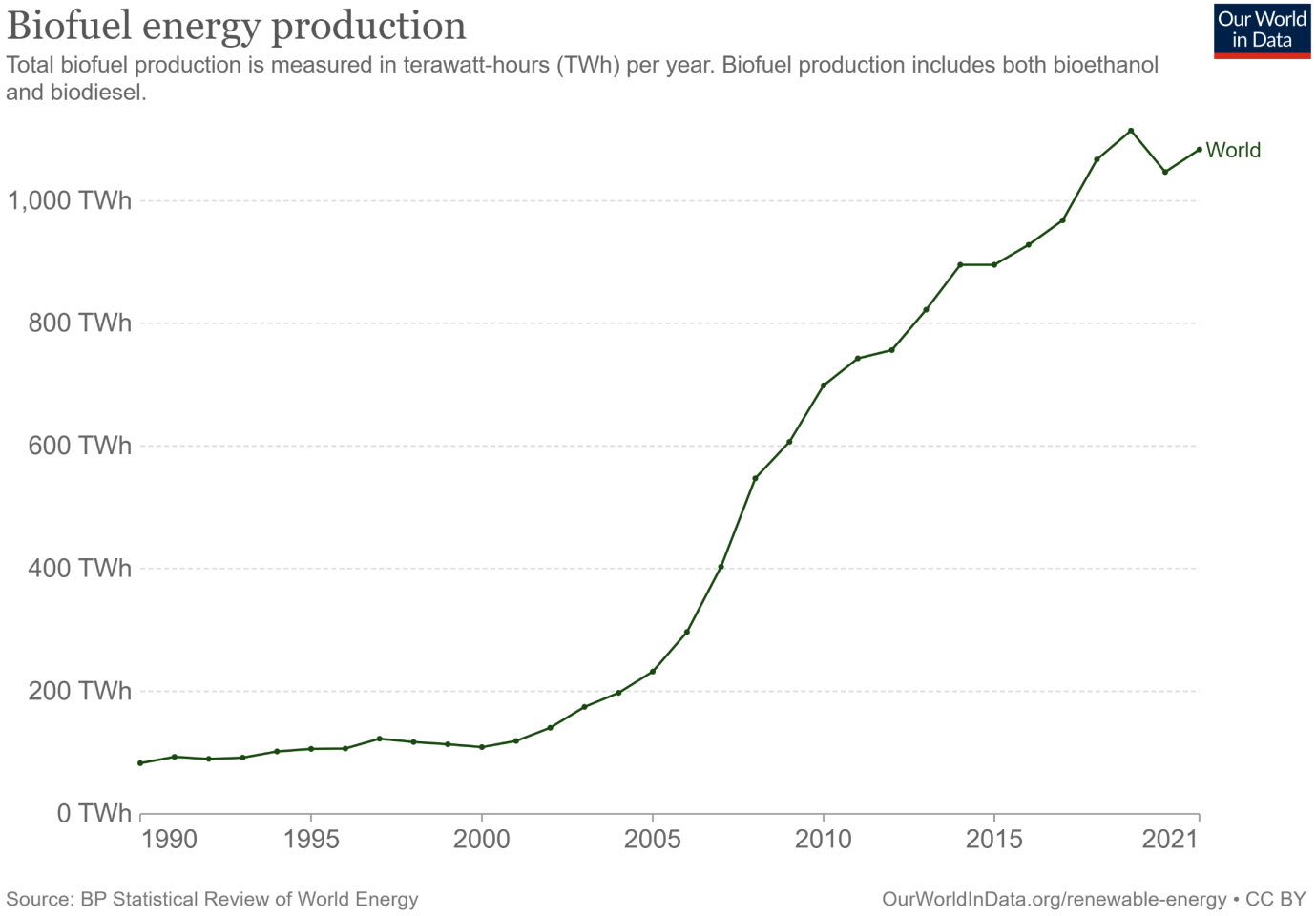
Biomass is defined as living plant and organic waste, which is made by *plants*, *humans*, *marine life*, and *animals*.

The main advantage of biomass is availability—it is found widely in all places.

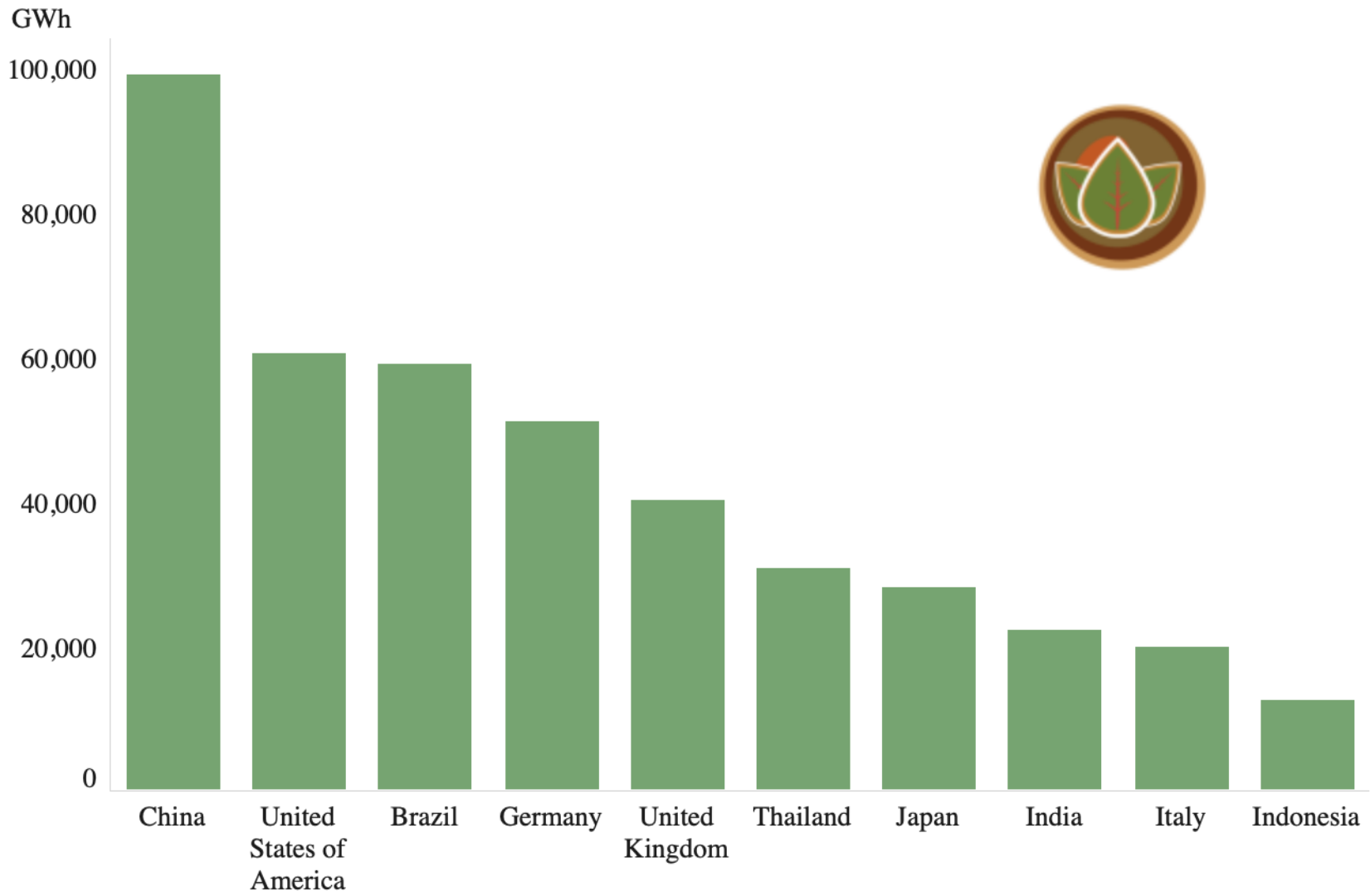
Many kinds of energy can be made from biomass: electricity, cooking, chemical feedstock, and so on.

As a feedstock, biomass has lower sulfur content than coal.

Therefore, lower emission is produced by combustion.



SHOW BY	TECHNOLOGY	SUB-TECHNOLOGY	YEAR
Electricity Generation	Bioenergy	(All)	2020



Energy Efficiency Technologies

Energy Efficiency

Definition:

Energy efficiency refers to the optimal utilization of energy resources to perform a specific task or achieve a desired outcome while minimizing waste.

It involves adopting *technologies*, *practices*, and *systems* that maximize the output or service obtained per unit of energy input.

Goal:

The goal of energy efficiency is to reduce *energy consumption*, *lower costs*, and *minimize environmental impact* by improving the overall performance and effectiveness of energy-using processes, equipment, and systems.

Energy Efficiency

Cost Savings: Improving energy efficiency helps reduce energy consumption, leading to lower utility bills and operational costs for businesses and individuals.

Environmental Impact: Energy efficiency reduces the demand for energy production, lowering greenhouse gas emissions and mitigating environmental impact.

It contributes to sustainability goals and helps combat climate change.

Resource Conservation: Using energy more efficiently means making the most of available resources, whether it's electricity, fuel, or natural gas.

This contributes to the conservation of finite resources.

Enhanced Comfort and Productivity: Efficient energy use often involves better insulation, heating, ventilation, and air conditioning (HVAC) systems.

This not only saves energy but also improves living and working conditions, enhancing comfort and productivity.

Energy Efficiency

Technological Innovation: Investing in energy-efficient technologies fosters innovation. Research and development in this field lead to the creation of advanced and sustainable technologies.

Energy Security: Energy efficiency reduces dependence on external energy sources. It enhances energy security by making a nation or organization less vulnerable to supply disruptions and price fluctuations in the global energy market.

Regulatory Compliance: Many regions have regulations and standards in place that require businesses and industries to meet specific energy efficiency criteria. Adhering to these standards ensures compliance and avoids legal issues.

Community and Corporate Image: Demonstrating a commitment to energy efficiency contributes to a positive public image. It aligns with corporate social responsibility and community expectations, fostering goodwill among customers, employees, and stakeholders.

Energy Efficiency

Long-Term Savings: While upfront costs may be involved in implementing energy-efficient measures, the long-term savings often outweigh these initial investments.

This is especially true when considering the life cycle costs of equipment and systems.

Government Incentives: Governments often provide incentives, tax credits, or rebates for adopting energy-efficient practices.

Exploring and taking advantage of these programs can further encourage the implementation of energy-saving measures.

In summary, energy efficiency is a multifaceted concept with *economic*, *environmental*, and social benefits. It involves both individual and collective efforts to optimize energy use across various sectors.

Energy Efficiency Technologies

Energy efficiency is the second of the two main solutions to reduce CO_2 emissions and overcome the climate change problem.

Energy efficiency for electricity networks could be considered in different stages including:

- ✓Power generation
- ✓Transmission
- ✓Distribution
- ✓Consumption

For this purpose, different technologies are available such as *batteries*, *combined heat and power* (CHP), *virtual power plants* (VPPs), and *smart grids*.

Electric Vehicles

A way to counteract the fluctuations that come with the irregularity of renewable energy production is the use of batteries.

With the use of batteries, stable electricity can be produced on demand.

The cost of batteries is very high ➔ the cost of renewable energy would increase even further

Therefore, a **joint use of batteries** could be a valid opportunity.

In this case, the cost accounted to renewable energy would be less, and due to the higher production quantity of batteries, the unit cost would go down as well.

An example of a joint use could be the use of batteries and electric vehicles.

Energy Efficiency Technologies
Electric Vehicles

Electric vehicles have the potential to be considered for electricity storage.

Considering that the transportation sector is one of the main sources of emissions, improving fuel efficiency enables the largest fuel saving and CO_2 reduction in the short term.

Thus, implementation of electric vehicles and increasing their share in vehicle fleets can play a key role in the long term.

Together with smart grid technology, electric vehicles can be used as electricity storage devices and a source of electricity if required.

Electric vehicles have the potential to be considered for electricity storage!

Energy Efficiency Technologies
Electric Vehicles

Transport accounts for around 1/5 of global carbon dioxide (CO_2) emissions [24% if we only consider CO_2 emissions from energy].

Road travel accounts ¾ of transport emissions.

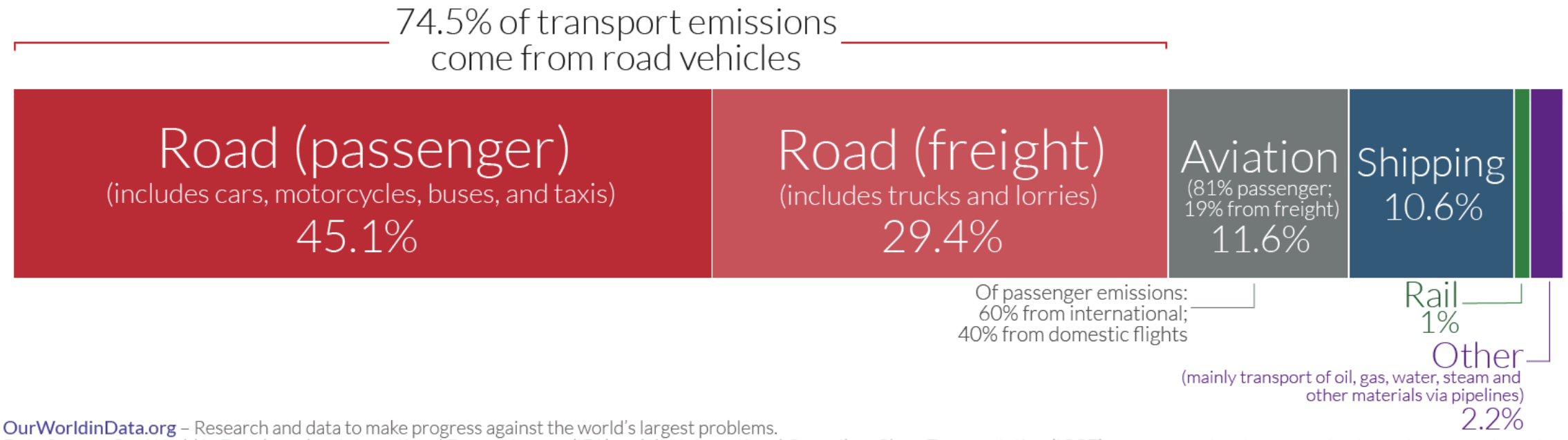
> Most of this comes from passenger vehicles – cars and buses – which contribute 45.1%. The other 29.4% comes from trucks carrying freight.

Since the entire transport sector accounts for 21% of total emissions, and road transport accounts for ¾ of transport emissions, road transport accounts for 15% of total CO_2 emissions.

Global CO_2 emissions from transport

This is based on global transport emissions in 2018, which totalled 8 billion tonnes CO_2.
Transport accounts for 24% of CO_2 emissions from energy.

Our World in Data



OurWorldinData.org – Research and data to make progress against the world's largest problems.
Data Source: Our World in Data based on International Energy Agency (IEA) and the International Council on Clean Transportation (ICCT).

Energy Efficiency Technologies

Electric Vehicles

Few areas in the world of clean energy are as dynamic as the electric car market.

Sales of electric vehicles doubled in one year (2020-2021) to a new record of 6.6 million.

In 2012, just 120 000 electric cars were sold worldwide.

In 2021, more than that many are sold each week!

Nearly 10% of global car sales were electric in 2021, four times the market share in 2019.

This brought the total number of electric cars on the world's roads to about 16.5 million, triple the amount in 2018.

Global sales of electric cars have kept rising strongly in 2022, with 2 million sold in the first quarter, up 75% from the same period in 2021.

Energy Efficiency Technologies

Electric Vehicles

The success of electric vehicles is being driven by multiple factor

➔Sustained policy support is the main pillar.

Public spending on subsidies and incentives for electric vehicles nearly doubled in 2021 to nearly USD 30 billion.

A growing number of countries have pledged to phase out internal combustion engines or have ambitious vehicle electrification targets for the coming decades.

Many carmakers have plans to electrify their fleets that go further than policy targets.

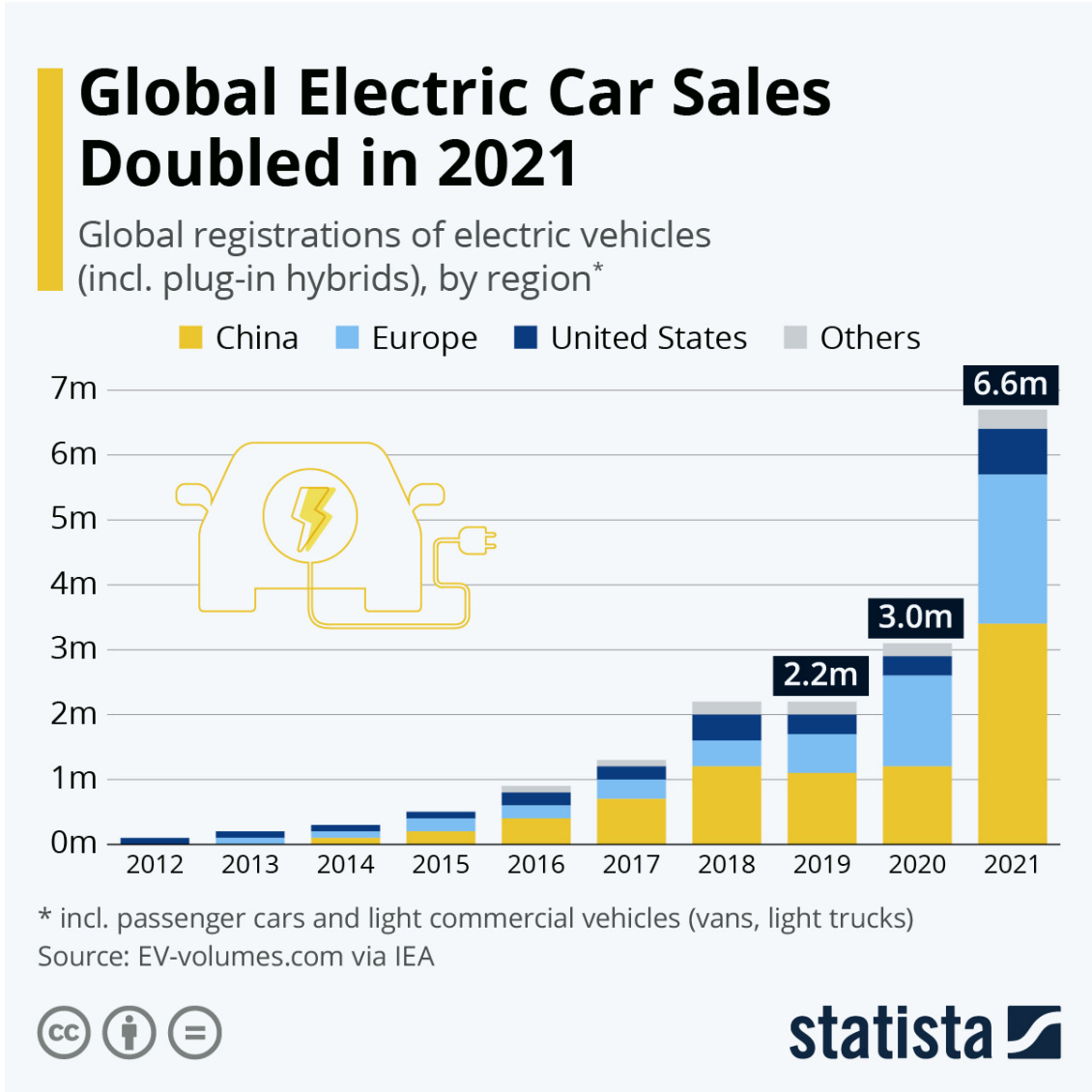
- Five times more new electric vehicles models were available in 2021 than in 2015, increasing the attractiveness for consumers.
- The number of electric vehicles models available on the market is around 450.

The increase in electric vehicles sales in 2021 was primarily led by China, which accounted for half of the growth.

More vehicles were sold in China in 2021 (3.3 million) than in the entire world in 2020.

Sales in Europe showed continued robust growth (up 65% to 2.3 million) after the 2020 boom, and they increased in the USA as well (to 630 000) after two years of decline.

The first quarter of 2022 showed similar trends, with sales in China more than doubling compared with the first quarter of 2021 (accounting for most of global growth), a 60% increase in the USA and a 25% increase in Europe.



Energy Efficiency Technologies
Combined Heat and Power (CHP)

Cogeneration or combined heat and power is the use of heat and electric power together.

This is expected to enable substantial gains in efficiency.

Most power distribution companies supply only electricity, not hot water or steam.

Considering that almost 30-40 % of a country's total energy load is used for heating, the lack of possibility to purchase thermal energy is not fortune.

CHP is an efficient use of fuel when some energy is discarded as waste heat.

It captures some or all waste energy as a byproduct for heating.

Energy Efficiency Technologies
Combined Heat and Power (CHP)

The Avedøre Power Station (Denmark) is a combined heat and power station.

Is a high-technology facility and one of the world's most efficient of its kind, being able to utilize as much as 94% of the energy in the fuel and convert 49% of the fuel energy into electricity.

Apart from using coal, oil and natural gas, the plant runs on a wide variety of biomass fuels such as straw and wood pellets.

The plant consists of two units with a total capacity of 793 MW of electricity and 918 MW of heat.

The combination of producing electricity (combined heat and power) and heat for district heating at the same time is widely used in Denmark and the rest of Scandinavia, due to the need of domestic (and industrial) heating together with the Danish energy companies putting a big effort into optimizing the energy plants.

Energy Efficiency Technologies

Virtual Power Plants (VPP)

Virtual power plant (VPP) is a cluster of distributed energy resources (DER) such as micro-CHP, wind turbines, and solar photovoltaic panels, which are controlled and managed by a central control unit.

The DER system was conceived to overcome the energy waste problem due to long-distance and transmission losses.

Therefore, DERs are generally located close to distribution networks.

The share of distributed generation (DG) in electricity networks is increasingly gaining importance, and VPP is considered as an emerging technology to enhance energy efficiency.

Energy Efficiency Technologies

Smart Meter

The most important objective for power generation companies in demand-side management is to reduce peak demand during a certain period of hours.

In this regard, smart meter is a device to record consumption of electricity in hourly intervals, and the information is monitored by utility and customers.

Smart meter can have two-way communication and intelligence management for home appliances.

Smart meters allow for demand management policies to reduce the consumption and generation of electricity.

Smart meters could be the gateway of home appliance communication through the Internet and will enable the use of advanced communication capabilities in the future.

Εργασίες