University of Piraeus
Department of European
and International Studies

Renewable Energy Sources (RES) in Global Politics

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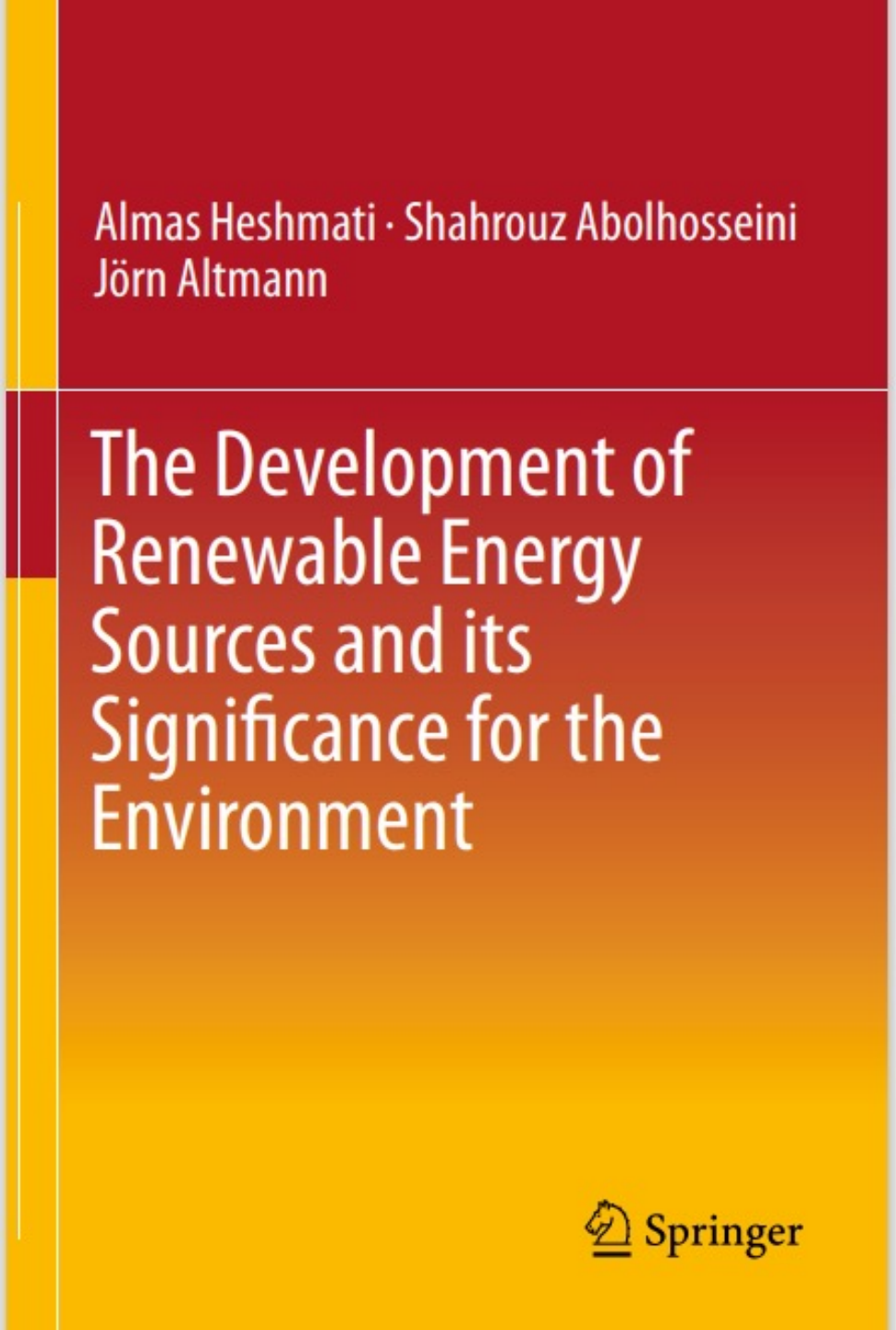


Main objectives of the presentation

Focus on

- ✓ The current situation of renewable energy consumption
- ✓ The global outlook

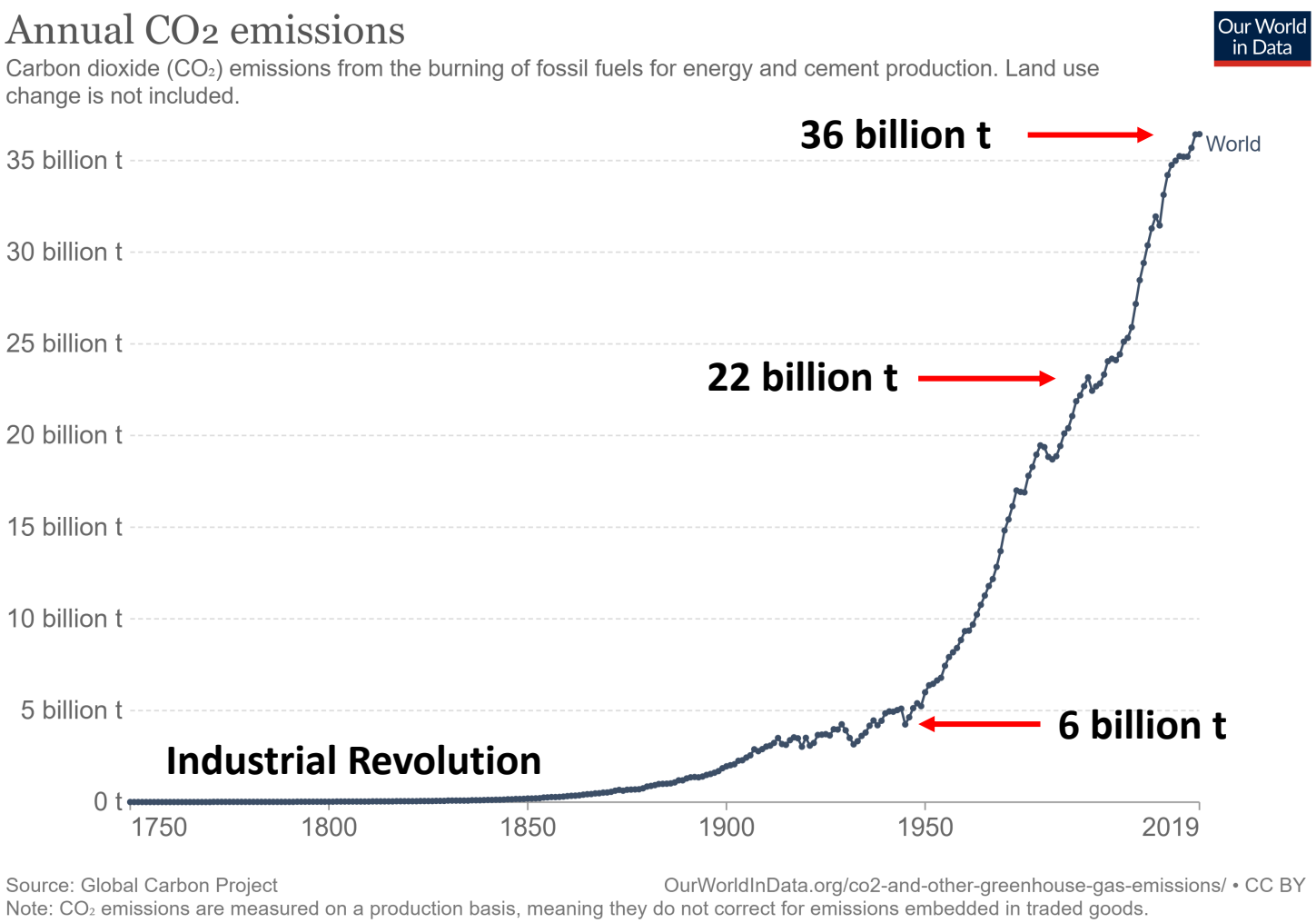
Review of the main drivers in the development of renewable energy

- ✓ Economic growth
- ✓ Energy security
- ✓ Carbon dioxide emission reduction

Presentation Outline

- Introduction of Renewables
- The General Trend of Energy Consumption
  - Fossil Fuels
  - Renewable Energy
  - Outlook of Energy Consumption
- Energy Consumption and Economic Growth
- The Main Drivers for Using Renewable Energy
  - Energy Security
  - Economic Impacts
  - CO_2 Emission Reduction

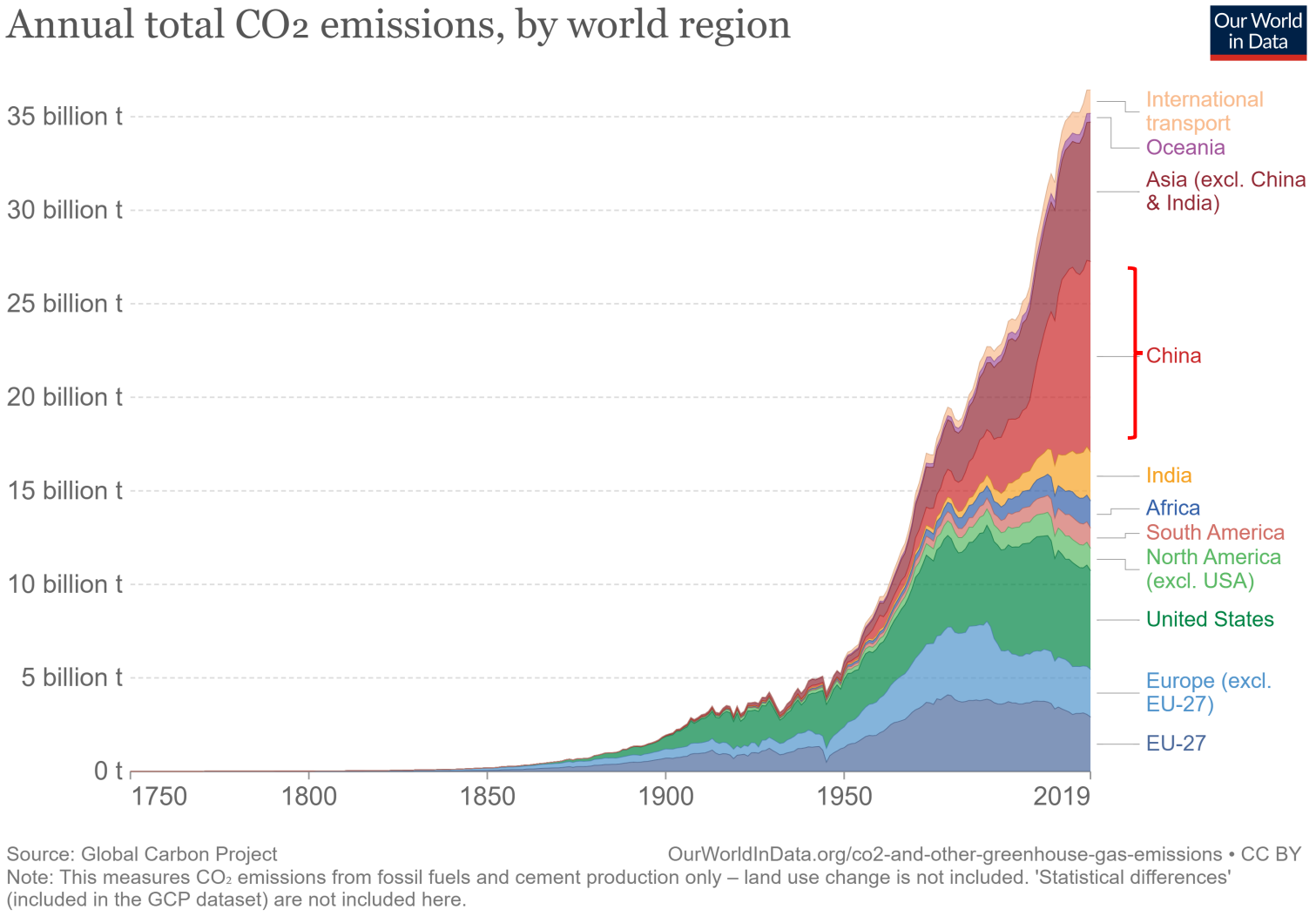
Growth of global emissions from the mid-18th century through to today



- Prior to the Industrial Revolution, emissions were very low
- Growth in emissions was still relatively slow until the mid-20th century
- In 1950 the world emitted 6 billion tonnes of CO_2
- By 1990 this had almost quadrupled, reaching more than 22 billion tonnes
- We now emit over 36 billion tonnes each year
- Emissions growth has slowed over the last few years, but they have yet to reach their peak

https://ourworldindata.org/co2-emissions

Annual total CO_2 emissions by region



1900: More than 90% of emissions were produced in Europe or the US

- Even by 1950, they accounted for more than 85% of emissions each year

Second half of the 20th century: Significant rise in emissions in the rest of the world

- Particularly across Asia (China)

The US and Europe now account for just under one-third of emissions

https://ourworldindata.org/co2-emissions

Introduction

Relation between climate change and the carbon dioxide (CO_2) emissions

- CO_2 emission pollutants are primarily produced by combustion of fossil fuels

Increasing prices of fossil fuels

Increasing concerns about the environment

- Have renewed the interest in the development of alternative energy resources

Turning point for alternative sources: Fukushima nuclear disaster (2011)

- It led to retrenchment, amid fresh concerns over the technological, institutional and cultural vulnerabilities of nuclear infrastructures

Introduction

Renewable energy:

A more desirable source of fuel than nuclear power plants because of the absence of fatal risks

The benefits of renewable energy sources are breathtaking

- Renewable Energy is eco-friendly
- Renewable Energy is a renewable resource
- Renewable Energy is a reliable source of energy
- Renewable Energy leads to job creation
- Renewable Energy has stabilized global energy prices
- Renewable energy boosts public health
- Lower reliance on foreign energy sources

Why is renewable energy important for our future?

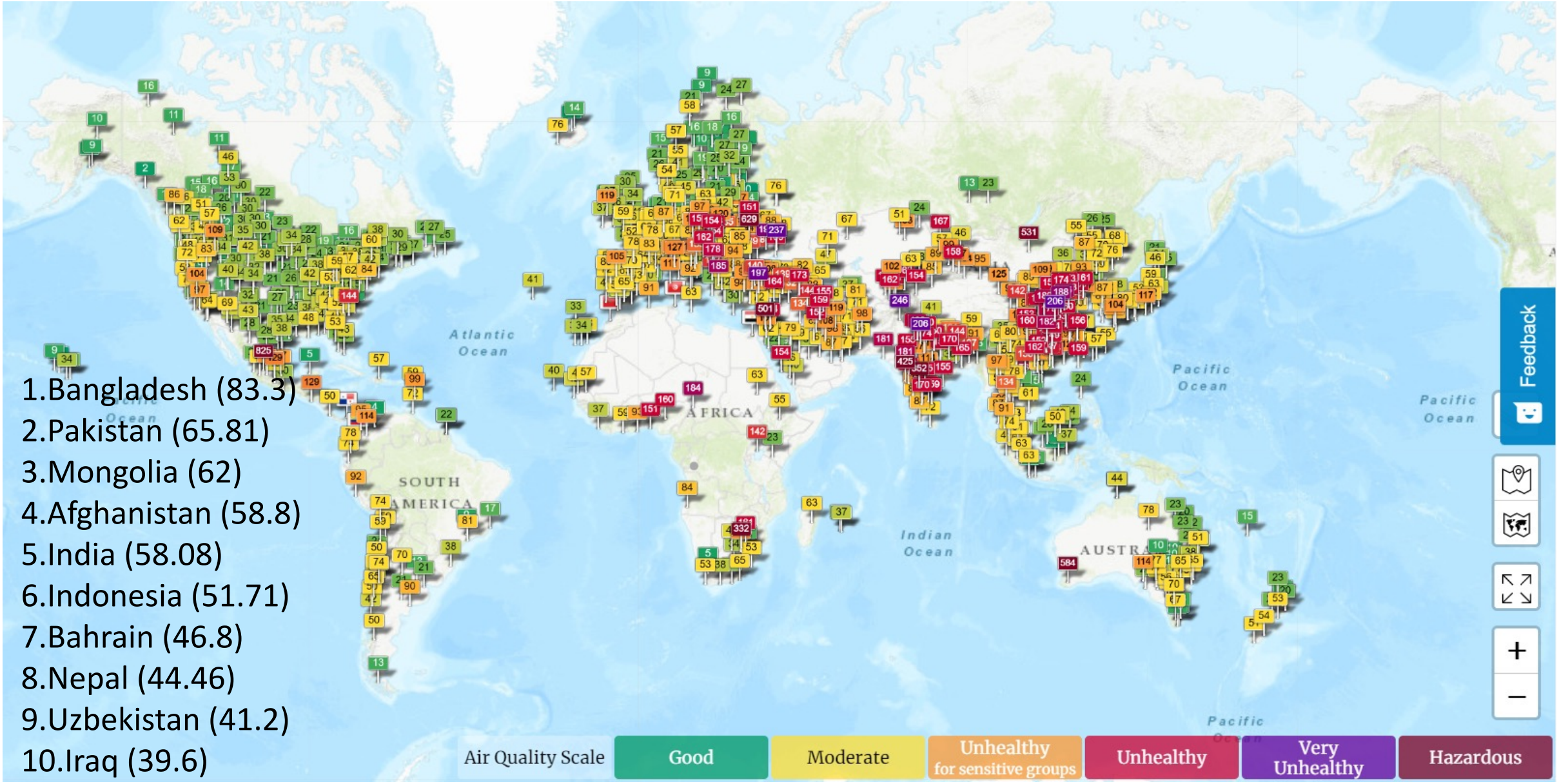
It is important because without it, we will run out of ways to power our world

- Experts estimate that we could run out of fossil fuels within the next 100 years

It is important because all nonrenewable sources harm the planet when they are converted into energy

- They pollute the air
  - Air pollutants and smog cause allergies, symptoms of asthma, and even lung disease
- Climate change, acid rain, and physical damage to the environment

World's Air Pollution: Real-time Air Quality Index



1.Bangladesh (83.3)
2.Pakistan (65.81)
3.Mongolia (62)
4.Afghanistan (58.8)
5.India (58.08)
6.Indonesia (51.71)
7.Bahrain (46.8)
8.Nepal (44.46)
9.Uzbekistan (41.2)
10.Iraq (39.6)

https://waqi.info/#/c/6.271/0.007/1.8z
https://worldpopulationreview.com/country-rankings/most-polluted-countries

Energy policy

Different policies can be applied in this regard

e.g., enhancing renewable energy deployment and encouraging technological innovations

Supporting mechanisms

e.g., feed-in tariffs, renewable portfolio standards, and tax policies

Increase renewable energy generation and achieve energy efficiency

Many countries have started installing facilities for power generation that can use renewable energy sources

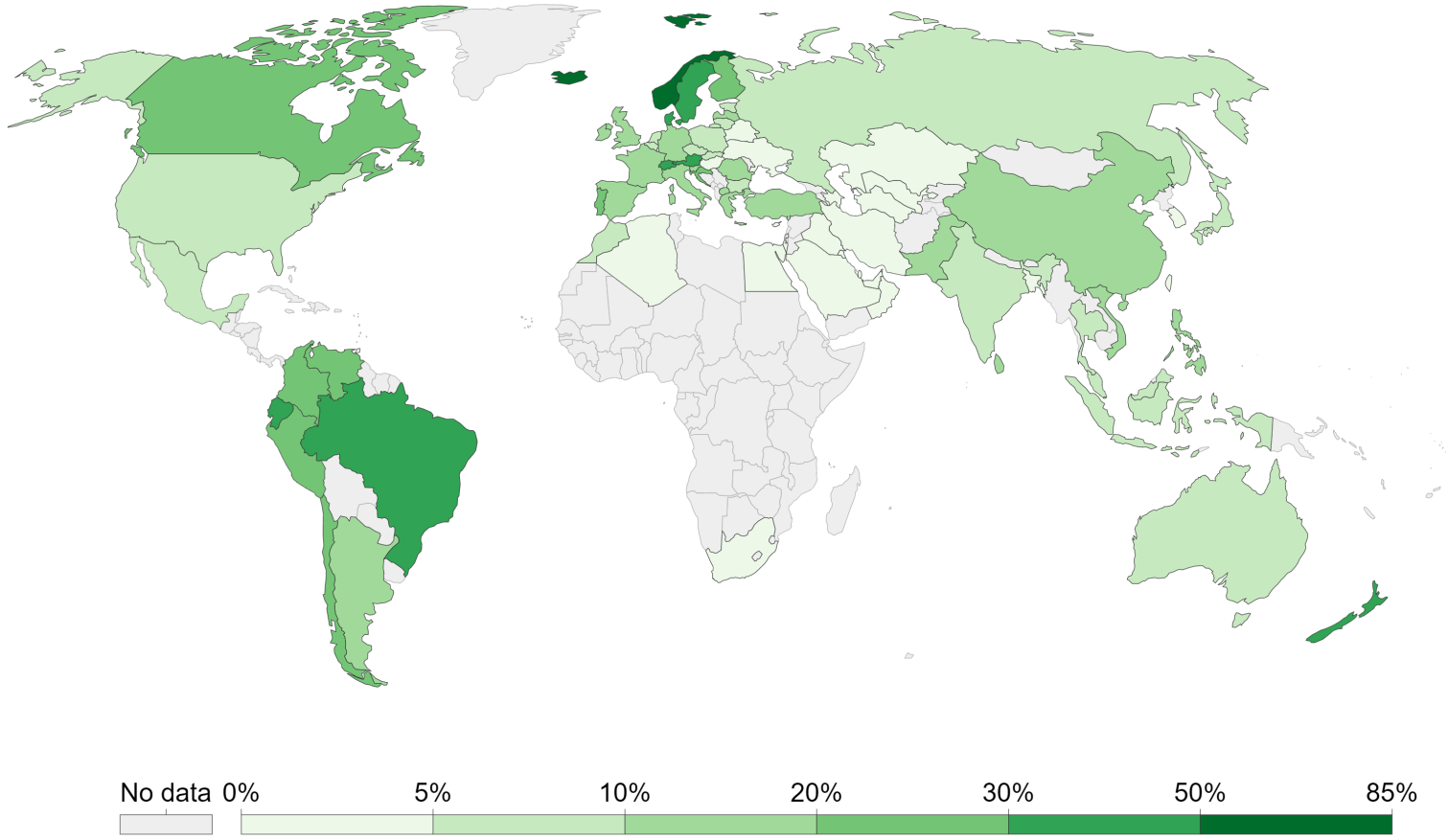
The share of a renewable energy supply differs by region and country

❖ European Union (EU): Forefront of using renewable energy technologies

Share of primary energy from renewable sources

Renewable energy sources includes hydropower, solar, wind, geothermal, bioenergy, wave and tidal. It does not include traditional biofuels, which can be a key energy source especially in lower-income settings.

Our World in Data



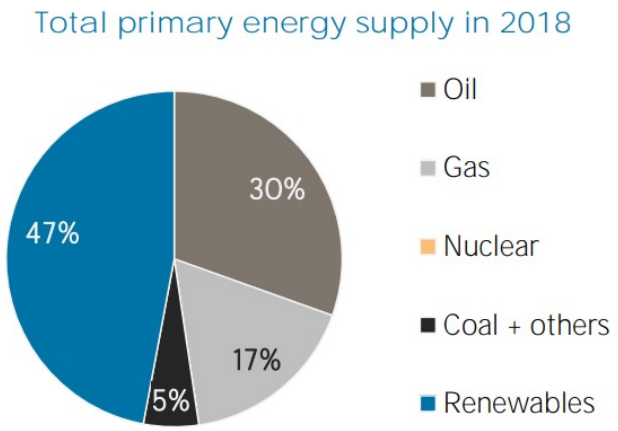
Source: Our World in Data based on BP Statistical Review of World Energy (2020)

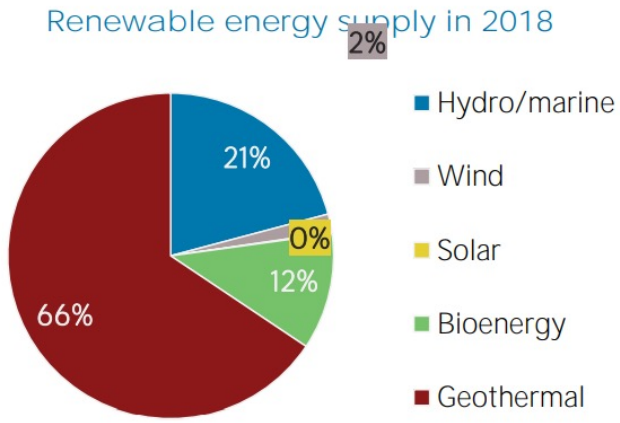
OurWorldInData.org/energy • CC BY

Note: Primary energy is calculated using the 'substitution method' which takes account of the inefficiencies energy production from fossil fuels.

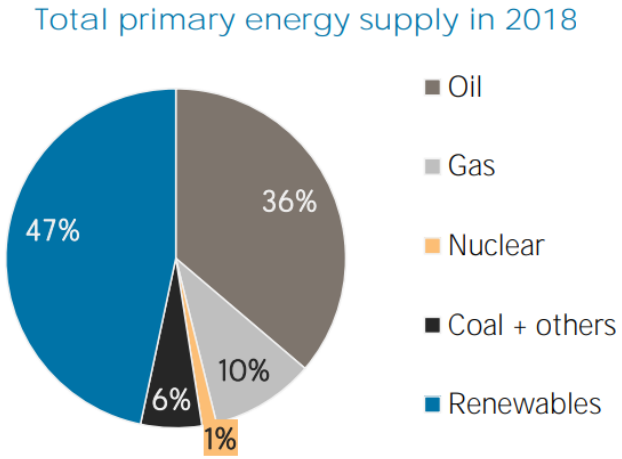
Energy Profile of the selected countries

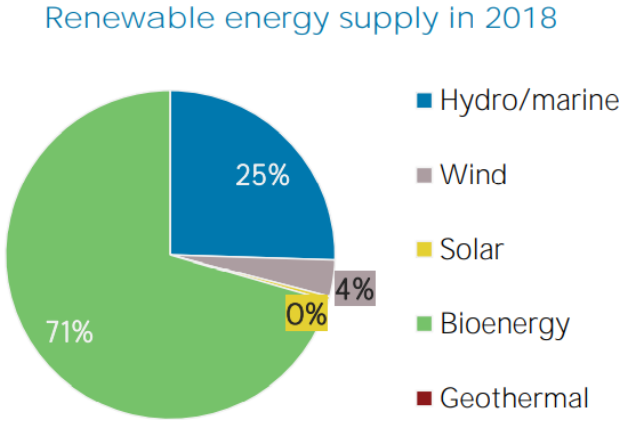
New Zealand



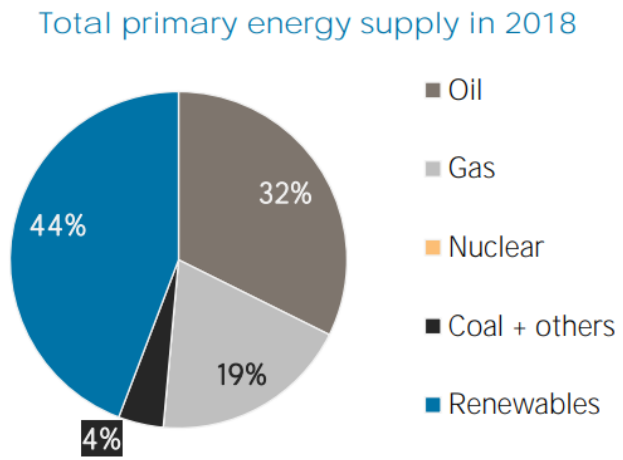


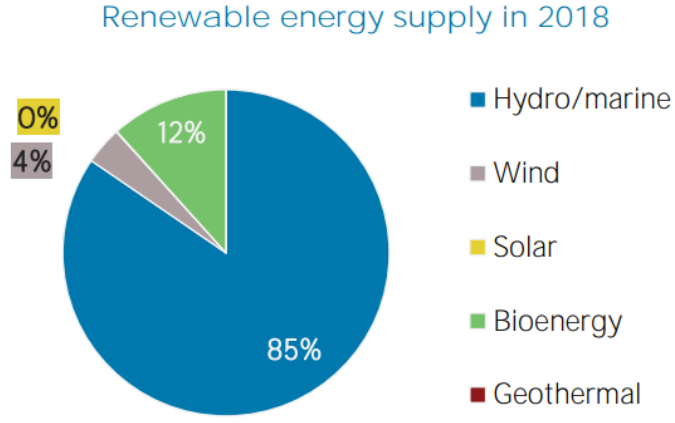
Brazil





Norway





https://www.irena.org/Statistics/Statistical-Profiles

Energy policy

Government policies have played a crucial role in the recent growth in renewable energy sources

- Especially in the electric power sector

Core part of environmental concerns: Reducing CO_2 emission and local pollutants

According to IEA, more than 70 countries were expected to implement policies for deploying renewable energy technologies in the power sector

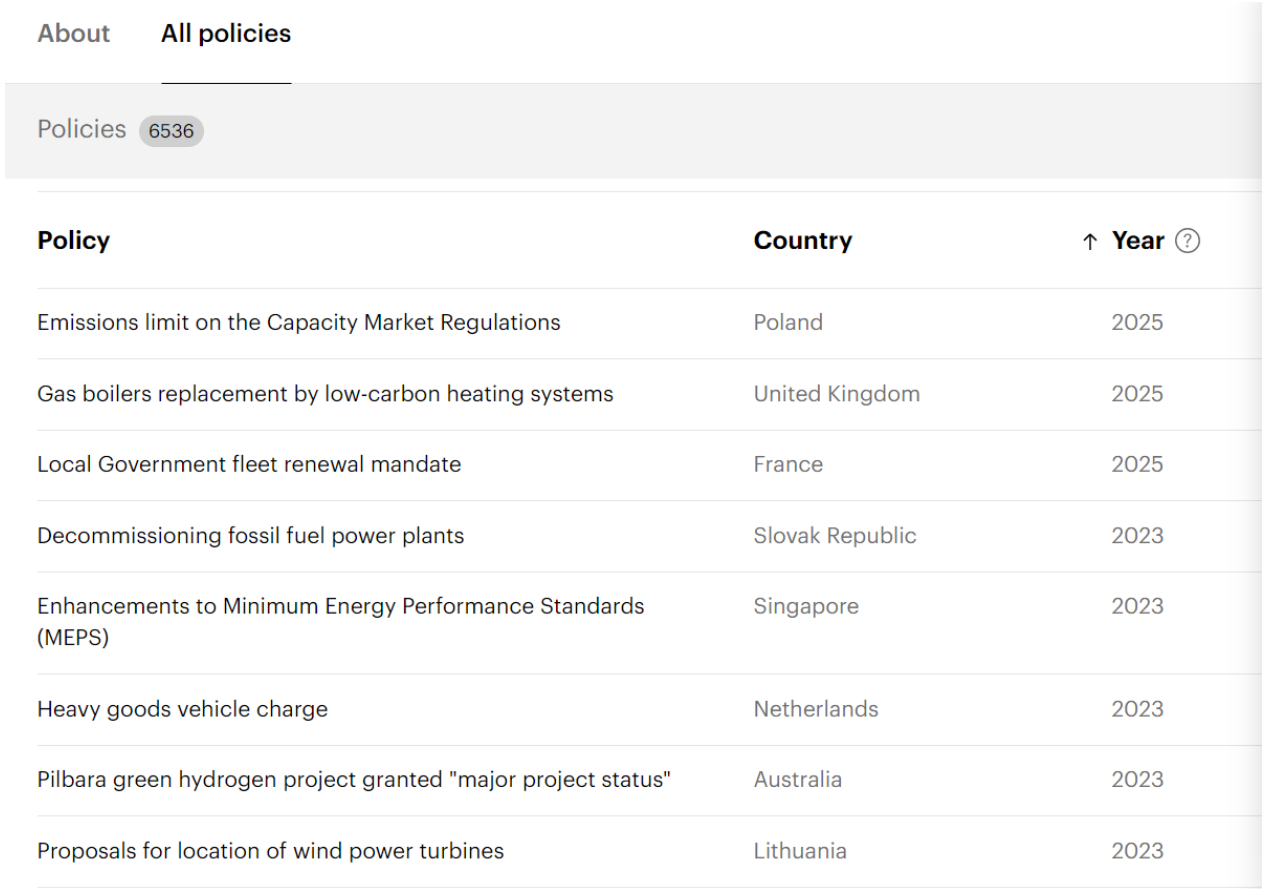
- These policies need to achieve an increase in power generation through RES so that the unit cost decreases to the level of other energy sources
- IEA Policies Database:
  - https://www.iea.org/policies

IEA's Policies and Measures Database

Provides access to information on past, existing or planned government policies and measures to reduce greenhouse gas emissions, improve energy efficiency, and support the development and deployment of renewables and other clean energy technologies

Databases:

- ✓ **IEA/IRENA Renewable Energy Policies and Measures**
- ✓ **IEA Energy Efficiency**
- ✓ **Addressing Climate Change**
- ✓ **Building Energy Efficiency Policies** (BEEP)



About | All policies

Policies 6536

Policy	Country	↑ Year
Emissions limit on the Capacity Market Regulations	Poland	2025
Gas boilers replacement by low-carbon heating systems	United Kingdom	2025
Local Government fleet renewal mandate	France	2025
Decommissioning fossil fuel power plants	Slovak Republic	2023
Enhancements to Minimum Energy Performance Standards (MEPS)	Singapore	2023
Heavy goods vehicle charge	Netherlands	2023
Pilbara green hydrogen project granted "major project status"	Australia	2023
Proposals for location of wind power turbines	Lithuania	2023

https://www.iea.org/policies

A brief history of renewable energy

The term “renewable energy” has been used as a contrast to exhaustible fossil fuel sources, at least since the early 1900s

Bell, 1906; Clarke et al., 1909

Distinction between “renewable” and “inexhaustible” energy sources

Renewable: Animal power sources and wood

Inexhaustible: Solar radiation, wind, tidal and hydropower

Clarke et al., 1909

The context for using this term was to oppose or at least provide an alternative to society's dependence on fossil fuels, although the rationale was not overuse as today but predicted exhaustion

A brief history of renewable energy

1960s: The environmental movements latched on to “renewable energy” as a conceptual alternative to perceived dehumanizing, environmentally destructive “centralized” energy sources

1970s: The environmental movement abandoned the 1950s and 1960s environmental conservation movements’ acceptance of nuclear power

All subsequent environmental discourse, energy sources have been divided between

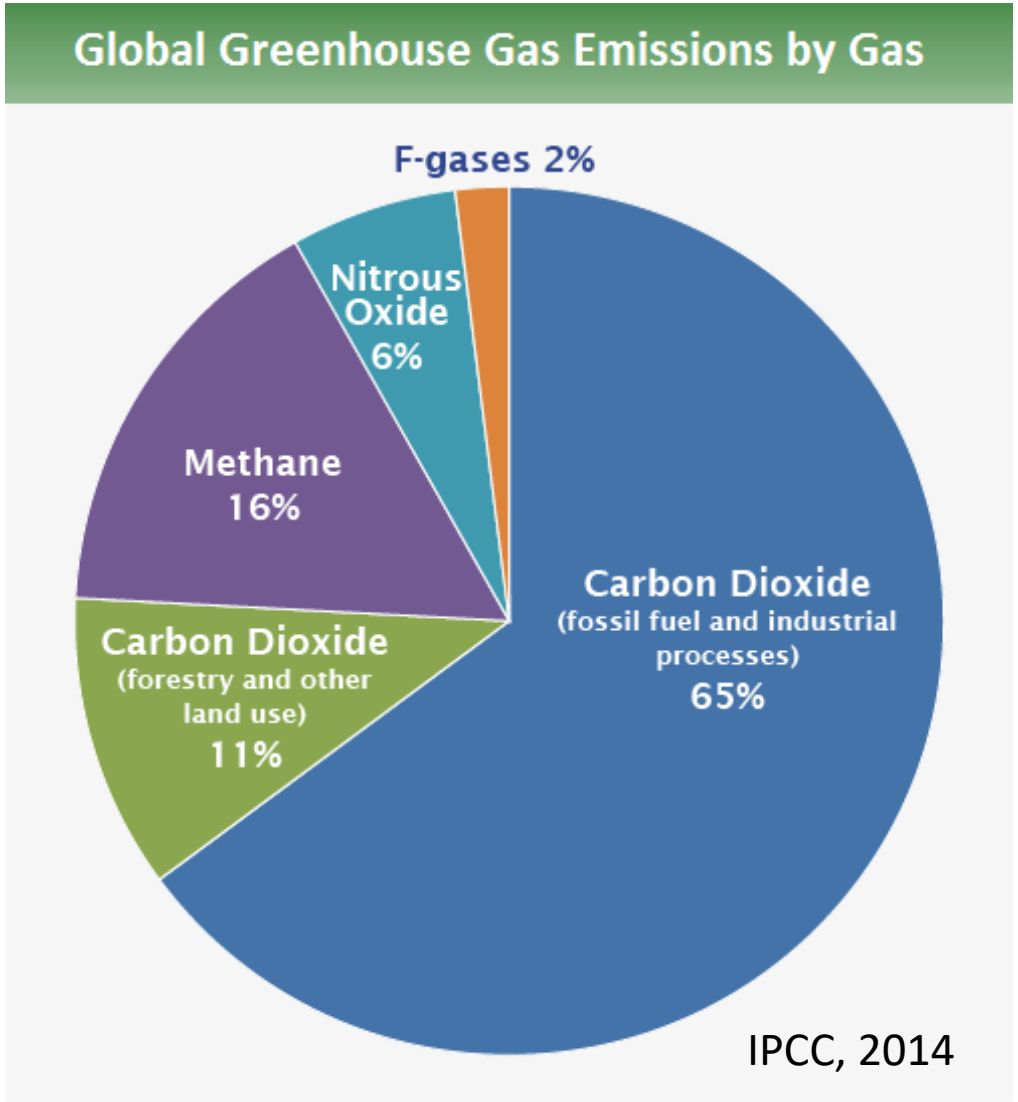
- good: solar, wind, tidal, geothermal, biomass, and hydropower
- tolerable for time being: small scale use of fossil fuels and peat
- bad – large-scale, centralized power plants, most notably nuclear power

Today: The environmental movement drives to the reduction of 1980s-era tolerance of coal, gas and peat as “bridge” fuels to be used until such time as the world is ready for totally renewable energy system

GHG emissions by gas

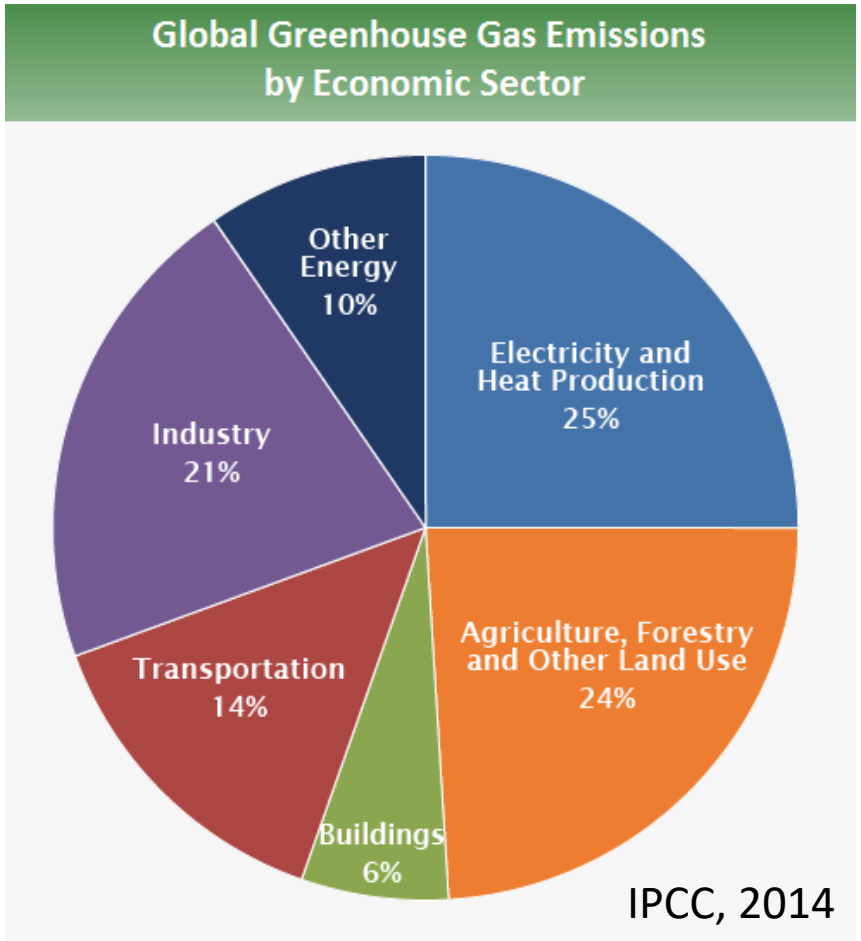
- **Carbon dioxide (CO_2)**: Fossil fuel use is the primary source of CO_2
- **Methane (CH_4)**: Agricultural activities, waste management, energy use, and biomass burning all contribute to CH_4 emissions
- **Nitrous oxide (N_2O)**: Agricultural activities, such as fertilizer use, are the primary source of N_2O emissions

  Fossil fuel combustion also generates N_2O
- **Fluorinated gases (F-gases)**: Industrial processes, refrigeration, and the use of a variety of consumer products contribute to emissions of F-gases, which include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)



GHG emissions by economic sector

- **Electricity and Heat Production**: GHG emissions of burning coal, natural gas, and oil for electricity and heat is the largest single source of global
- **Industry**: GHG emissions from industry primarily involve fossil fuels burned on site at facilities for energy
- **Agriculture, Forestry, and Other Land Use**: GHG emissions come mostly from agriculture and deforestation
- **Transportation**: GHG emissions primarily involve fossil fuels burned for road, rail, air, and marine transportation
- **Buildings**: GHG emissions arise from onsite energy generation and burning fuels for heat in buildings or cooking in homes



IPCC, 2014

Other Energy: GHG emissions refers to all emissions from the Energy sector which are not directly associated with electricity or heat production

World CO_2 emissions outlook (2020)

Global CO_2 emissions declined by 5.8%

- The largest ever decline
- Almost five times greater than the 2009 decline

CO_2 emissions fell further than energy demand in 2020

- Renewables increased

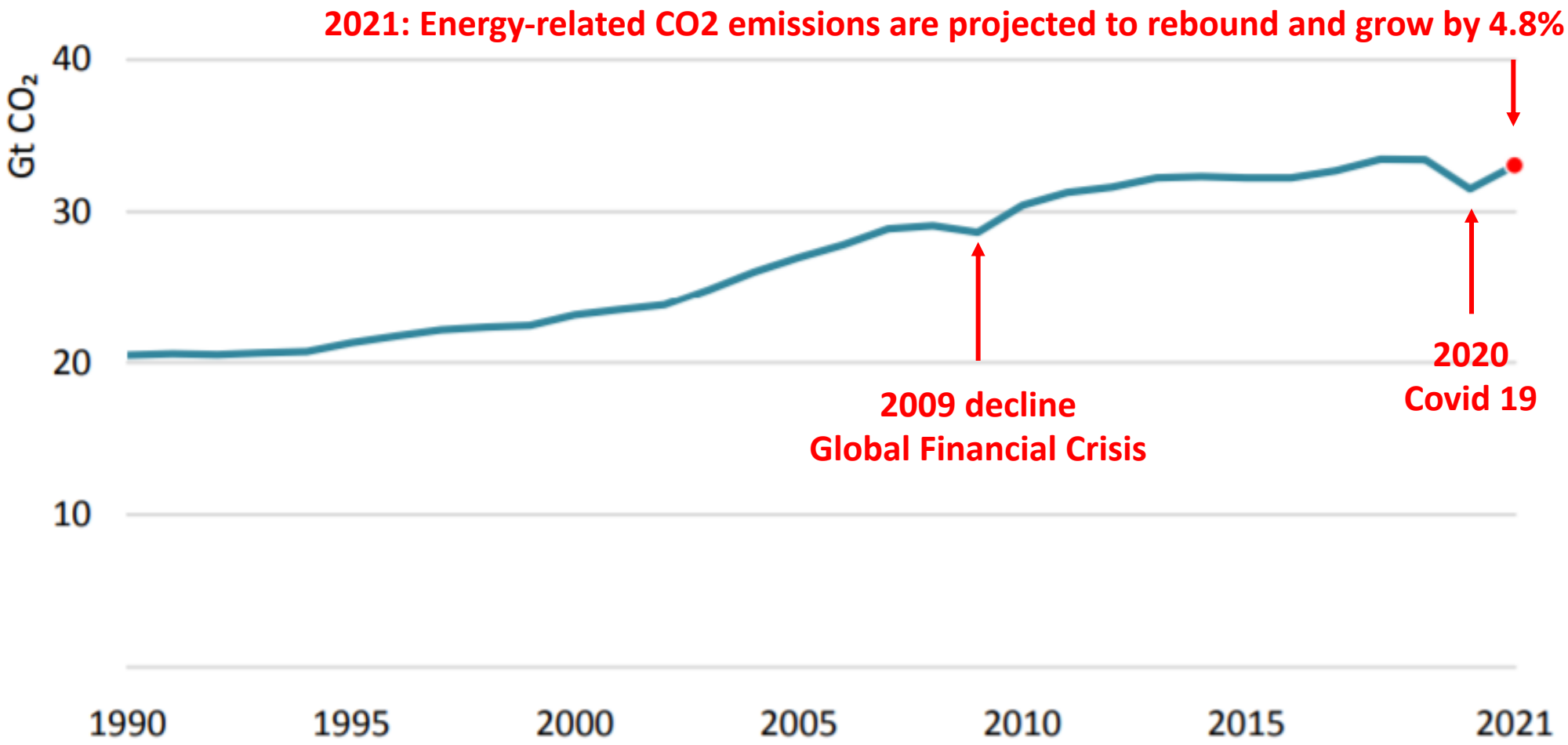
CO_2 reached its highest ever average annual concentration in the atmosphere of 412.5 parts per million

- Around 50% higher than when the industrial revolution began

In 2021 global energy-related CO_2 emissions are projected to rebound and grow by 4.8% as demand for coal, oil and gas rebounds with the economy

- Leaves global emissions in 2021 around 1.2%, below the 2019 peak

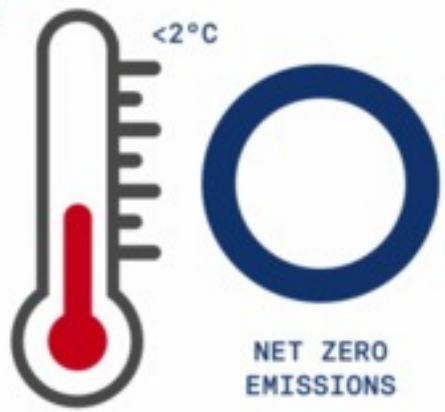
Global energy-related CO_2 emissions (1990-2021)



https://www.iea.org/reports/global-energy-review-2021/co2-emissions

PARIS CLIMATE AGREEMENT

1.



Limit the avg. global temperature increase to < 2° centigrade + achieve net zero emissions by mid-century

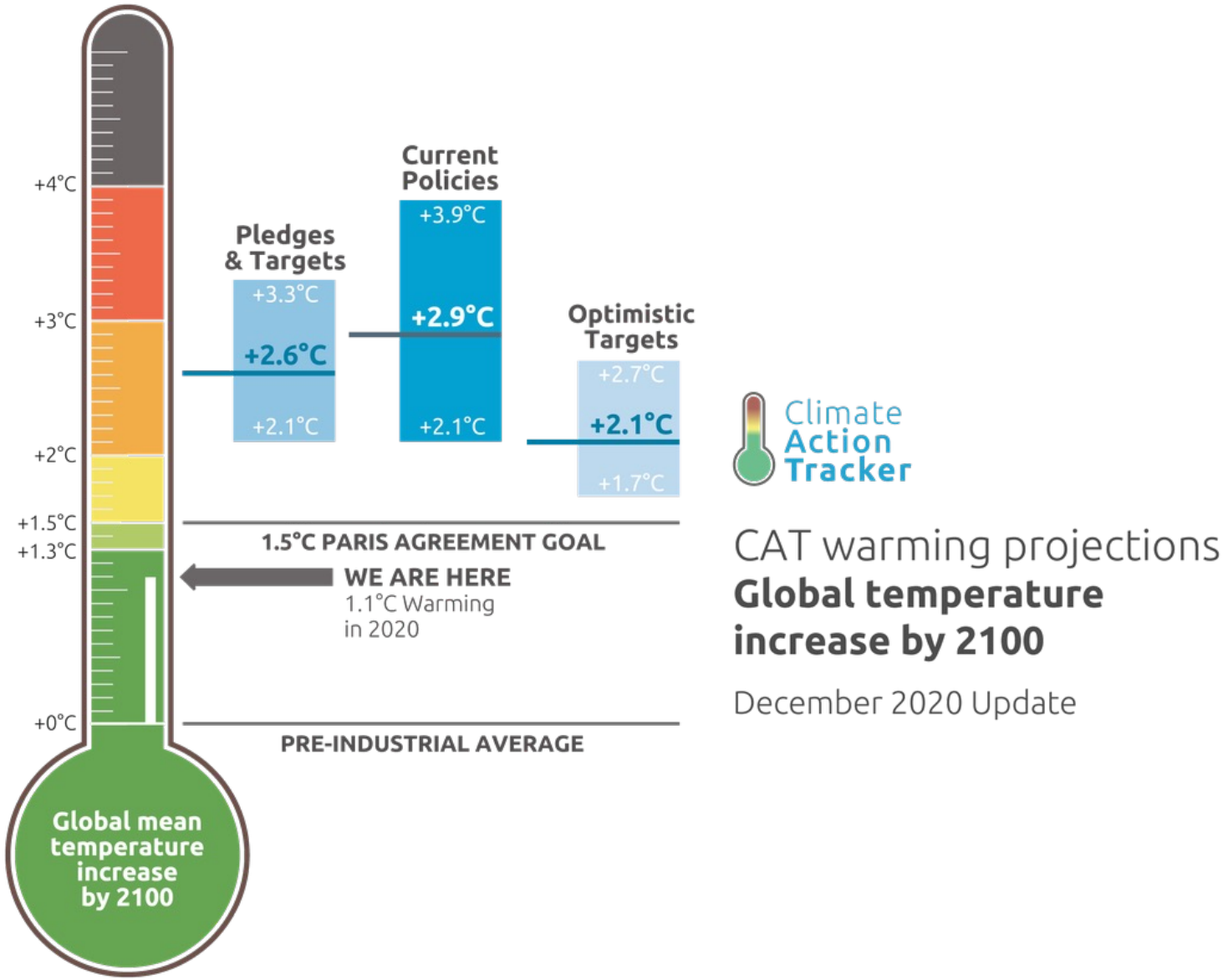
2.

Enhance resilience and adaptation to climate impacts certain to occur

3.

Align financial flows in the world with these objectives

https://energytracker.asia/cop26-is-this-make-or-break-for-the-paris-agreement/



https://climateactiontracker.org/publications/global-update-paris-agreement-turning-point/

Defining the Renewables

Renewable energy is defined as energy that is produced by natural resources—such as sunlight, wind, rain, waves, tides, and geothermal heat—that are naturally replenished within a time span of a few years

Renewable Energy Systems, 2010

The International Energy Agency (IEA) defines renewable energy as *"energy derived from natural processes that are replenished at a faster rate than they are consumed",* and mentions solar, wind, geothermal, hydro and biomass as examples of renewable energy

IEA, 2018

The European Union includes wind, solar, hydro and tidal power, geothermal energy, biofuels and the renewable part of waste as renewable energy in its statistical accounting

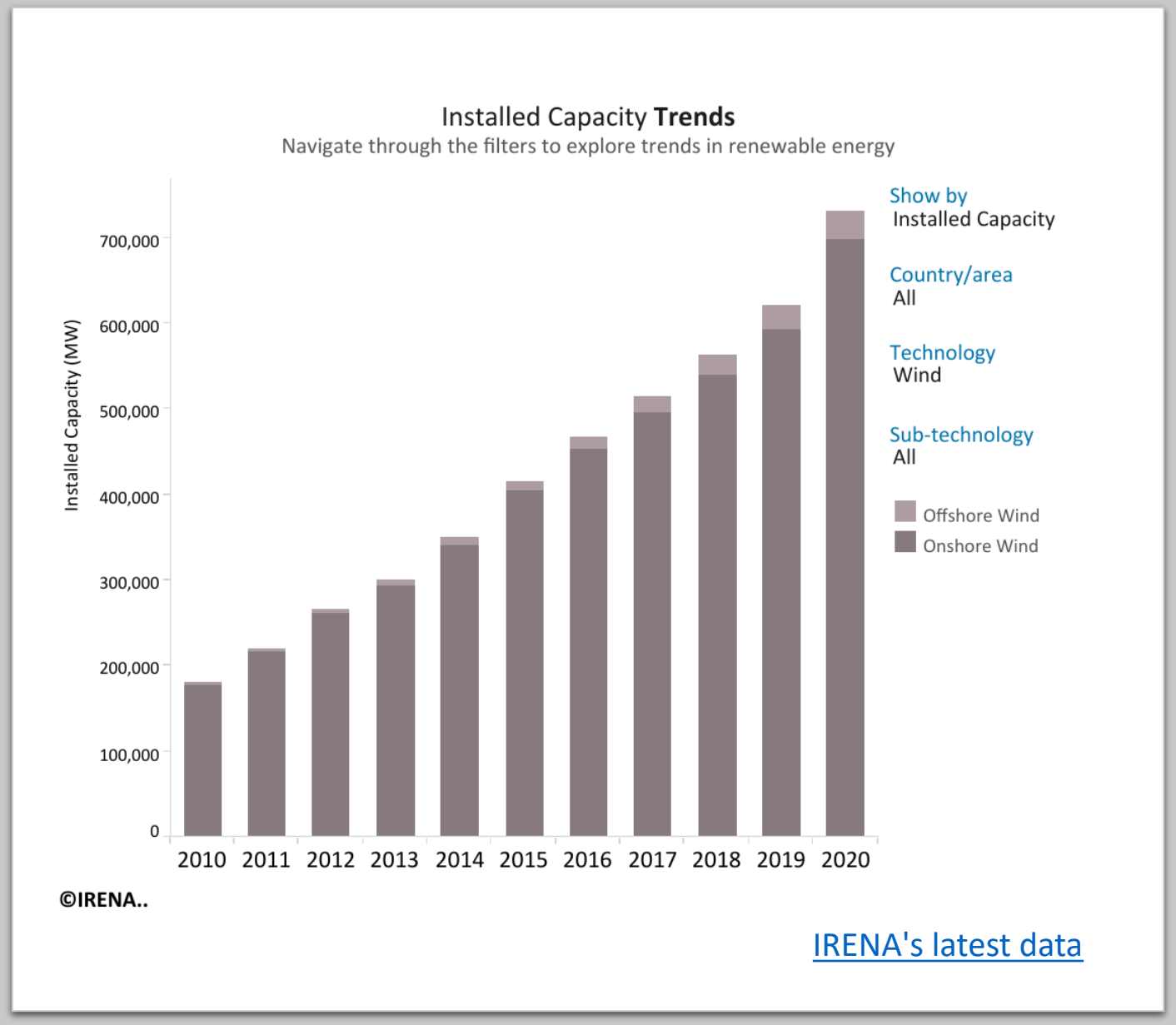
Eurostat, 2018

The United Nations Environment Programme follows the same logic

Frankfurt Scholl, 2018

Wind Energy

- Wind power is one of the fastest-growing renewable energy technologies
- Global installed wind-generation capacity onshore and offshore has increased by a factor of almost 75 in the past two decades, jumping from 7.5 GW in 1997 to some 564 GW by 2018
- Production of wind electricity doubled between 2009 and 2013
- In 2016 wind energy accounted for 16% of the electricity generated by renewables



Wind Energy

Wind turbines first emerged more than a century ago

- Wind is used to produce electricity using the kinetic energy created by air in motion
- This is transformed into electrical energy using wind turbines or wind energy conversion systems

The amount of power that can be harvested from wind depends on the size of the turbine and the length of its blades

- The output is proportional to the dimensions of the rotor and to the cube of the wind speed

Wind-turbine capacity has increased over time

- In 1985, typical turbines had a rated capacity of 0.05 MW and a rotor diameter of 15 metres
- Today’s new wind power projects have turbine capacities of about 2 MW onshore and 3–5 MW offshore

Εσωτερική άποψη του πύργου μιας ανεμογεννήτριας

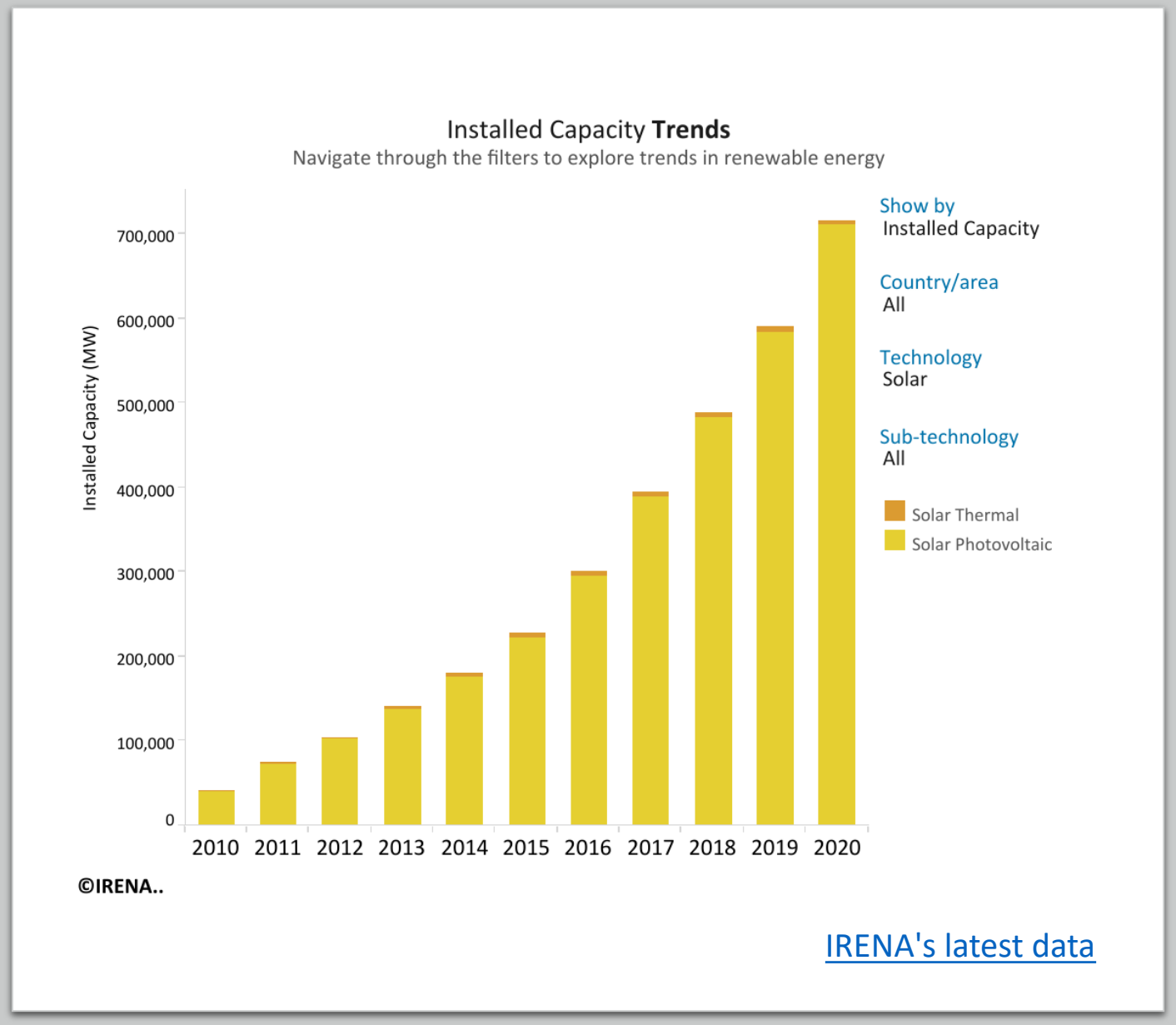
Μεταφορά πτερυγίων ανεμογεννήτριας οριζόντιου άξονα που περνάει μέσα από το Edenfield, Μ. Βρετανία

Solar Energy

- Energy can be harnessed directly from the sun, even in cloudy weather
- Solar energy is used worldwide and is increasingly popular for generating electricity or heating and desalinating water
- Solar power is generated in two main ways:

  Photovoltaics (PV), also called solar cells, are electronic devices that convert sunlight directly into electricity

  Concentrated solar power (CSP), uses mirrors to concentrate solar rays



IRENA's latest data

Solar Energy

Photovoltaics (PV)

The modern solar cell is likely an image most people would recognise – they are in the panels installed on houses and in calculators

PV is one of the fastest-growing renewable energy technologies and is ready to play a major role in the future global electricity generation mix

The cost of manufacturing solar panels has plummeted dramatically in the last decade, making them not only affordable but often the cheapest form of electricity

Concentrated Solar Power (CSP)

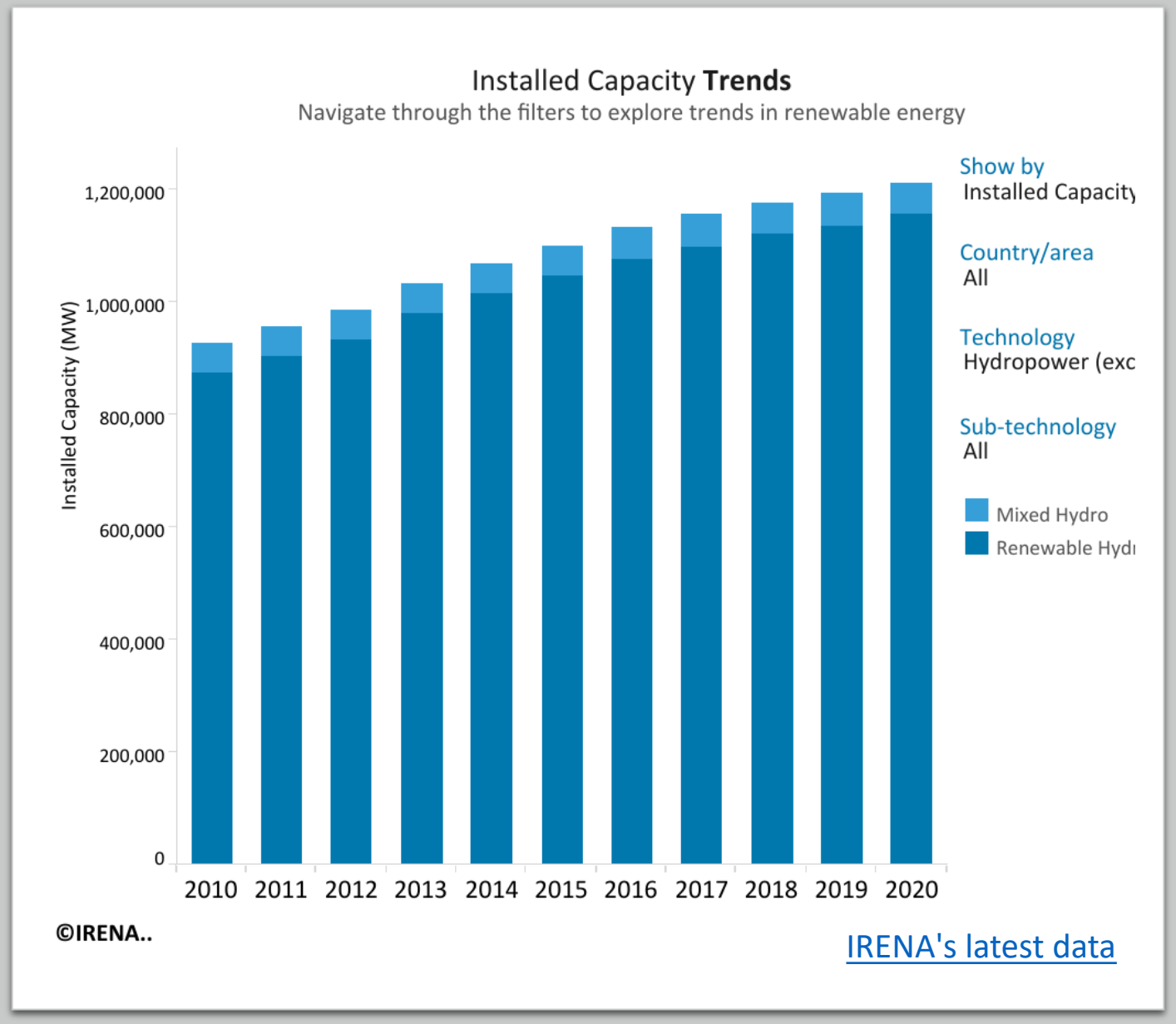
Solar rays heat fluid, which creates steam to drive a turbine and generate electricity

CSP is used to generate electricity in large-scale power plants

❖ One of the main advantages of a CSP power plant over a solar PV power plant is that it can be equipped with molten salts in which heat can be stored, allowing electricity to be generated after the sun has set

Hydropower

- Hydropower is energy derived from flowing water
- The basic principle of hydropower is using water to drive turbines
- Today it is among the most cost-effective means of generating electricity and is often the preferred method where available
- In Norway 99% of electricity comes from hydropower



Hydropower

The ancient Greeks used waterpower to run wheels for grinding grain

Small-scale micro-hydropower projects can make a big difference to communities in remote locations

Hydropower plants consist of two basic configurations: with dams and reservoirs, or without.

- ✓ Hydropower dams with a large reservoir can store water over short or long periods to meet peak demand.
- ✓ Hydropower without dams and reservoirs means producing at a smaller scale, typically from a facility designed to operate in a river without interfering in its flow

For this reason, many consider small-scale hydro a more environmentally-friendly option

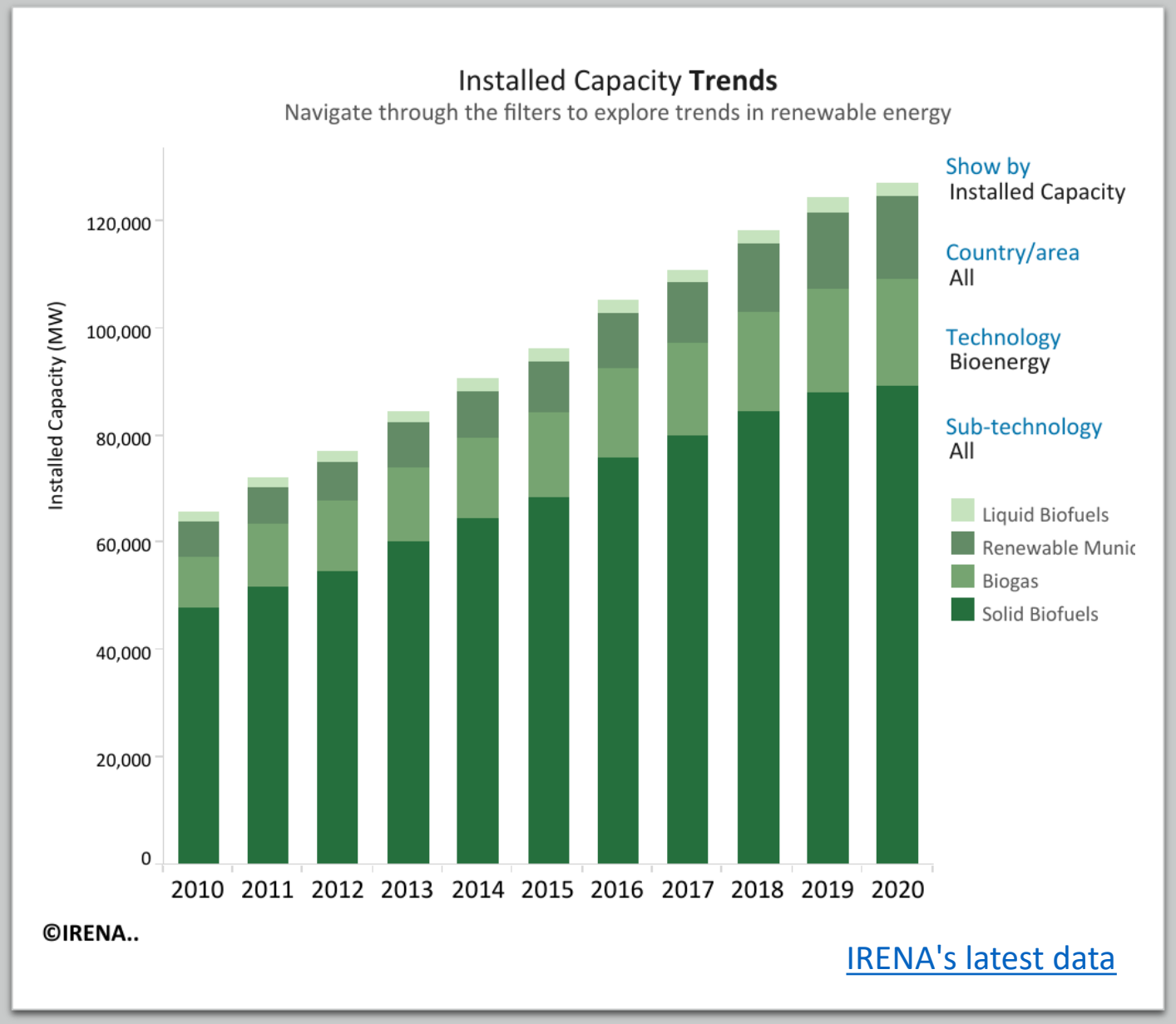
Three Gorges Dam in China:

- ✓ The world's largest hydropower plant (22.5-gigawatt)
- ✓ It produces 80 to 100 terawatt-hours per year, enough to supply between 70 million and 80 million households

https://www.power-technology.com/projects/gorges/

Bioenergy

- About 3/4 of the world's renewable energy use involves bioenergy, with more than half of that consisting of traditional biomass use
- Bioenergy accounted for about 10% of total final energy consumption and 1.9% of global power generation in 2015
- Biomass has significant potential and can be directly burned for heating or power generation, or it can be converted into oil or gas substitutes
- Liquid biofuels, a convenient renewable substitute for gasoline, are mostly used in the transport sector



Bioenergy

Bioenergy use falls into two main categories: “**traditional**” and “**modern**”

- **Traditional** use refers to the combustion of biomass in such forms as wood, animal waste and traditional charcoal
- **Modern** bioenergy technologies include liquid biofuels produced from bagasse and other plants; bio-refineries; biogas produced through anaerobic digestion of residues; wood pellet heating systems; and other technologies

Biomass can be directly burned for heating or power generation, or it can be converted into oil or gas substitutes

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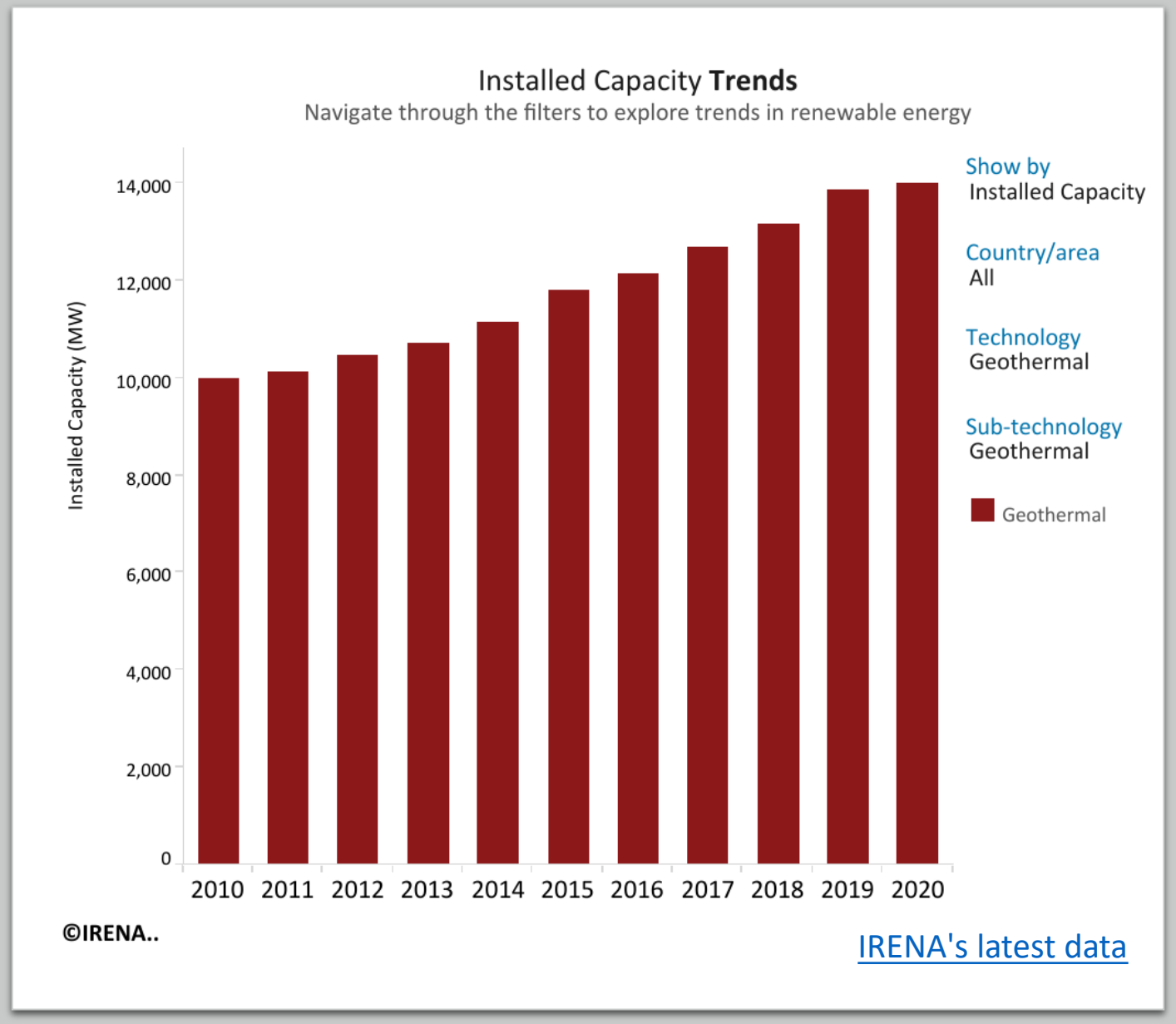
Geothermal Energy

- Geothermal energy is heat derived within the sub-surface of the earth
- Depending on its characteristics, geothermal energy can be used for heating and cooling purposes or be harnessed to generate clean electricity.
- It covers a significant share of electricity demand in countries like Iceland, El Salvador, New Zealand, Kenya, and Philippines and more than 90% of heating demand in Iceland
- The main advantages are that it is not depending on weather conditions and has very high-capacity factors



Geothermal Energy

There are different geothermal technologies with distinct levels of maturity

Technologies for direct uses like district heating, geothermal heat pumps, greenhouses, and for other applications are widely used and can be considered mature

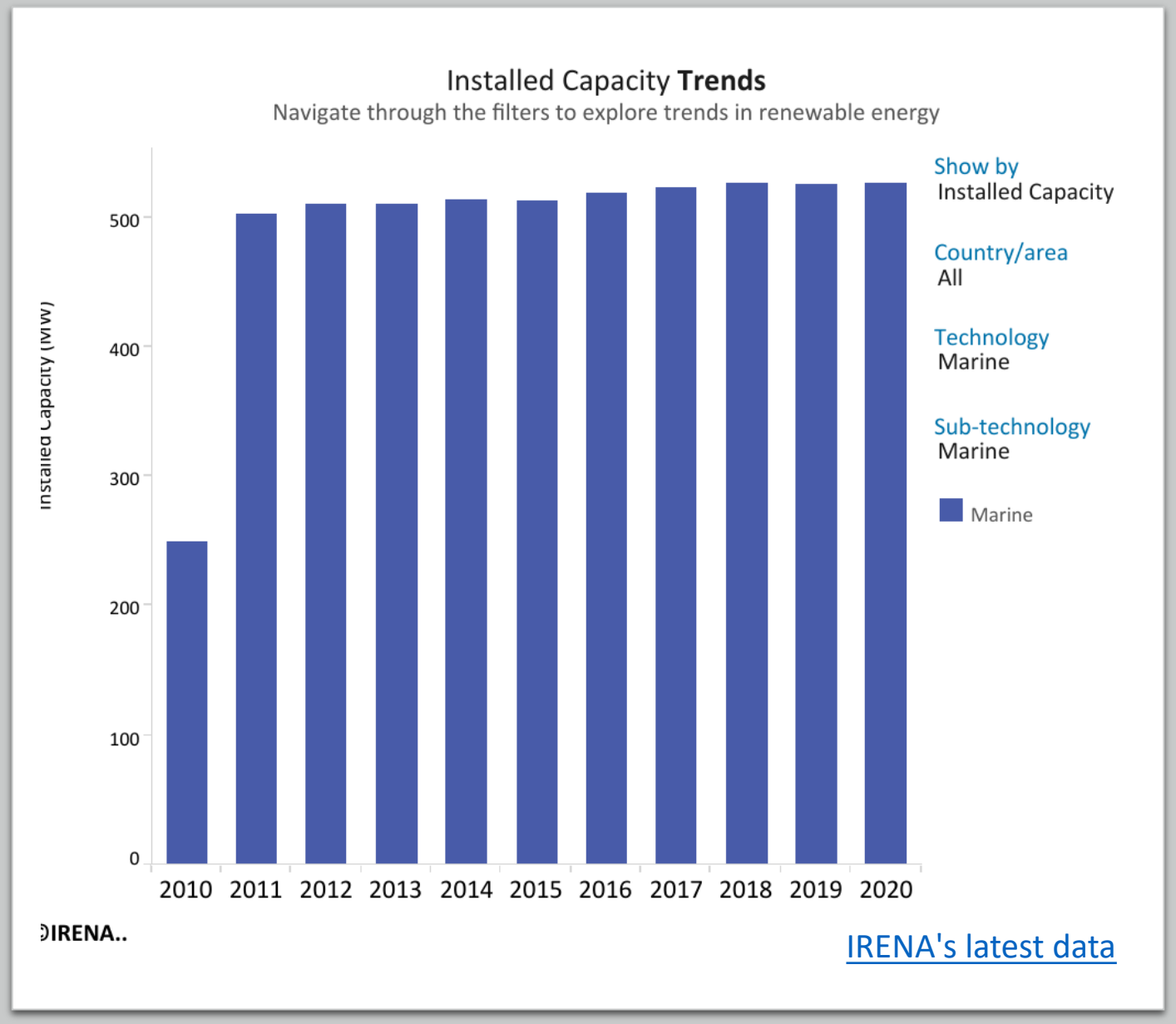
Many of the power plants in operation today are dry steam plants or flash plants (single, double and triple) harnessing temperatures of more than 180°C

- Medium temperature fields are more and more used for electricity generation or for combined heat and power thanks to the development of binary cycle technology, in which geothermal fluid is used via heat exchangers to heat a process fluid in a closed loop

Additionally, new technologies are being developed like Enhanced Geothermal Systems (EGS), which are in the demonstration stage

Ocean/Marine Energy

- Tides, waves and currents can be used to produce electricity
- Although still at the research and development stage and not yet commercially available
- Promising ocean technologies include:
  - Wave energy
  - Tidal energy
  - Salinity gradient energy
  - Ocean thermal energy conversion



Ocean/Marine Energy

Wave energy, whereby converters capture the energy contained in ocean waves and use it to generate electricity

Converters include oscillating water columns that trap air pockets to drive a turbine; oscillating body converters that use wave motion; and overtopping converters that make use of height differences.

Tidal energy, produced either by tidal-range technologies using a barrage (a dam or other barrier) to harvest power between high and low tide; tidal-current or tidal-stream technologies; or hybrid applications.

Salinity gradient energy, arising from differing salt concentrations, as occurs where a river empties into an ocean

Ocean thermal energy conversion, which generates power from the temperature difference between warm surface seawater and cold seawater at 800–1,000 metres depth

The General Trend of Energy Consumption

Energy consumption depends on different factors such as:

- economic progress, population growth, energy prices, extreme weather events, technology… and pandemic crisis

COVID-19: Had a dramatic impact on energy markets, with both primary energy and carbon emissions falling at their fastest rates since the World War II

- Nevertheless, renewable energy continued to grow, with solar power recording its largest ever increase
- Carbon emissions from energy use fell by 6.3%, to their lowest level since 2011

This was the largest decline since the end of World War II

The energy in 2021… at a glance

Energy demand and emissions bounced back to around pre-pandemic levels in 2021, reversing the temporary reduction in 2020 resulting from the COVID-19 pandemic

Energy developments

- *Primary energy** demand increased by 5.8% in 2021, exceeding 2019 levels by 1.3%
- Between 2019 and 2021, renewable energy increased by over 8 EJ ($8x10^{18}J$)
- Consumption of fossil fuels was broadly unchanged
- Fossil fuels accounted for 82% of primary energy use, down from 83% in 2019 and 85% in 2016

* *Energy* in the form that it is first accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy (e.g., coal can be converted to synthetic gas, which can be converted to electricity)

Carbon emissions in 2021… at a glance

Carbon dioxide emissions from energy use, industrial processes, flaring and methane (in carbon dioxide equivalent) rose 5.7% in 2021 to 39.0 $GtCO_2e$

- With carbon dioxide emissions from energy rising 5.9% to 33.9 $GtCO_2$, close to 2019 levels

Carbon dioxide emissions from flaring and emissions from methane and industrial processes rose more modestly by 2.9% and 4.6% respectively

Oil in 2021… at a glance (1)

Oil prices averaged $70.91/bbl in 2021

- The second highest level since 2015

Oil consumption increased by 5.3 million barrels per day (b/d)

- It remained 3.7 million b/d below 2019 levels

A majority of the consumption growth came from:

- ✓ gasoline (1.8 million b/d)
- ✓ diesel/gasoil (1.3 million b/d)

Most of the growth took place in the US (1.5 million b/d), China (1.3 million b/d) and the EU (570,000 b/d)

Oil in 2021… at a glance (2)

Global oil production increased by 1.4 million b/d in 2021

with OPEC+ accounting for more than three-quarters of the increase

- ✓ Libya (840,000 b/d), Iran (540,000 b/d) and Canada (300,000 b/d) saw the largest increases
- ✓ Nigeria (-200,000 b/d), the UK (-170,000 b/d) and Angola (-150,000 b/d) reported the biggest declines

Refinery capacity declined for the first time in over 30 years by almost 500,000 b/d last year driven by a sharp reduction in the OECD (1.1 million b/d)

Refining capacity in the OECD in 2021 was at its lowest level since 1998.

Natural gas in 2021… at a glance (1)

Natural gas prices rebounded strongly across all three major gas regions

- Rising fourfold to record annual levels in Europe and tripling in the Asian LNG spot market
- US Henry Hub prices nearly doubled to average their highest annual level since 2014

Global natural gas demand grew 5.3% in 2021, recovering above pre-pandemic 2019 levels and crossing the 4 Tcm mark for the first time

- Its share in primary energy in 2021 was unchanged from the previous year at 24%.

LNG supply grew 5.6% its slowest rate of growth since 2015 (other than in 2020).

LNG supply from the US rose by 34 Bcm, accounting for most of the new incremental supplies and more than offsetting declines from mainly other Atlantic Basin exporters.

Natural gas in 2021… at a glance (2)

China surpassed Japan as the world's largest LNG importer and accounted for close to 60% of global LNG demand growth in 2021

Algerian pipeline exports to Europe were the largest source of pipeline supply growth to the region (+13 Bcm) last year, followed by Azerbaijan (+6 Bcm)

Russian pipeline supply to Europe overall was steady at 167 Bcm in 2021, exports to the EU decreased by 8.2% (-12 Bcm)

Coal in 2021… at a glance

Coal prices rose dramatically in 2021, with European prices averaging $121/tonne and the Asian marker price averaging $145/t, its highest since 2008

Coal consumption grew over 6% in 2021 to 160 EJ, slightly above 2019 levels and its highest level since 2014

China and India accounted for over 70% of the growth in coal demand in 2021, increasing by 3.7 and 2.7 EJ, respectively

Global production matched consumption with an increase in supply of 440 Mt. China and India accounted for much of the increase in production, which was largely consumed domestically, as well as Indonesia, supporting higher exports

Both Europe and North America showed an increase in coal consumption in 2021 after nearly 10 years of back-to- back declines

Renewables (and hydro) in 2021… at a glance

Renewable primary energy (including biofuels but excluding hydro) increased by around 5.1 EJ in 2021 – corresponding to an annual growth rate of 15%, stronger than the previous year's 9%, and higher than that of any other fuel in 2021

Solar and wind capacity continued to grow rapidly in 2021, increasing by 226 GW, close to the record increase of 236 GW seen in 2020.

- China remained the main driver of solar and wind capacity growth last year, accounting for about 36% and 40% of the global capacity additions, respectively

Hydroelectricity generation decreased by around 1.4% in 2021, the first fall since 2015

Nuclear generation increased by 4.2% – the strongest increase since 2004 – led by China

Electricity in 2021… at a glance

Electricity generation increased by 6.2% in 2021 – similar to the strong bounce back seen in 2010 in the aftermath of the financial crisis (6.4%)

Wind and solar reached a 10.2% share of power generation in 2021, the first time wind and solar power have provided more than 10% of global power and surpassing the contribution of nuclear energy

Coal remained the dominant fuel for power generation in 2021, with its share increasing to 36%, up from 35.1% in 2020

Natural gas in power generation increased by 2.6% in 2021, although its share decreased from 23.7% in 2020 to 22.9% in 2021

https://ember-climate.org/insights/research/global-electricity-review-2022/

In conclusion... A snapshot of 2021

In 2021, the energy system rebounded strongly as the global economy recovered from the COVID-19 pandemic

Primary energy grew by 31 EJ in 2021, the largest increase in history and more than reversing the sharp decline seen in 2020

- Primary energy in 2021 was 8 EJ above 2019 levels

The increase in primary energy in 2021 was driven by emerging economies, which increased by 13 EJ, with China expanding by 10 EJ

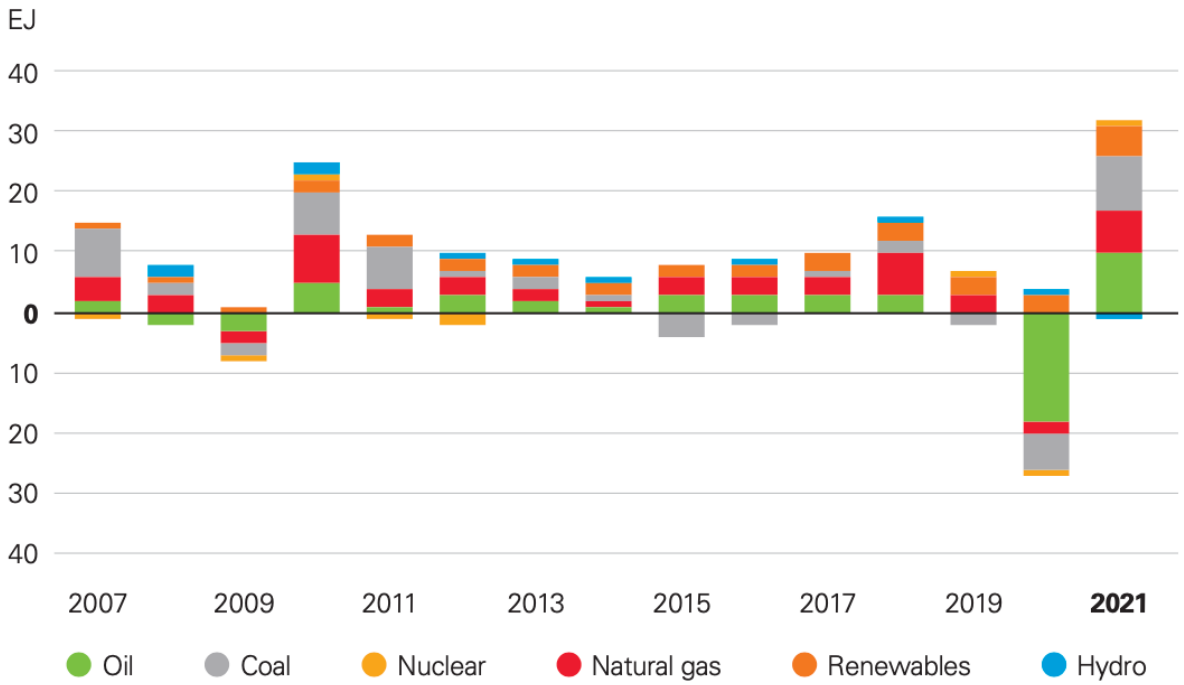
- Since 2019, primary energy consumption in emerging economies increased by 15 EJ, largely reflecting growth in China (13 EJ)

Energy demand in developed economies in 2021 was 8 EJ below 2019 levels

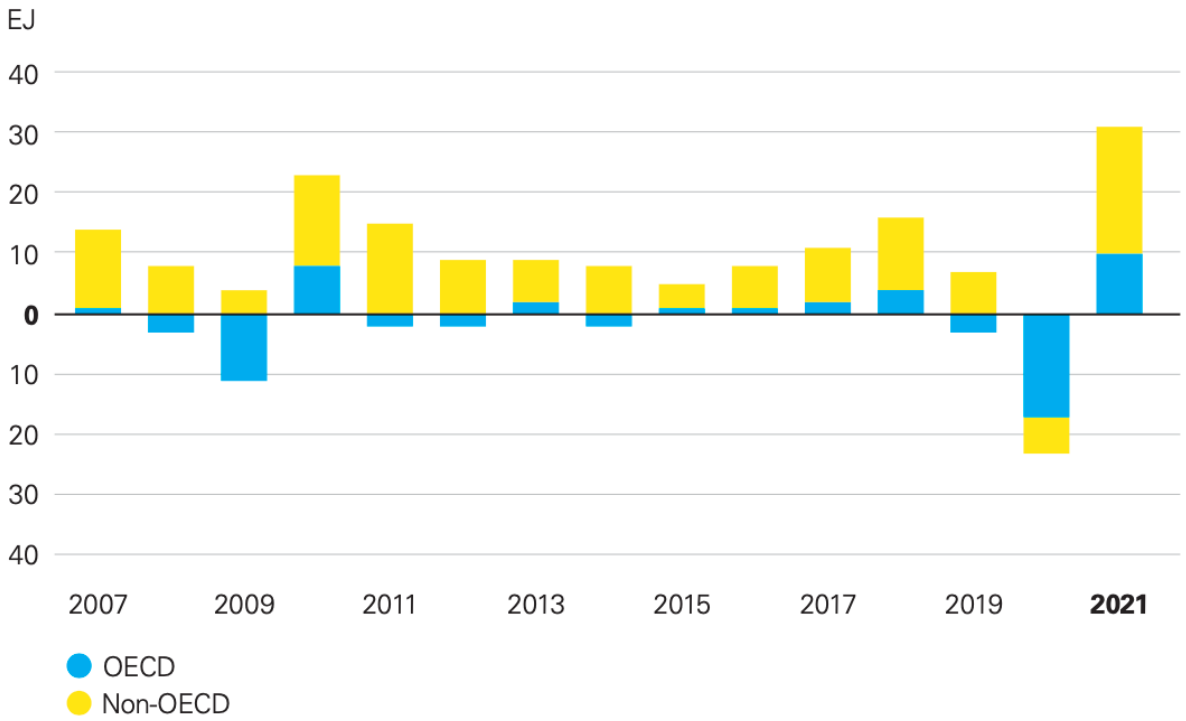
The increase in primary energy between 2019 and 2021 was entirely driven by renewable energy sources

Primary energy in 2021 grew by its largest amount in history, with emerging economies accounting for most of the increase

Change in primary energy by fuel



Change in primary energy by geography



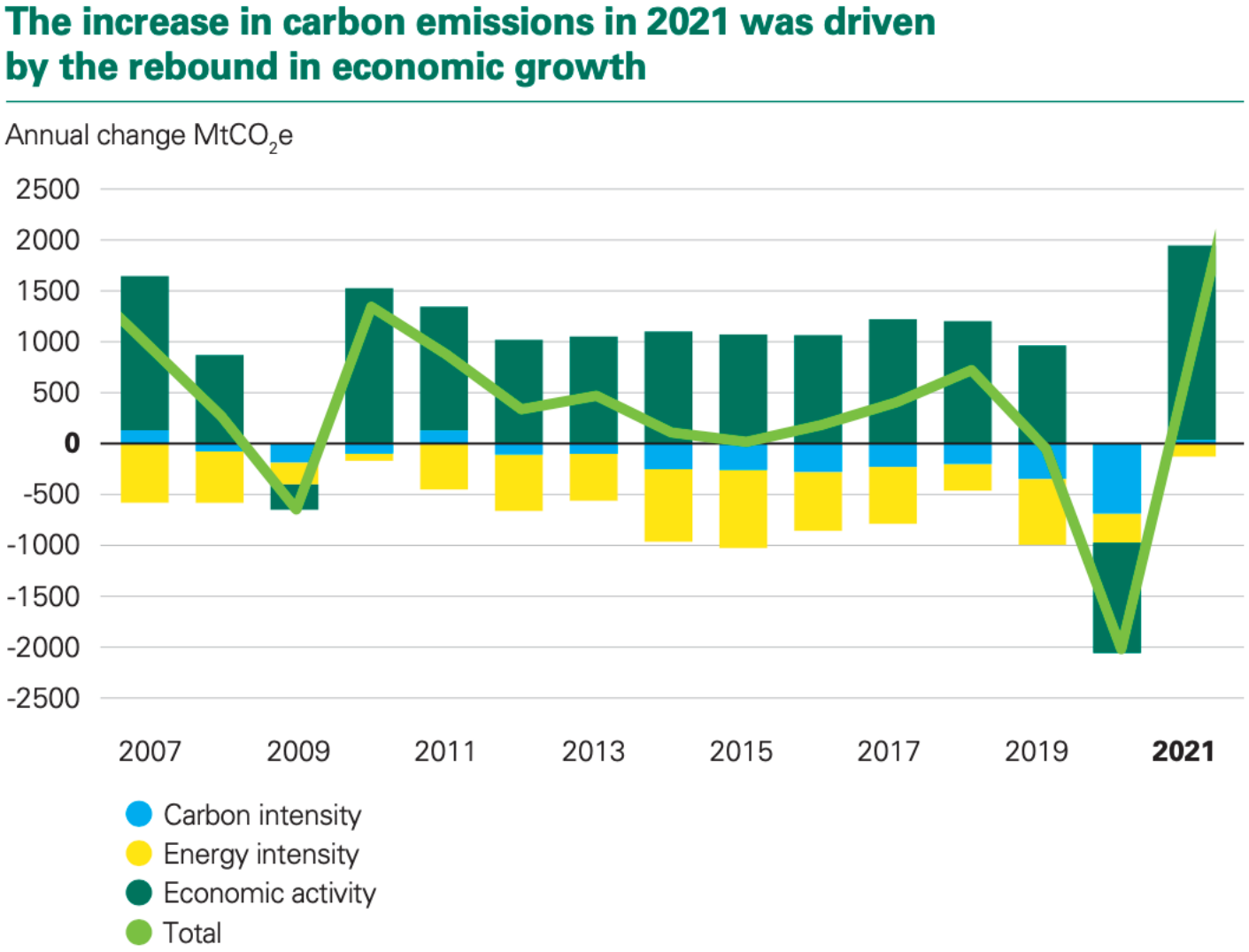
In conclusion... A snapshot of 2021

Emissions from energy rebounded strongly in 2021 back to around 2019 levels

The sharp rebound in emissions in 2021 was explained by economic growth

As economic activity recovered from lockdowns and other COVID-19 related measures, energy consumption increased sharply

Carbon intensity and, to lesser extent, energy intensity were largely unchanged in 2021



Carbon intensity & energy intensity

Carbon intensity is a measure of how clean our electricity is.

- It refers to how many grams of carbon dioxide (CO_2) are released to produce a kilowatt hour (kWh) of electricity
- Electricity that's generated using fossil fuels is more carbon intensive, as the process by which it's generated creates CO_2 emissions.

Renewable energy sources, such as wind, hydro or solar power, produce next to no CO_2 emissions, so their carbon intensity value is much lower and often zero

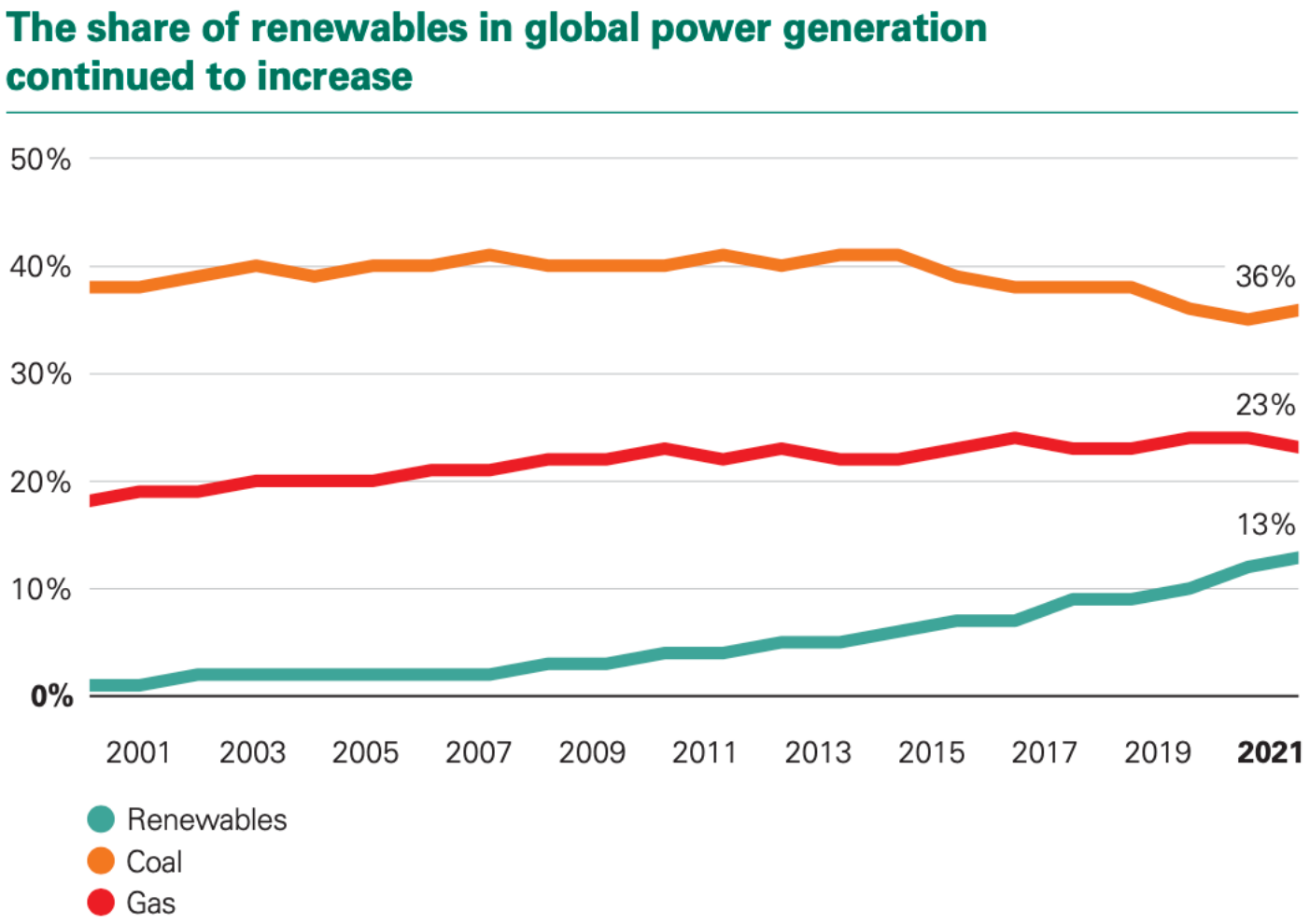
Energy intensity is defined as the amount of energy used to produce a given level of output or activity

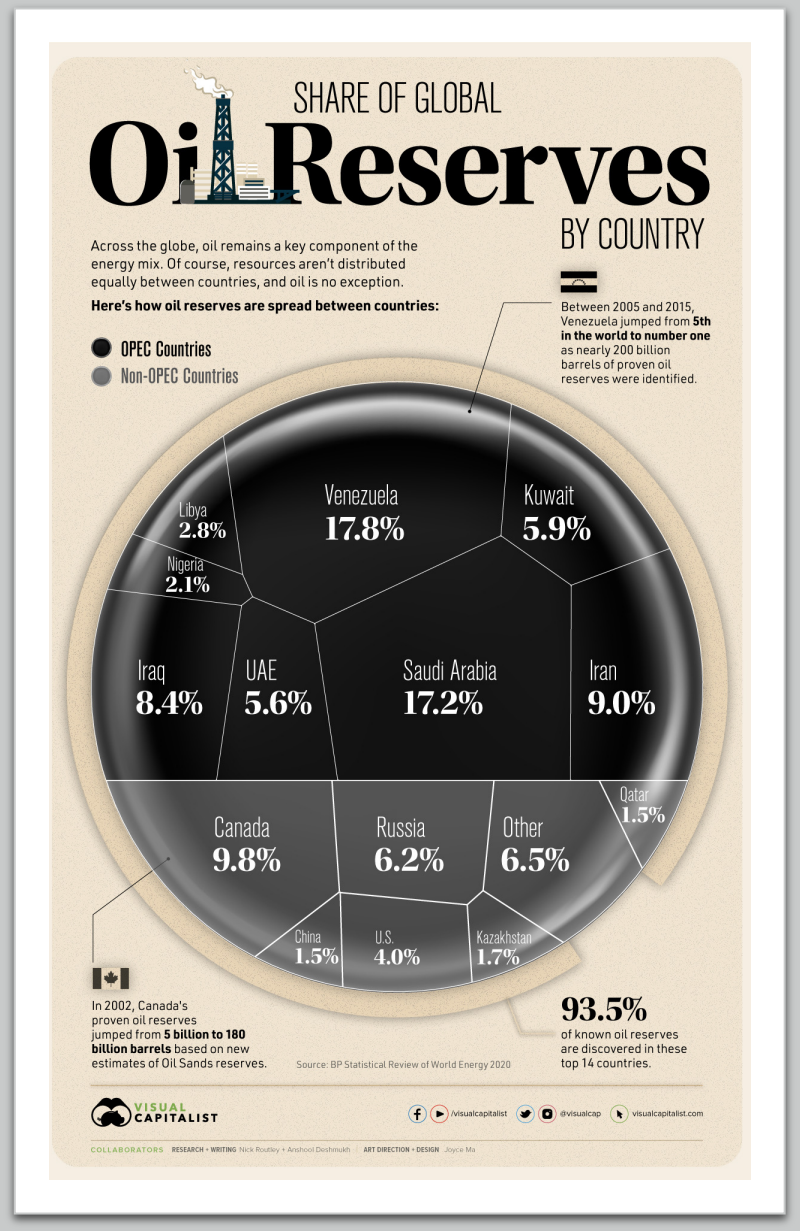
Using less energy to produce a product or provide a service results in reduced energy intensity

Carbon intensity & energy intensity

The share of renewables (excluding hydro) in global power generation continued its rising trend, driven by strong expansion in solar and wind energy

Renewables share in power generation reached almost 13% in 2021 higher than the share of nuclear energy (9.8%)





Oil (and/or gas) reserve definitions

Proved reserves

"Those quantities of petroleum anticipated to be commercially recoverable by application of development projects to known accumulations from a given date forward under defined conditions"

The proved reserves of a field are defined as that volume with a 90%, or greater, chance of being produced over the lifetime of the field

These proved reserves are a conservative estimate of future cumulative production from a field

BP, 2020

Oil (and/or gas) reserve definitions

Probable reserves have been variously designated as 'indicated' or 2P reserves

Reserves which are estimated to have a better than 50% chance of being technically and economically producible

Possible reserves have been designated as ‘inferred’ or 3P reserves

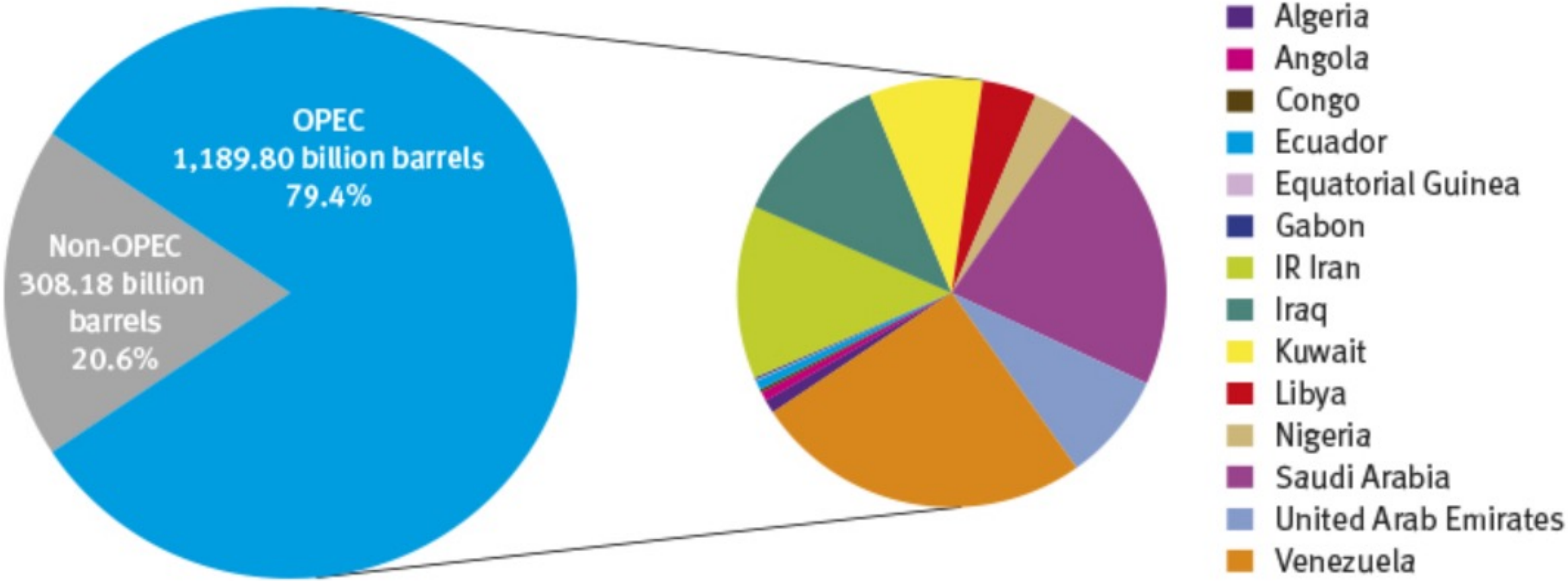
Include reserves which, at present, cannot be regarded as ‘probable’, but are estimated to have a significant (albeit less than 50%) chance of being technically and economically producible

A portion of a field's probable and possible reserves tend to get converted into proved reserves over time as operating history reduces the uncertainty around remaining recoverable reserves

BP, 2020

OPEC share of world crude oil reserves, 2018

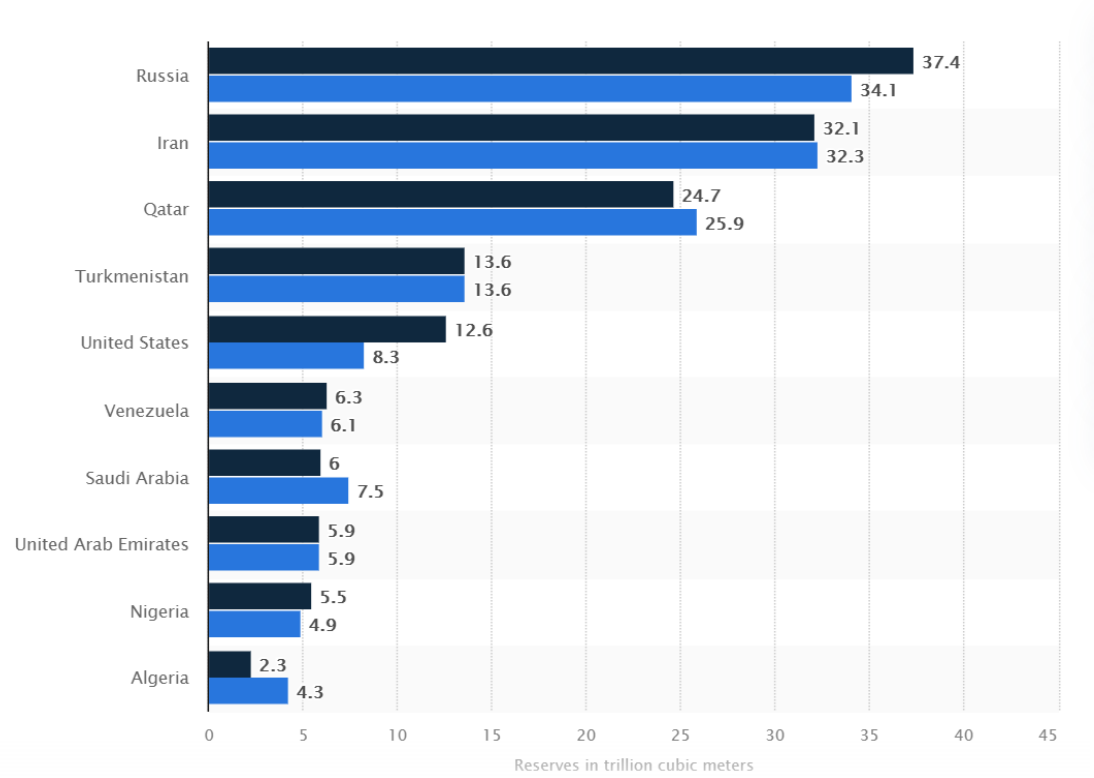
https://www.opec.org/opec_web/en/data_graphs/330.htm

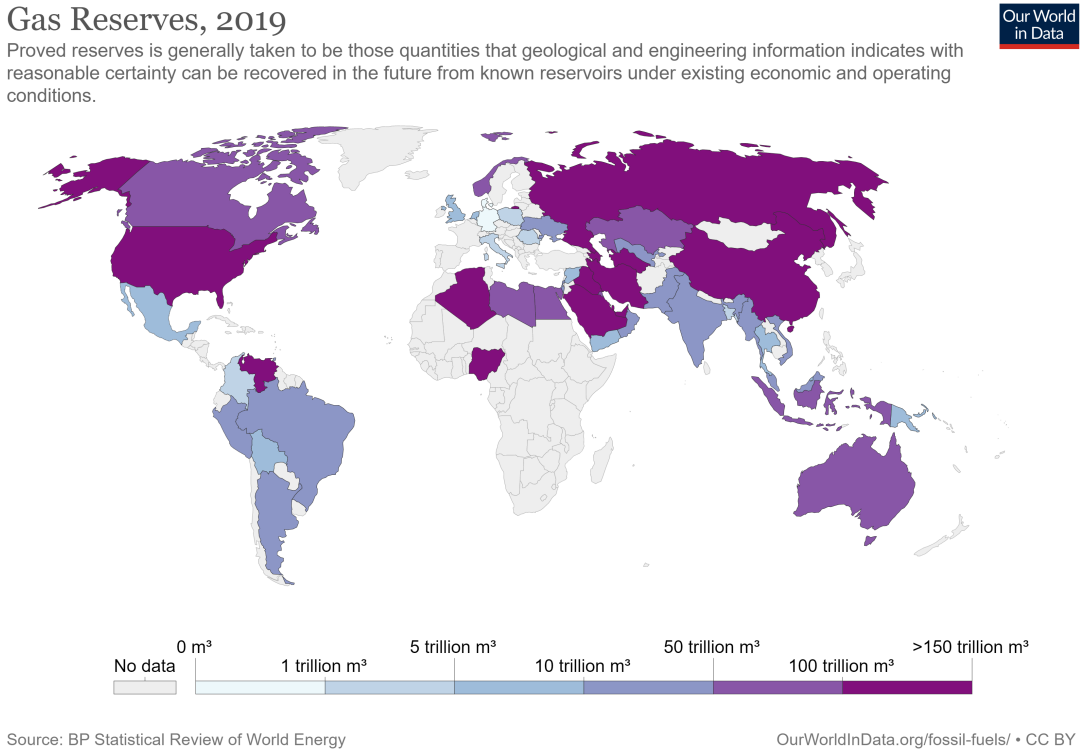


OPEC proven crude oil reserves, at end 2018 (billion barrels, OPEC share)

Venezuela	302.81	25.5%	Kuwait	101.50	8.5%	Algeria	12.20	1.0%	Gabon	2.00	0.2%
Saudi Arabia	267.03	22.4%	UAE	97.80	8.2%	Ecuador	8.27	0.7%	Equatorial Guinea	1.10	0.1%
IR Iran	155.60	13.1%	Libya	48.36	4.1%	Angola	8.16	0.7%			
Iraq	145.02	12.2%	Nigeria	36.97	3.1%	Congo	2.98	0.3%			

Natural gas proved reserves by country





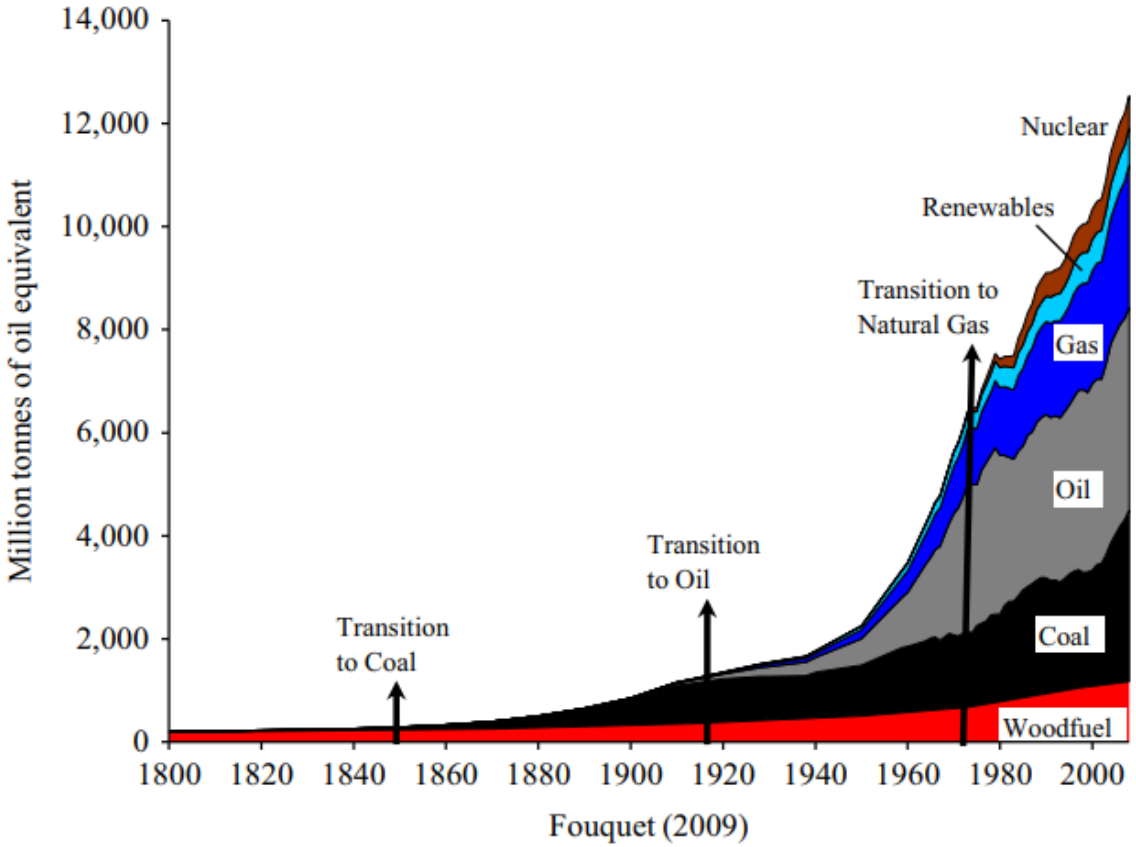
https://www.statista.com/statistics/265329/countries-with-the-largest-natural-gas-reserves/
https://ourworldindata.org/grapher/natural-gas-proved-reserves

Energy transition

Energy transition is a pathway toward transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century

IRENA's definition

Transitions have often depended on the timing and influence of broader external landscape forces



Fouquet, R., 2009. A brief history of energy. In: Evans, J., Hunt, L.C. (Eds.), International Handbook of the Economics of Energy. Edward Elgar Publications, Cheltenham, UK, and Northampton, MA, USA

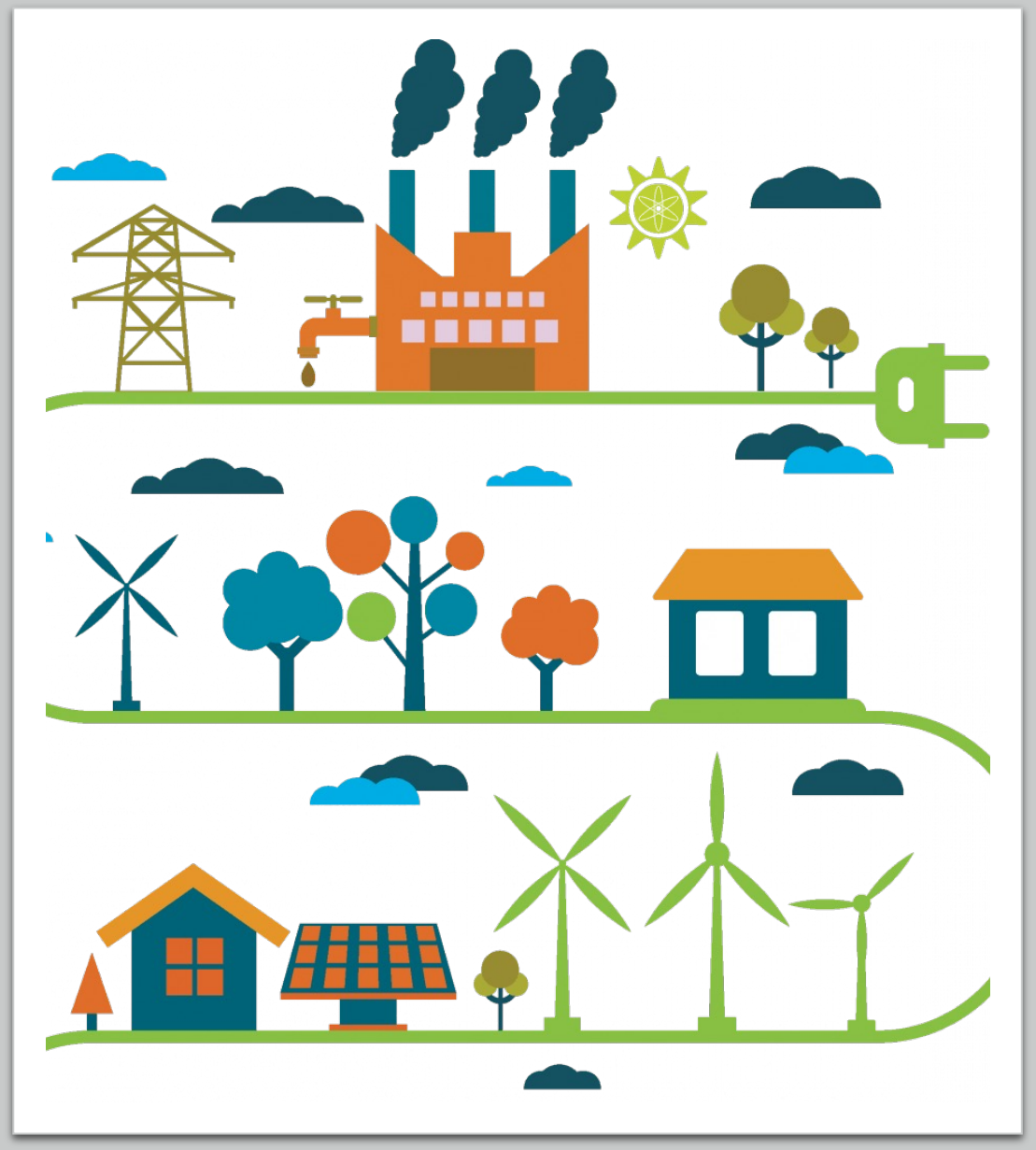
Energy Transition

At the heart of energy transition is the need

- to reduce energy-related CO_2 emissions
- to limit climate change

Renewable energy and energy efficiency measures can potentially achieve 90% of the required carbon reductions

IRENA_https://www.irena.org/energytransition



International Renewable Energy Agency

International Renewable Energy Agency (IRENA): Example of the diffusion and power of the concept of renewable energy

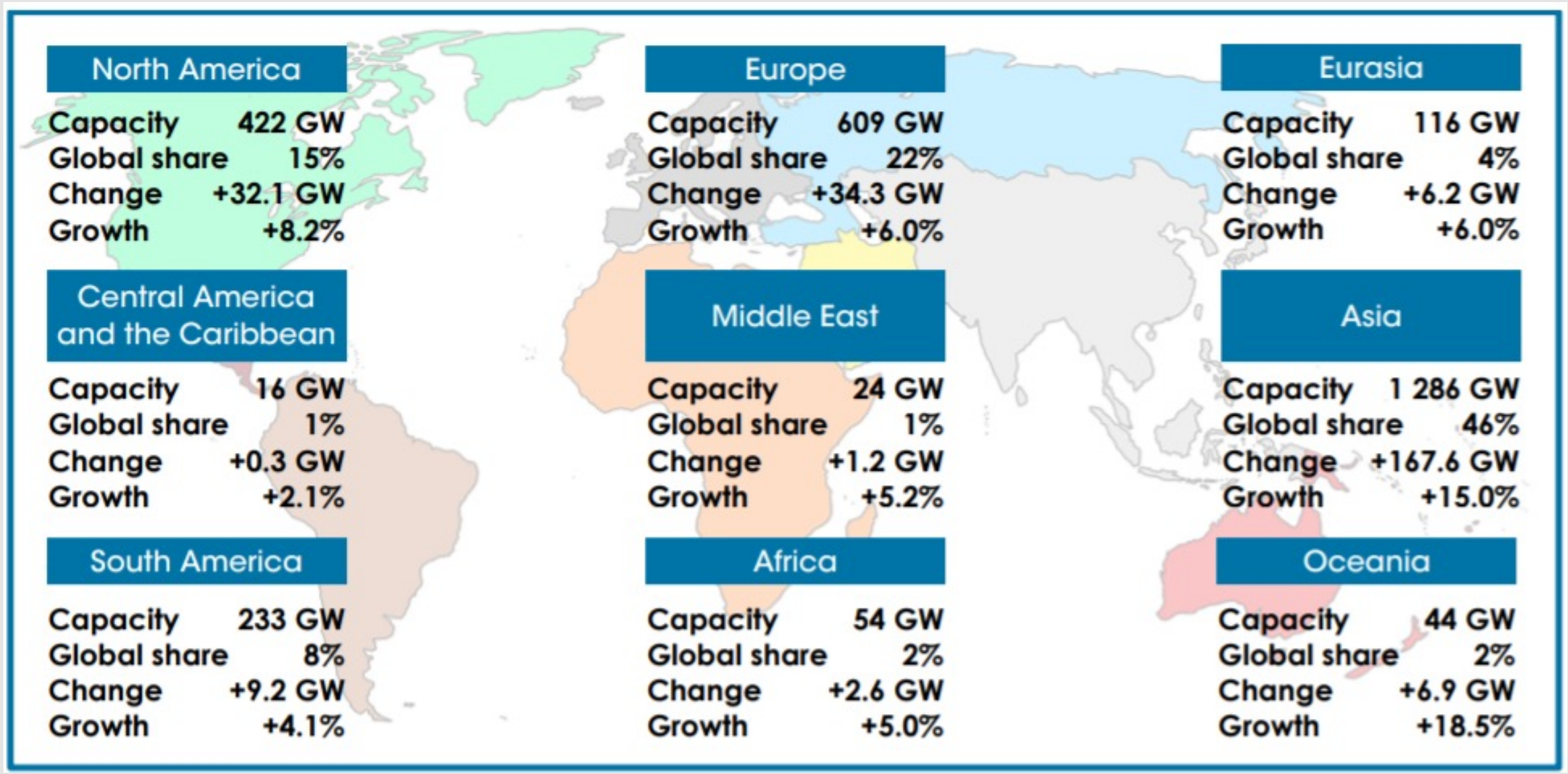
- Official United Nations (UN) observer
- 154 member states (including the EU)

The benefits of renewable energy are not only climate change mitigation and reduced pollution but also – increasingly – economic growth, employment and energy security

The existence and status of IRENA illustrate the role of renewable energy as a guiding concept

- International Renewable Energy Alliance (REN Alliance): Intergovernmental agency with states as members

Renewable generation capacity by region



Renewable capacity statistics 2021, available at: www.irena.org/publications

Geographical focus - Europe

Europe: Abundance of renewable energy sources

- European countries: Leaders in driving the deployment of renewable technologies (e.g., Denmark)
- Goal of the EU member states: Become *"the world number one in renewables"*

Jean-Claude Juncker (Former President of the European Commission)

EU targets: Achieve a **20% share of renewable energy in energy consumption by 2020, and 32% by 2030**

Russia-Ukraine gas disputes demonstrated the importance of enabling frameworks for renewables

- Such frameworks remain at the heart of the EU's policy process
- Promoting renewable energy is one of the cornerstones of the energy policy of the EU

Geographical focus – Special focus on EU

EU energy policy: Example of how the concept of renewable energy has been adopted

Renewable Energy Directive (2009): By the year 2020 1/5 of the total energy needs within the union must come from renewable energy (EU, 2009)

- Directive is currently being revised, with a planned goal of reaching 27% share for renewable energy by 2030 (EU, 2018)

Energy Roadmap looking toward the year 2050 (European Commission, 2011)

- The roadmap is not legally binding and presents five alternative scenarios for decarbonization
- Renewables play a major role, as their share of final energy consumption is at least 55% in all the scenarios

EU Emissions Trading System (ETS) is considered as the cornerstone of EU's policy to combat climate change (EU, 2016)

https://ec.europa.eu/energy/topics/renewable-energy_en

Geographical focus North America

North America features some of the world's richest renewable resources

Relies on renewable energy for large-scale power generation, particularly in the form of hydropower

- In Canada, hydropower accounts for 63% of electricity generation, and some dams are more than 100 years old
- The US, home to iconic hydropower projects like the Hoover Dam, which tames the Colorado River

Mexico relies heavily on hydropower, but also has an abundance of sun and wind, and an active geological landscape

- Mexico has the world's sixth-largest installed capacity for geothermal power, at 951 MW, surpassed only by the US, the Philippines, Indonesia, Kenya and New Zealand

Geographical focus – Latin America & the Caribbean

Latin America hosts some of the most dynamic renewable energy markets in the world, with more than 1/4 of primary energy coming from renewables

- **Twice the global average!!**

Power sectors are characterized by a high dependence on hydropower

- Total investment in power generation reached almost USD 120 billion between 2010 and 2015, including USD 38 billion for large-scale hydropower
- Recent auctions in Argentina, Brazil, Mexico, Chile, and Peru have helped to accelerate the deployment of thousands of megawatts of wind and solar energy in the region

https://energynow.tt/blog/renewable-energy-in-caricom

Photo: Sakaka Project in Saudi Arabia

Geographical focus Middle East & North Africa

Several countries in the region are among the global frontrunners in renewable energy development

The region recognizes the socio-economic benefits of renewable energy deployment

- Is perceived as an opportunity for industrial diversification, new value-chain activities and technology transfer

Sakaka solar project is the first utility-scale renewable energy project developed under the National Renewable Energy Programme of Saudi Arabia (NREP)

The power plant, which is connected to the national electricity grid, will supply enough clean energy to power more than 75,000 Saudi Arabian households and avoid the production of more than 430,000t of carbon dioxide (CO_2) a year

The project will offset approximately 10.5 million tonnes of CO_2 and avoid the use of more than 50 million barrels of diesel during its lifetime

Geographical focus – Asia & Pacific

Asia and the Pacific account for more than half of global energy consumption

- **85% of that regional consumption coming from fossil fuels**

1/10 of the people lack access to electricity, and many more rely on traditional biomass use (such as wood combustion) for cooking and heating

Demand for energy is rising thanks to rapid urbanisation and industrialization

- Considerable opportunities exist to avoid long-term lock-in with carbon-based energy technologies

Along with vast renewable energy potential, the region already possesses significant knowledge and expertise on renewables

Geographical focus – Africa

Africa's rapid economic expansion creates a daunting energy challenge

- Rising expectations of improved resilience and sustainability

Core development challenges for Africa: Finding a sustainable way to meet growing energy needs

Africa is rich in renewable energy sources (hydro, sun, wind and others)

- The time is right for sound planning to ensure the right energy mix
- Decisions made today will shape the continent's energy sector for decades

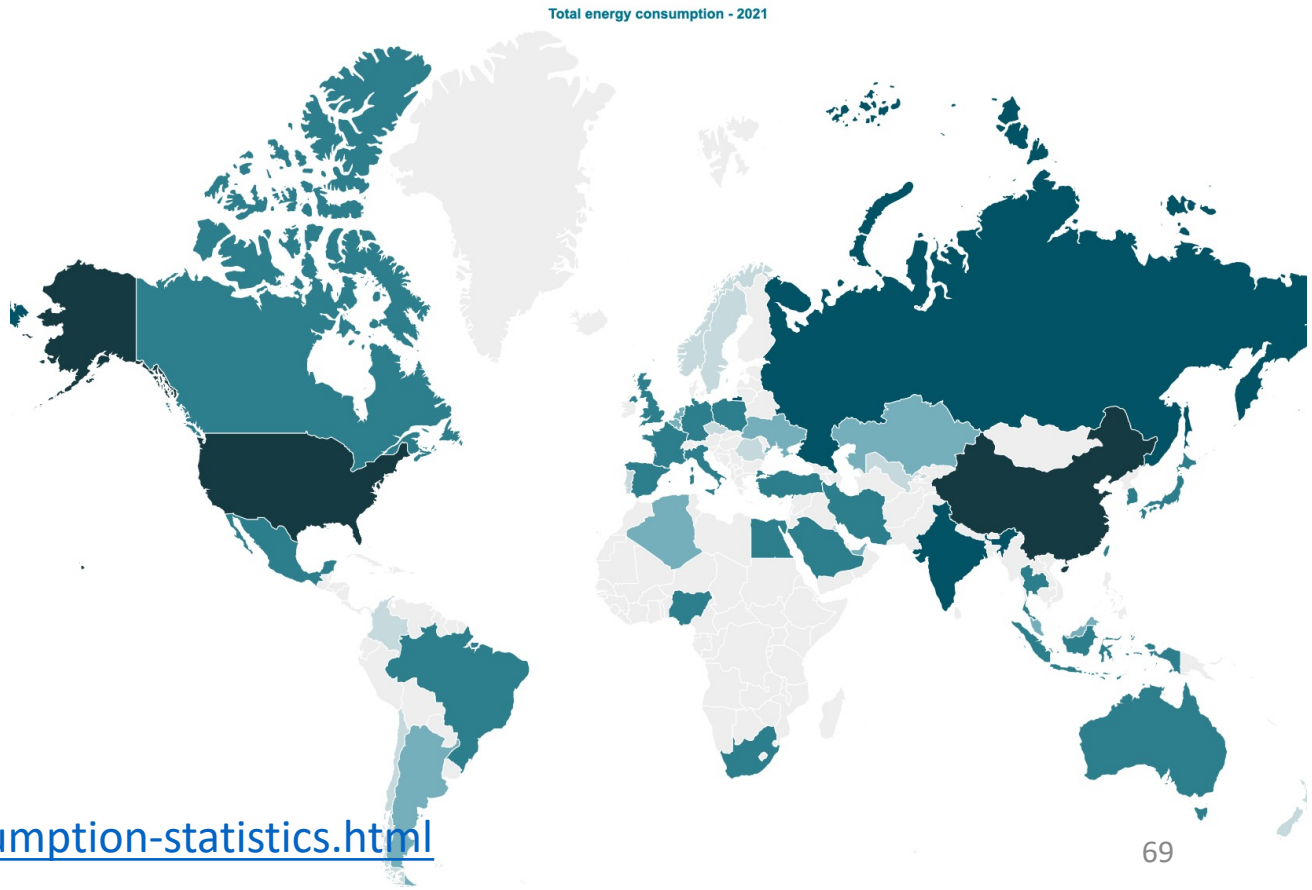
Global energy consumption in 2021

Energy consumption increased in most countries:

- +5.2% in China (after a +2.2% in 2020)
- +4.7% in India (after a -5.6% in 2020)
- +4.7% in the United States (after a -8.6% drop in 2020)
- +9% in Russia (after a -4% in 2020)
- +4.5% in the EU (after a -6.8% in 2020)
- +9% in the CIS
- +5% in Latin America
- +7% in Africa

Exception: Middle East (-0.4%) and the Pacific (-2.5%)

Global energy consumption rebounded with a 5% growth in 2021, after a 4.5% decline in 2020, in a context of global pandemic



https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html

Energy Consumption and Economic Growth

Relation between energy consumption and economic growth

Four types of hypotheses are defined in this regard

1. **Neutral hypothesis** (no causality): Means energy consumption is not related to GDP
2. **Conservation hypothesis** (unidirectional causality): May exist from economic growth to energy consumption
3. **Growth hypothesis:** May exist from energy consumption to economic growth
4. **Feedback hypothesis:** Is applicable when there is bidirectional causality

Depending on each hypothesis, energy policies have different influences on economic growth

The Main Drivers for Using Renewable Energy

The first driver for seeking alternative energy sources has been energy security since the Arab oil embargo in 1973 or the first oil shock

- The oil shocks in the 1970s stimulated interest in renewable energy sources

The global concern about climate change and sustainability encouraged countries to invest in renewable energies

Three main drivers for using renewable energy:

- **Energy security**
- **Economic impacts**
- **CO_2 emission reductions**

Energy Security: An umbrella term

Energy security is the *"reliable and affordable access to all fuels and energy sources"*

Energy security has many aspects:

- ✓ long-term energy security mainly deals with timely investments to supply energy in line with economic developments and environmental needs
- ✓ short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance

The integration of renewable energy in the energy mix:

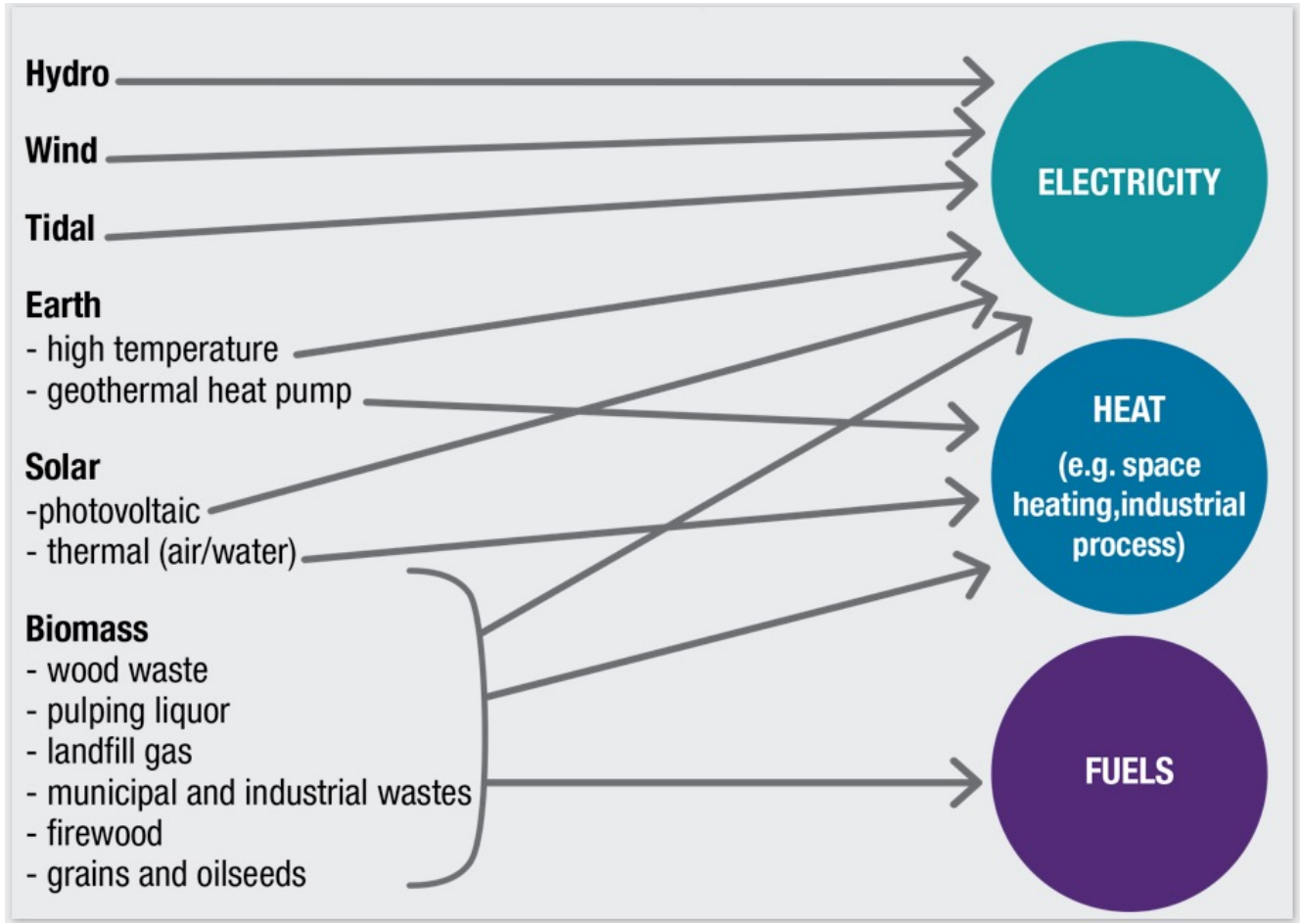
Can enhance energy security in

- Electricity generation
- Water heating/cooling
- Transportation

Can help us meet three goals

1. Reduce greenhouse emissions
2. Ensure reliability
3. Ensure cost-efficient delivery of energy

Energy Security & Renewable Energy



Energy Security

The massive diffusion of renewable energies forces one to rethink the relationships between producers, consumers, and transit countries

- Renewable energies, unlike fossil fuels, are not finite and their geographic concentration is rather low
- Renewable energies bring an important degree of diversification to energy systems
- Renewable energy technologies are beneficial for countries that produce and consume energy
- Renewable energy technologies reduce domestic demand for fossil fuels and increase the capability for export

Economic Impacts

The emphases for economic impacts are job creation, industrial innovation, and balance of payment

Renewable energy technologies could enable countries with good solar or wind resources to deploy these energy sources to meet their domestic demand

- Demand management policies are used in energy areas to reduce the demand through various energy-saving technologies and policies

Renewable energy technologies may even enable these countries to deploy renewable energy sources with long-term export potential

Therefore, if these countries could reduce their balance of payment by producing renewable energy to replace fossil fuels, they could make a capacity for investment in other sections

Employment in renewable energy worldwide was estimated at 11.5 million in 2019

Asia accounted for 63% of total jobs in renewables globally

The solar PV industry retains the top spot, with 33% of the total renewable energy workforce

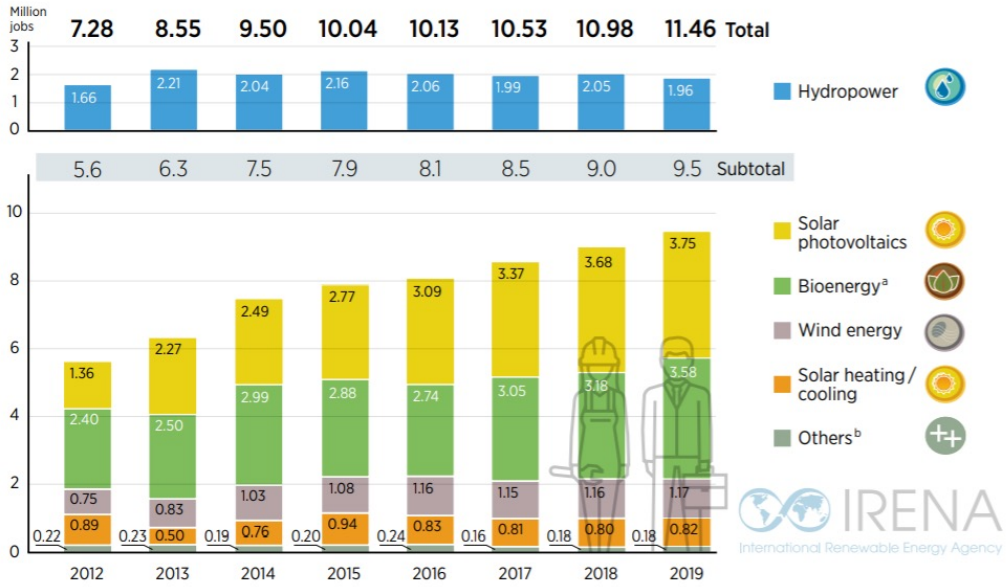
Employment in wind power supports 1.2 million jobs, 21%

Onshore projects continue to predominate, but the number of countries with offshore farms now stands at 18, up from 10 a decade ago

Hydropower has the largest installed capacity of all renewables, but its growth is slowing

- The sector employs close to 2 million people directly, many in operations and maintenance

Renewable Energy and Jobs



The role of RES in combating climate change & increasing resilience

Action to reduce the impact of climate change is critical

The Paris Agreement sets a goal to limit the increase in global average temperature to well below 2°C above pre-industrial levels and to attempt to limit the increase to 1.5°C

Implicit in these goals is the need for a transition to a low-carbon energy sector, which accounts for two-thirds of global emissions

Renewable Energy, coupled with energy efficiency gains, can provide 90% of the CO_2 emissions reductions needed by 2050

Renewable energy is a key component of Nationally Determined Contributions (NDCs)

- Central implementation tool for countries under the Paris Agreement

Nationally Determined Contributions (NDCs)

Nationally Determined Contributions (NDCs) submitted by countries under the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC) represent pledges on climate action that seek to limit global warming to well below 2°C, preferably to 1.5 °C, over pre-industrial levels

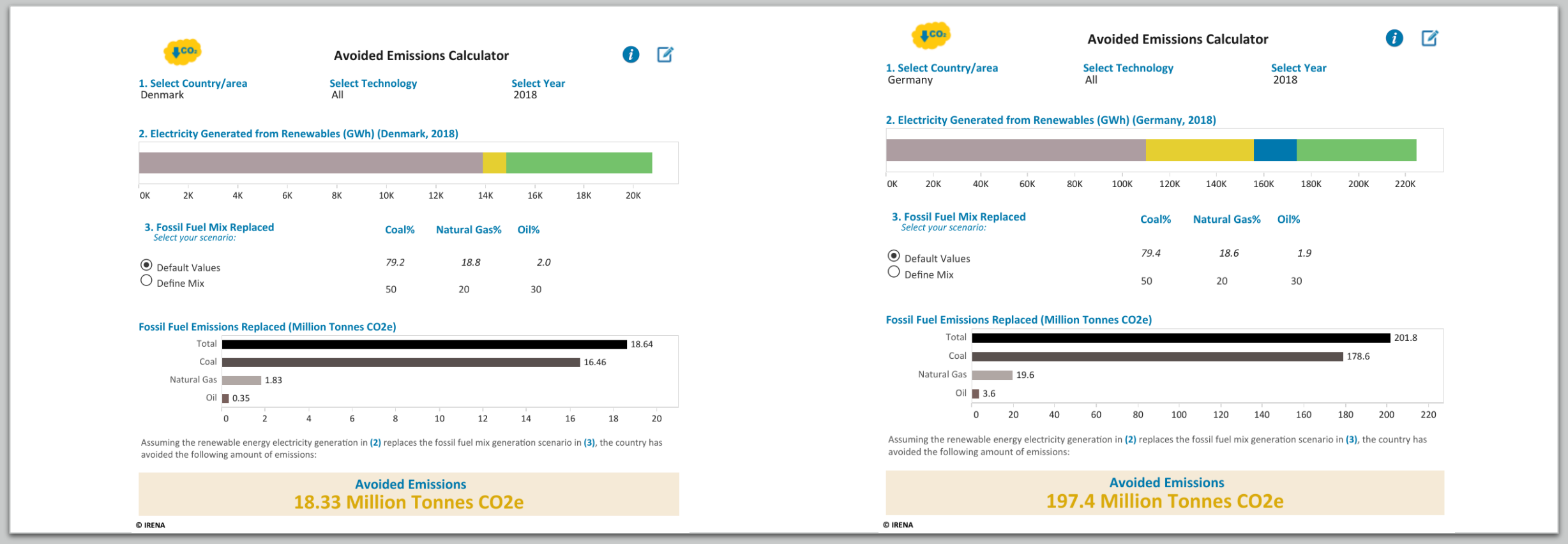
IRENA estimates that if renewable energy targets included in the NDCs were implemented, global renewable power installed capacity would reach over 3.5 terawatts (TW) in 2030

Although significant, this is not nearly enough to put the world on a pathway compatible with the objectives set by the Paris Agreement, which would require renewables to reach 7.7 TW globally by 2030

Avoided Emissions Calculator

Renewable energy has a key role to play in the decarbonization of the energy sector and the resulting mitigation of climate change effects

IRENA has developed a tool to estimate the greenhouse gas emissions avoided each year as a result of renewable energy deployment in a country



https://www.irena.org/climatechange/Avoided-Emissions-Calculator

CO_2 Emission Reduction

Renewable energy technologies could reduce CO_2 emissions by replacing fossil fuels in the power generation industry and transportation sector

✓ Life-cycle CO_2 emissions for renewable energy technologies are much lower than fossil fuels

Based on an analysis performed by IEA, renewable power generation enabled focused countries to save 1.7 Gt CO_2 emissions in 2008

more than the total power sector's CO_2 of the Europe region (1.4 Gt)

The analysis shows that hydropower technology constitutes the largest share for saving CO_2 emissions with 82% followed by biomass and wind with 8 and 7 % respectively

Ölz, 2011

Thank you for your attention