Renewable Energy Systems: Global status and Prospects

Soteris A. Kalogirou

Cyprus University of Technology

Department of Mechanical Engineering and Materials Sciences and Engineering

Dean of the School of Engineering and Technology

Editor-in-Chief, *Renewable Energy*

Deputy Editor-in-Chief, *Energy*

Fellow of the *European Academy of Sciences*

Founding Member of the Cyprus Academy of Sciences , letters, and Arts

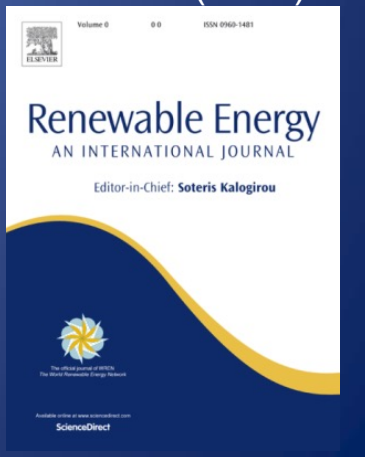
IF 7.147 (2020)

Cyprus University of Technology

CYPRUS ACADEMY OF SCIENCES, LETTERS, AND ARTS

ACADEMIA SCIENTIARUM EUROPAEA EUROPEAN ACADEMY OF SCIENCES

IF 8.001 (2020)



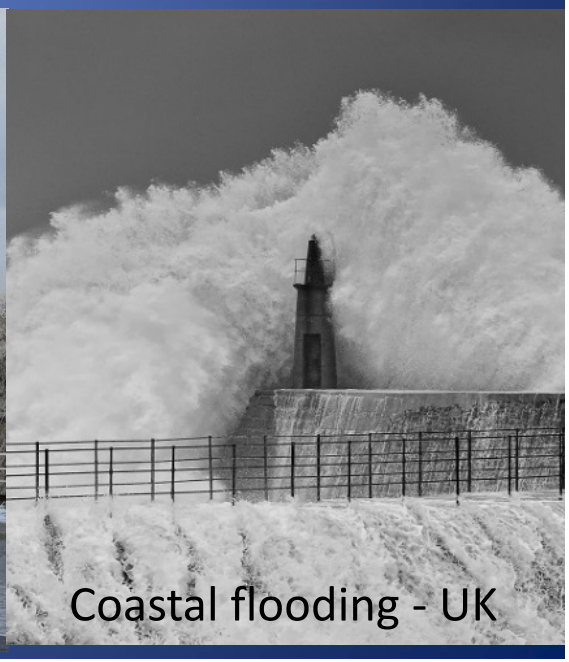
Outline

- Introduction – Climate change
- Status of Renewables
  - Solar thermal
  - Photovoltaics
  - Hydro Power
  - Wind Energy
  - Biomass



- Prospects – New research

Convincing Evidence



The term Climate Change represents better the situation instead of Global Warming

Flooding in India - 2020

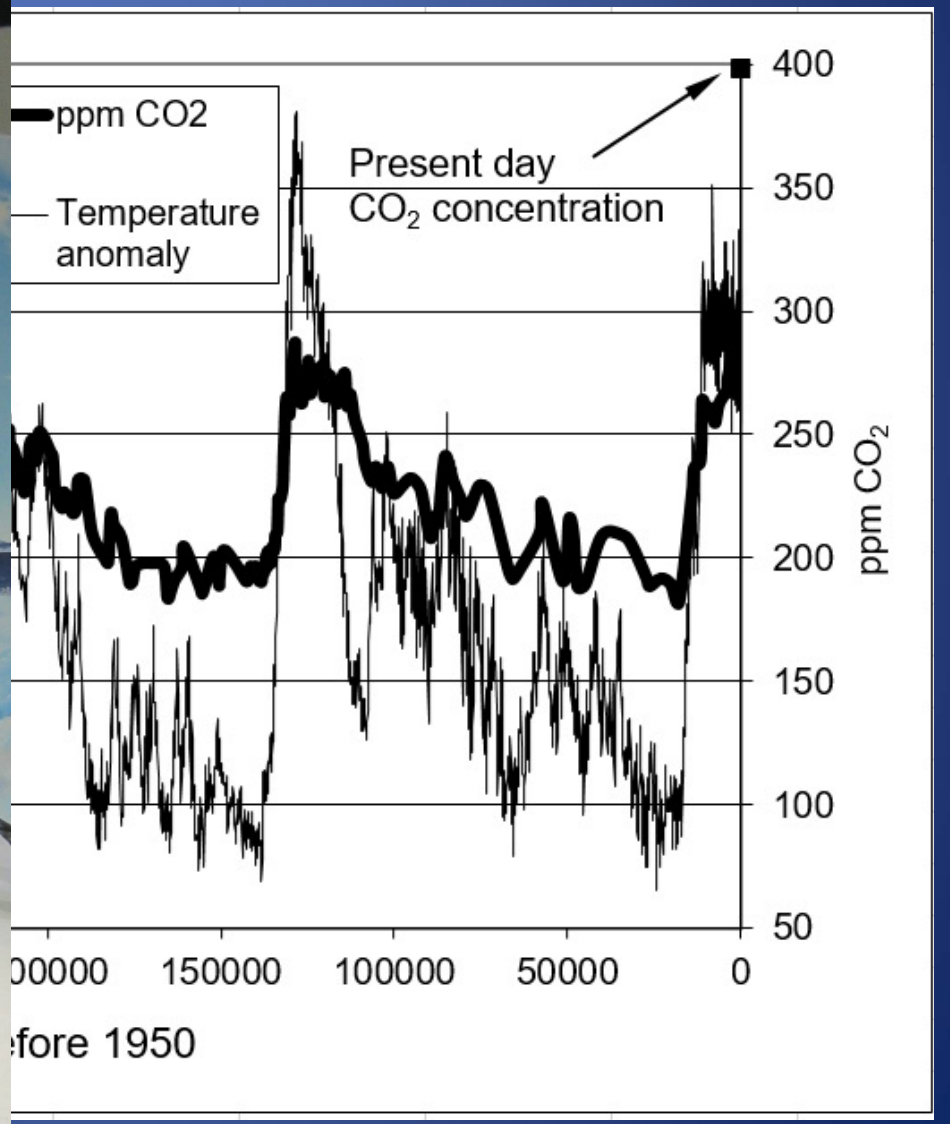
Climate refugees

16th sdewes Conference DUBROVNIK 2021

Effect of Climate Change on India

Cyprus University of Technology

Temperature anomaly and CO_2 concentration From Vostok ice-cores (East Antarctica)



CO_2 in the last 1000 years

Conventional Fuels - Reserves

- Coal >100
- Crude Oil ~ 50 Years (because of shale oil)
- Natural Gas ~ 52.8 Years

  * BP Statistical Review of World Energy

Biggest problem: Environmental issues related to the use of these fuels – China & India are the most polluting countries

Renewable Energy Systems

Solar power (solar thermal & PV)

Hydro systems

Wind energy systems

Biomass-Biogas-Biofuels

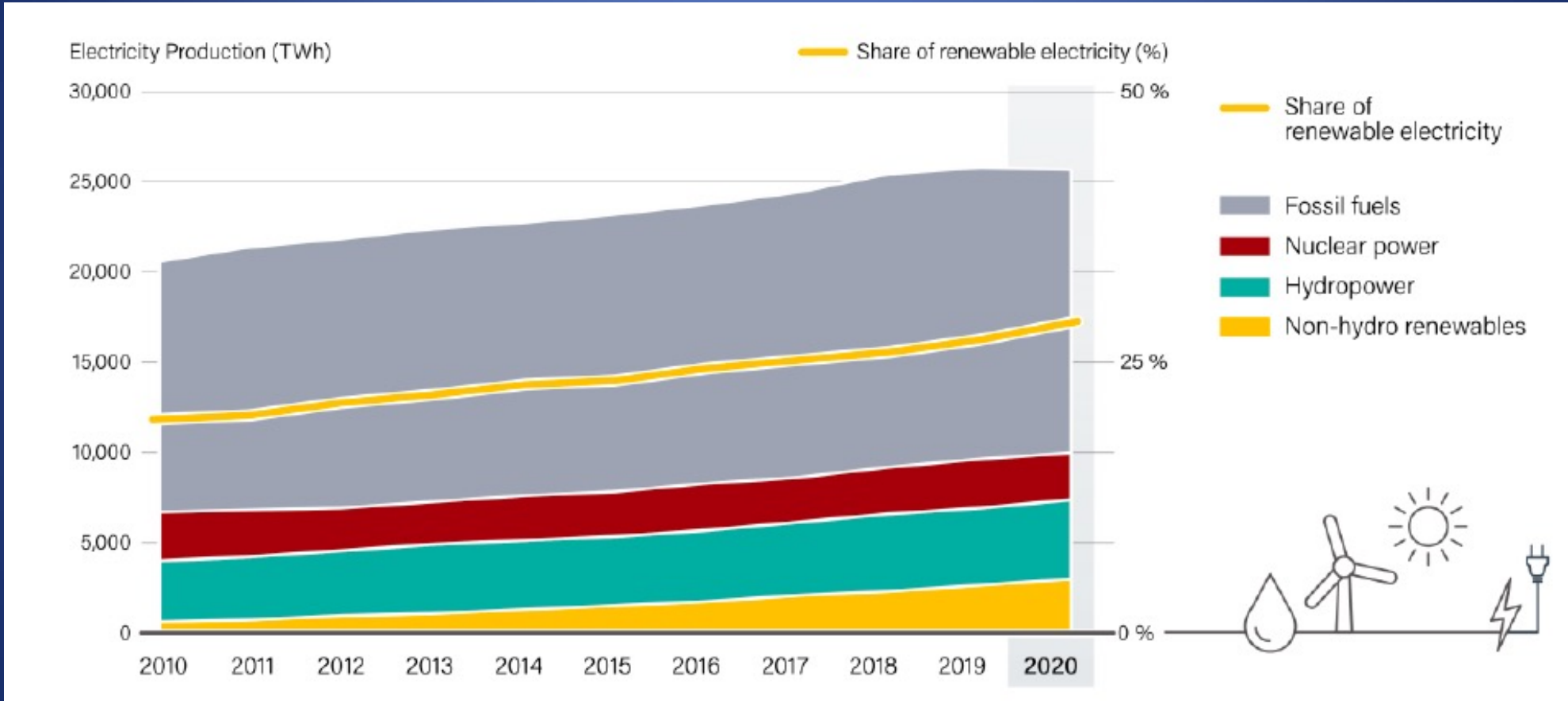
Renewable Energy Indicators 2020

		2019	2020
INVESTMENT			
New investment (annual) in renewable power and fuels[1]	billion USD	298.4	**303.5**
POWER			
Renewable power capacity (including hydropower)	GW	2,581	**2,838**
Renewable power capacity (not including hydropower)	GW	1,430	**1,668**
Hydropower capacity[2]	GW	1,150	**1,170**
Solar PV capacity[3]	GW	621	**760**
Wind power capacity	GW	650	**743**
Bio-power capacity	GW	137	**145**
Geothermal power			**14.1**
Concentrating sola			**6.2**
Ocean power capa			**0.5**
HEAT			
Modern bio-heat d			**13.9**
Solar hot water der			**1.5**
Geothermal direct-			**462**
TRANSPORT			
Ethanol production (annual)	billion litres	115	**105**
FAME biodiesel production (annual)	billion litres	41	**39**
HVO biodiesel production (annual)	billion litres	6.5	**7.5**

- **Total power capacity rose almost 10%**
  - 2,839 GW including hydropower
  - Non-hydropower: 16.6% increase
- **256 GW of renewable power additions**
  - Solar PV: 139 GW; Wind: 93 GW; Hydro: 20 GW

Source: Renewable 2021: Global Status Report, REN21

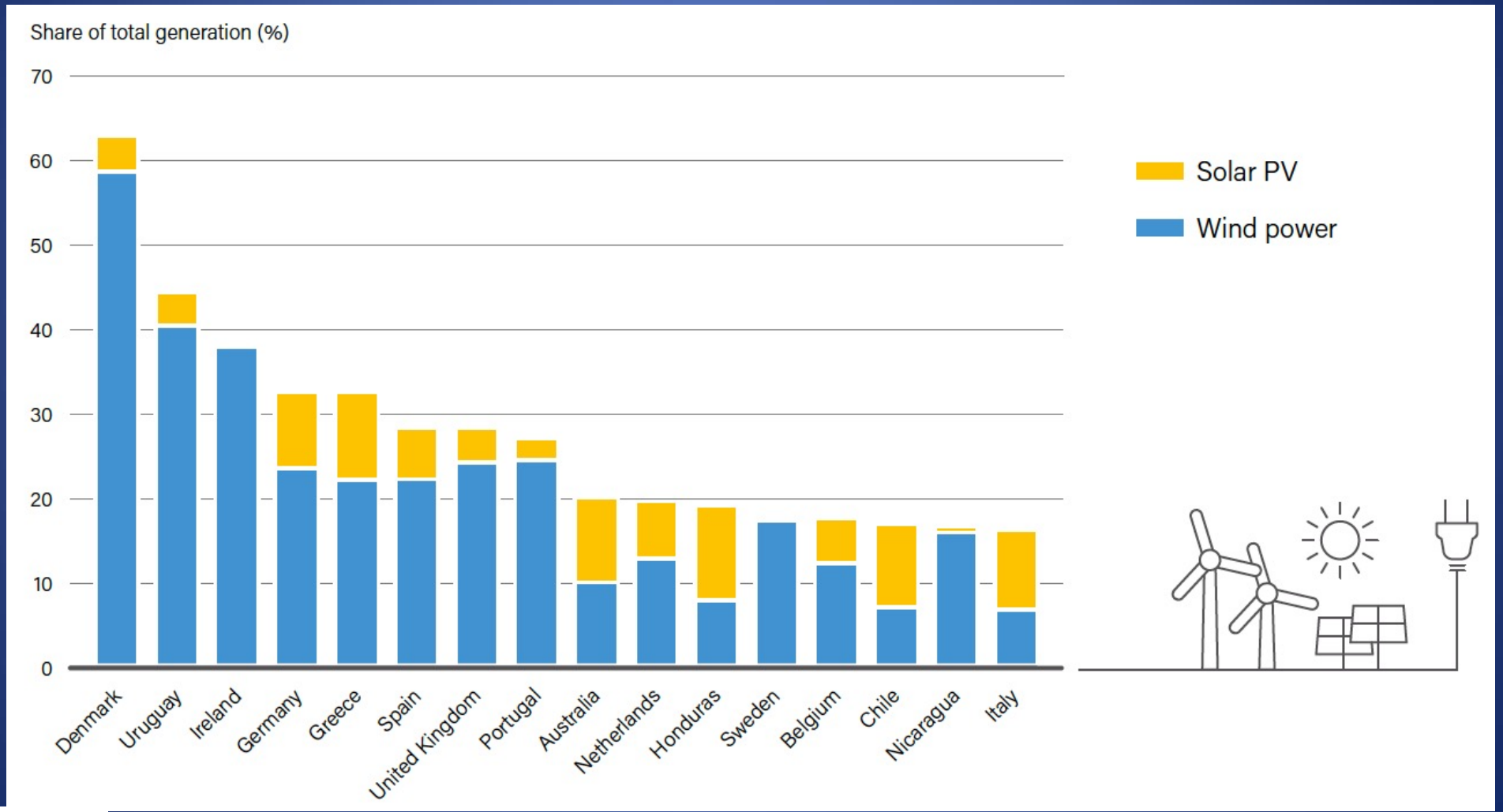
Global Electricity Production by Source and Share of Renewables (2010-2020)



ALMOST 30% OF GLOBAL ELECTRICITY IS NOW RENEWABLE

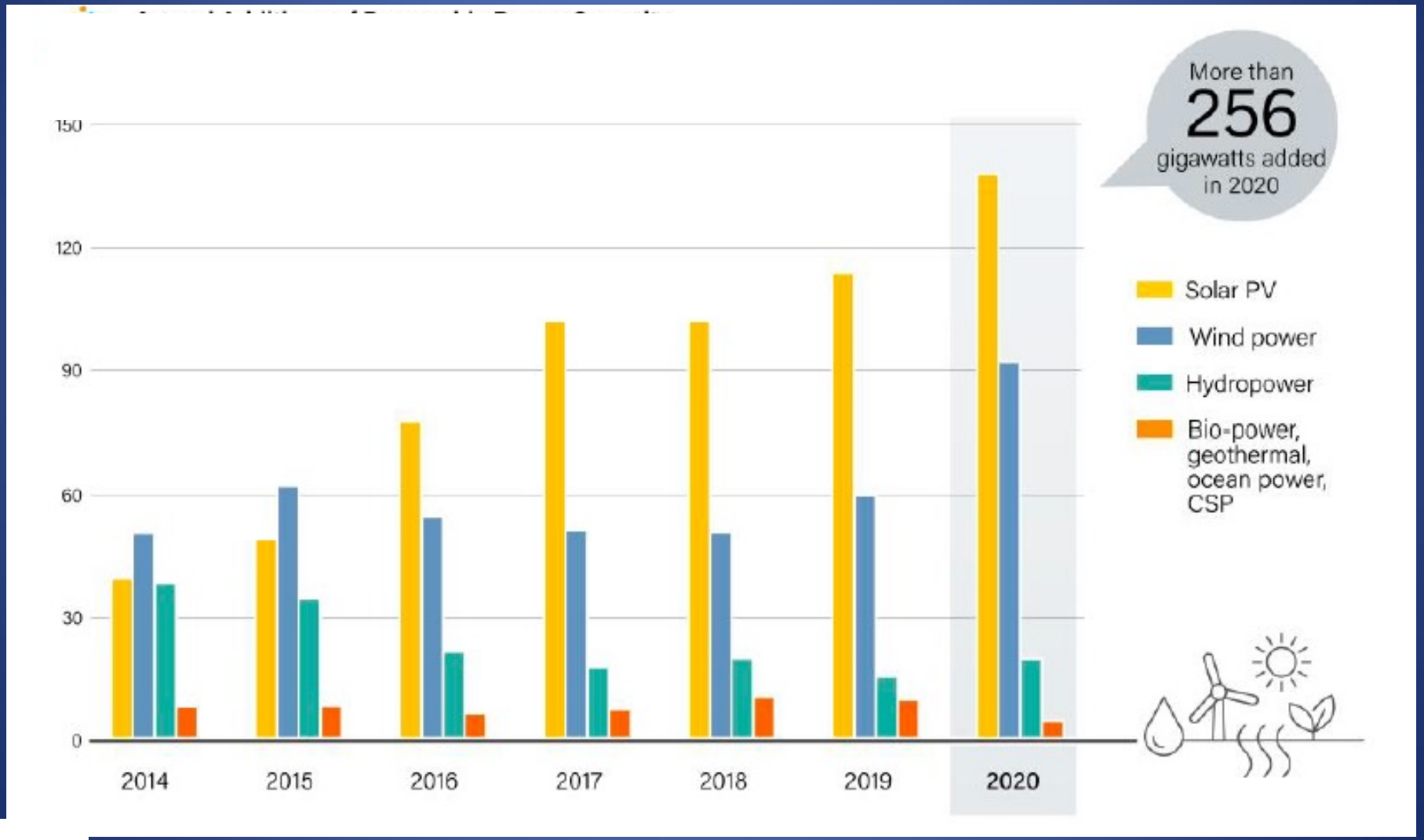
Source: Renewable 2021: Global Status Report, REN21

Share of Electricity Generation from Variable Renewable Energy, Top Countries, 2020

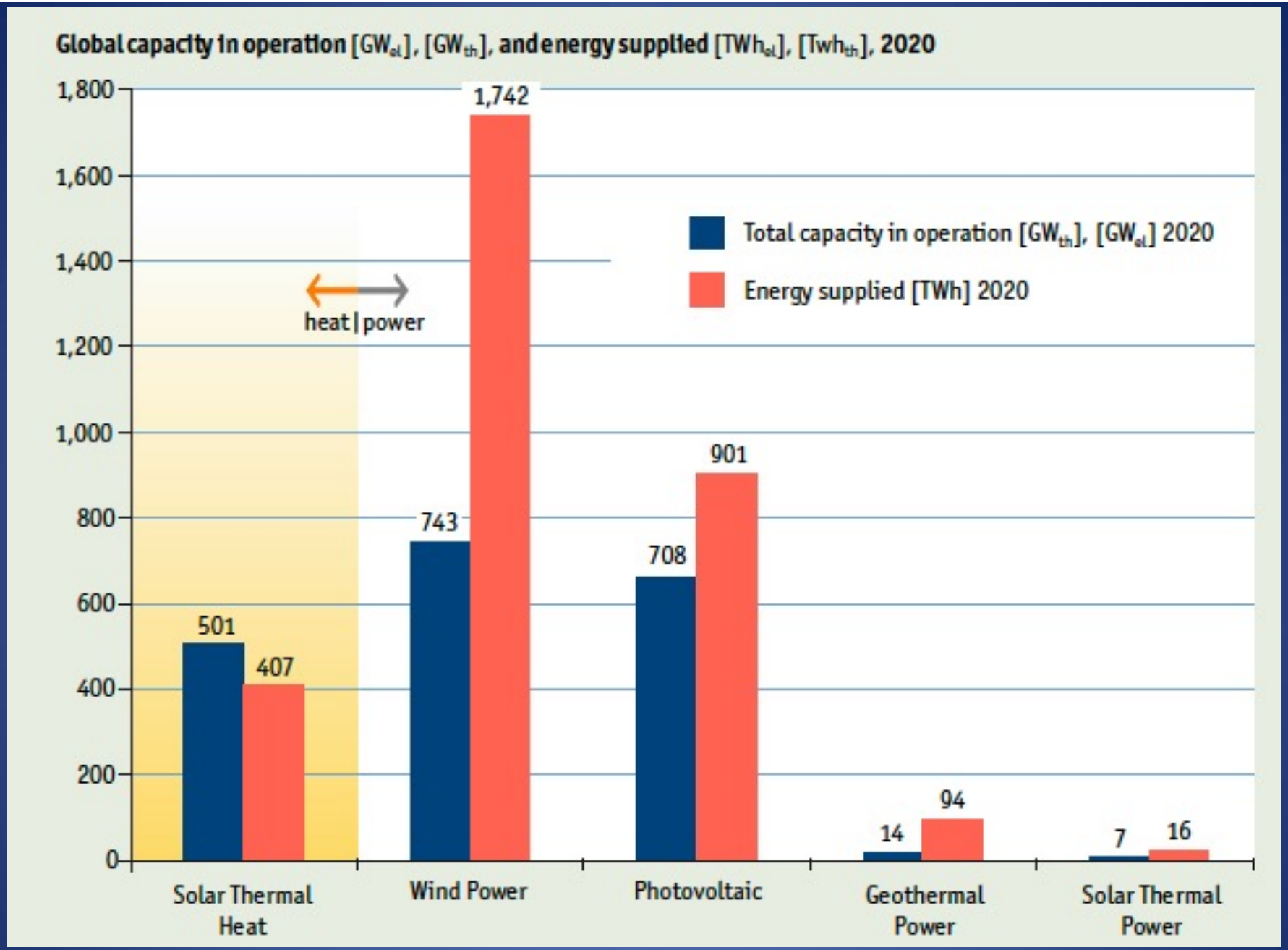


Source: Renewable 2021: Global Status Report, REN21

Annual Additions of Renewable Power Capacity by Technology 2014-2020

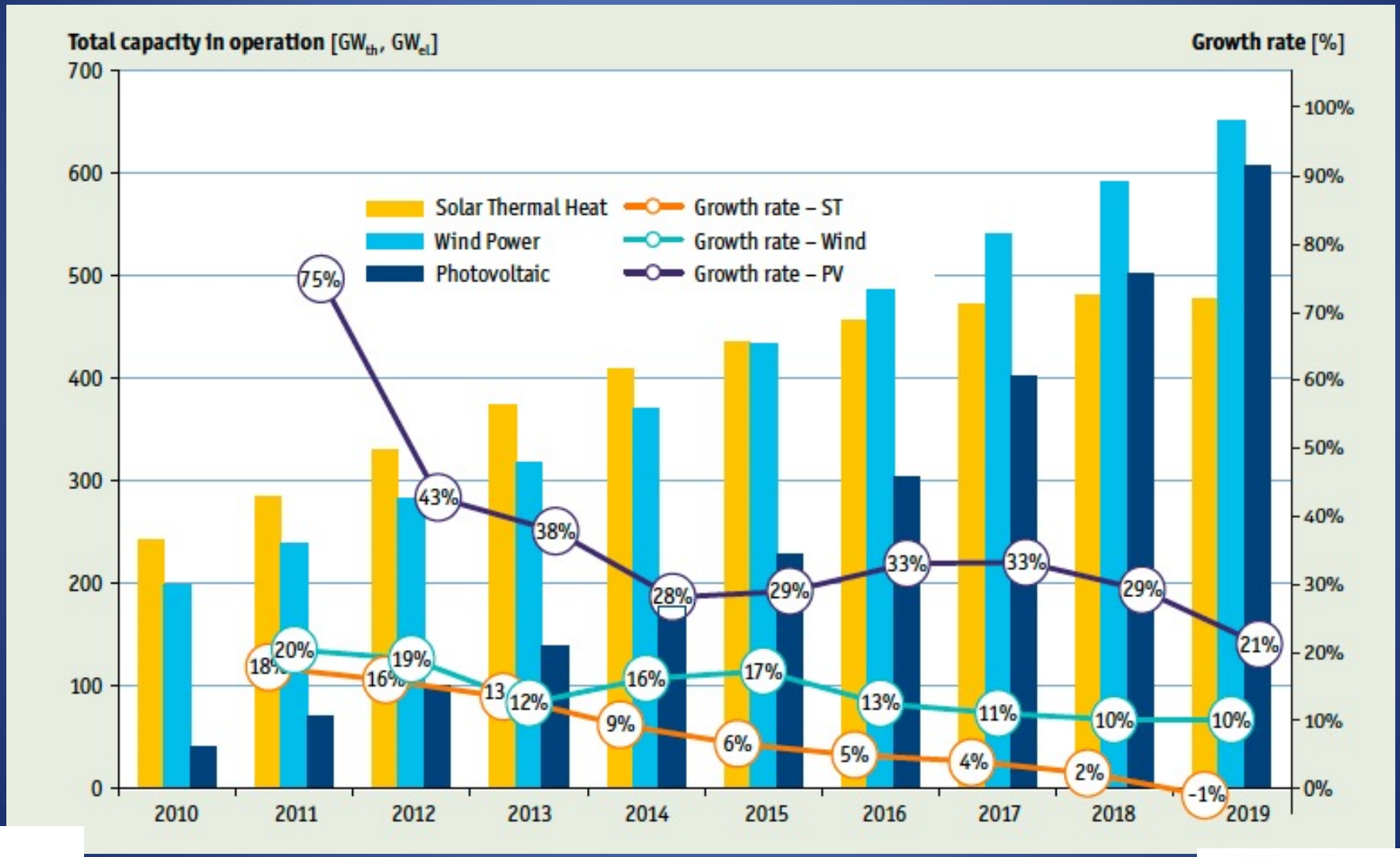


Source: Renewable 2021: Global Status Report, REN21



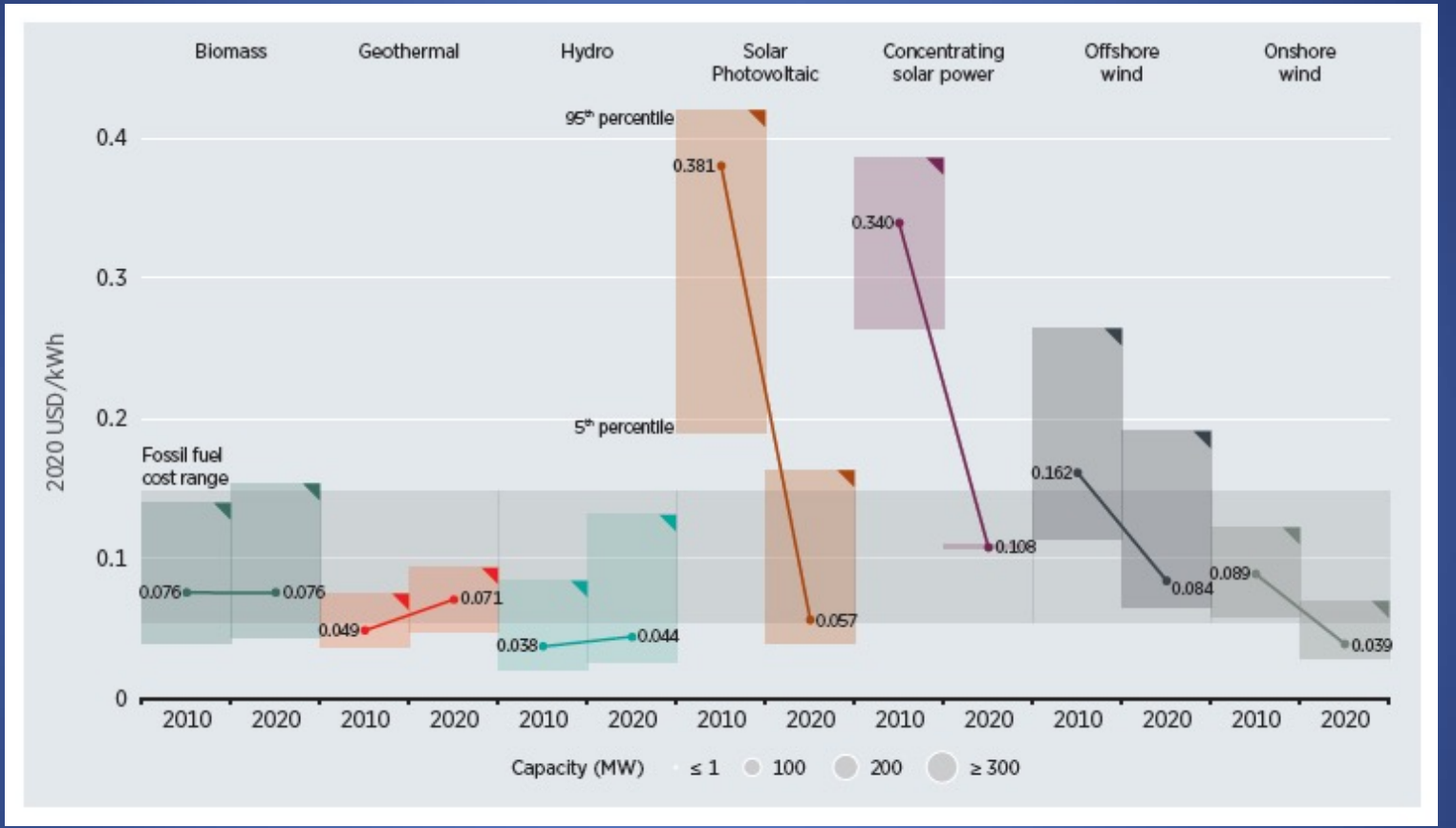
Source: Solar Heat Worldwide: Global Market Development and Trends in 2020, Edition 2021

Global capacity in operation and market growth rates between 2010 and 2019



Source: Solar Heat Worldwide: Global Market Development and Trends in 2019, Edition 2020

Global Levelized Cost of Electricity (LCOE) for utility scale RES 2010-2020

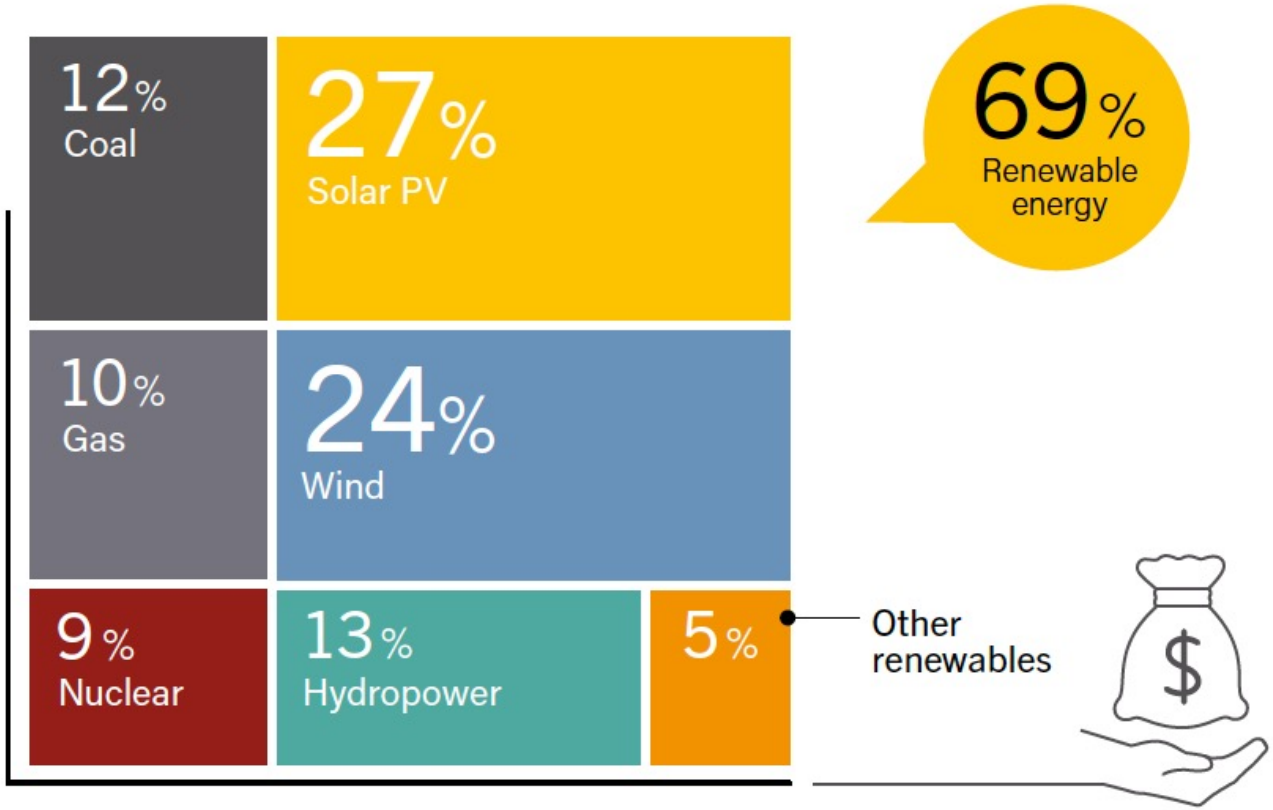


Obstacles in RES penetration:

1. Price per kWh – Now RES are very competitive
2. Permission procedures – need simplification

Source: IRENA Renewable Power Generation Cost in 2020

Global Investment in New Power Capacity by type 2020



Source: Renewable 2021: Global Status Report, REN21

Estimated Direct and Indirect Jobs in Renewable Energy Worldwide, by country and technology

Estimated Direct and Indirect Jobs in Renewable Energy, by Country/Region and Technology, 2017-2018

	World	China	Brazil	United States	India	European Union[l]
	Thousand jobs					
Solar PV	**3,605[e]**	2,194	15.6	225	115[k]	96
Liquid biofuels	**2,063**	51	832[g]	311[h]	35	208
Hydropower[a]	**2,054**	308	203	66.5	347	74
Wind power	**1,160**	510	34	114	58	314
Solar thermal heating/cooling	**801**	670	41	12	20.7	24[m]
Solid biomass[b, c]	**787**	186		79[i]	58	387
Biogas	**334**	145		7	85	67
Geothermal energy[b,d]	**94**	2.5		35[j]		23
Concentrating solar thermal power (CSP)	**34**	11		5		5
Total	**10,983[f]**	**4,078**	**1,125**	**855**	**719**	**1,235[n]**

→ Today it is estimated that more than 12,000,000 are working in RES jobs

→ Next, we will examine the main renewable energy systems separately.

Source: Renewable 2019: Global Status Report, REN21

Solar Thermal Power

- Systems utilising either the thermal radiation or the light of solar irradiance.
- Solar thermal systems
  - *Low temperature* systems (mostly for water heating and industrial processes)
  - *High temperature* systems (mostly for CSP and high temperature industrial processes)
- Solar photovoltaics

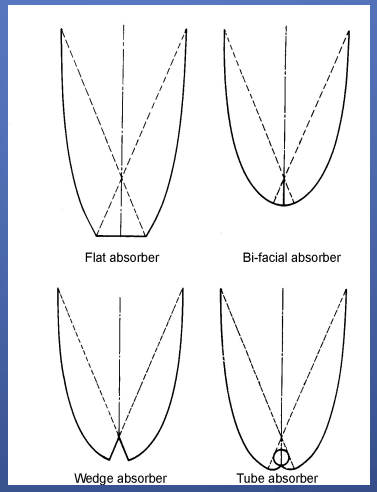
Low temperature collectors

- Flat plate collectors

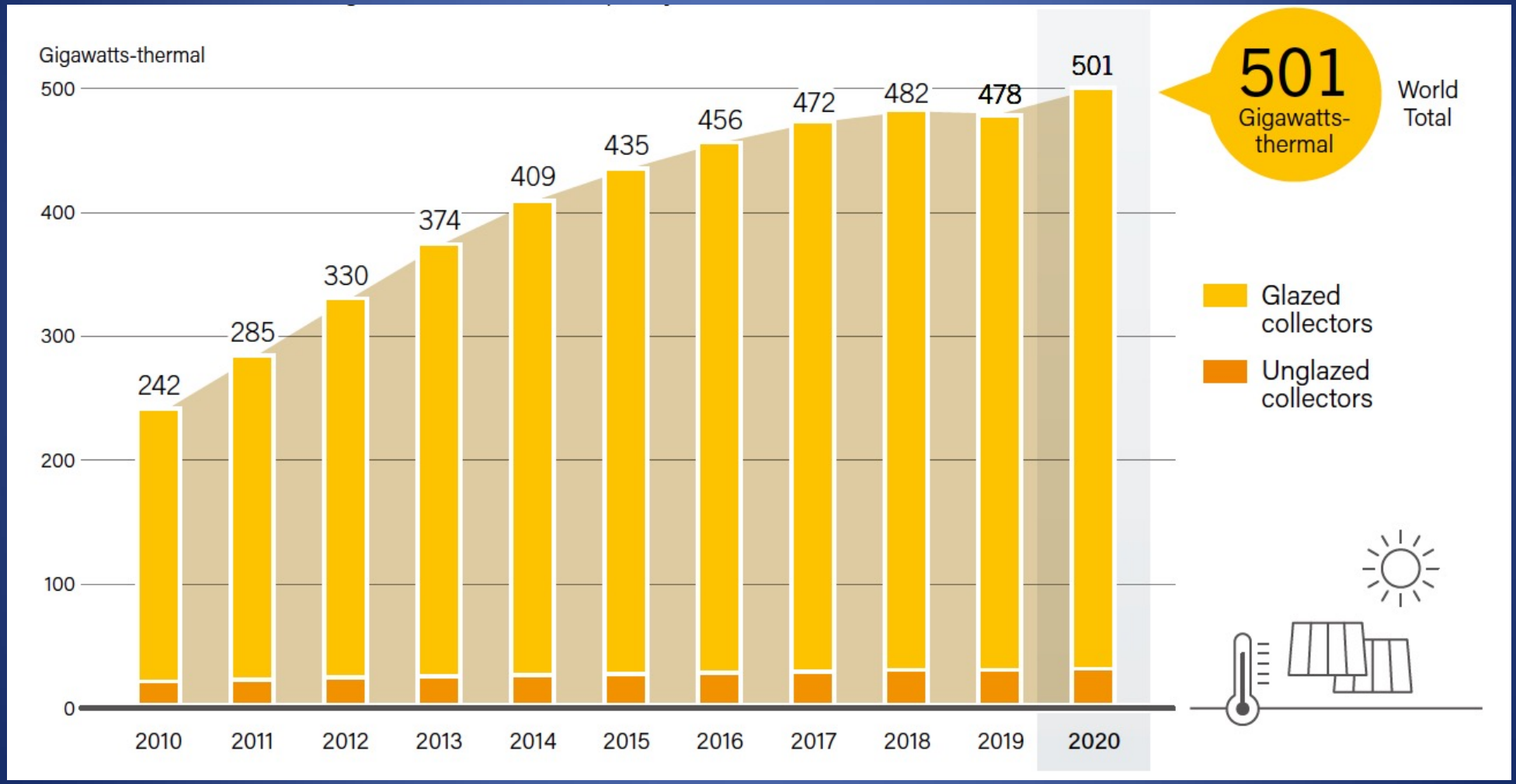


- Evacuated tube collectors


- Compound parabolic collectors



Solar Water Heating Collectors Global Capacity, 2010–2020

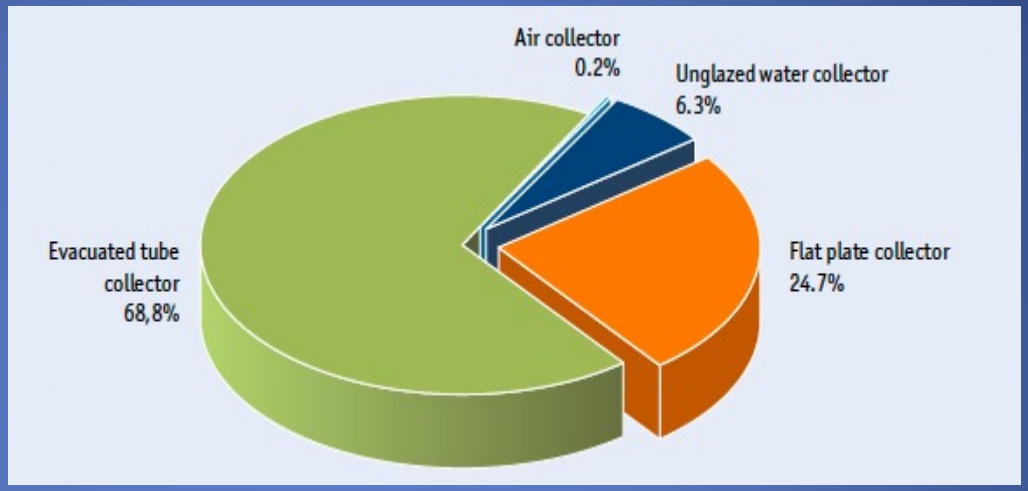


Source: Renewable 2021: Global Status Report, REN21

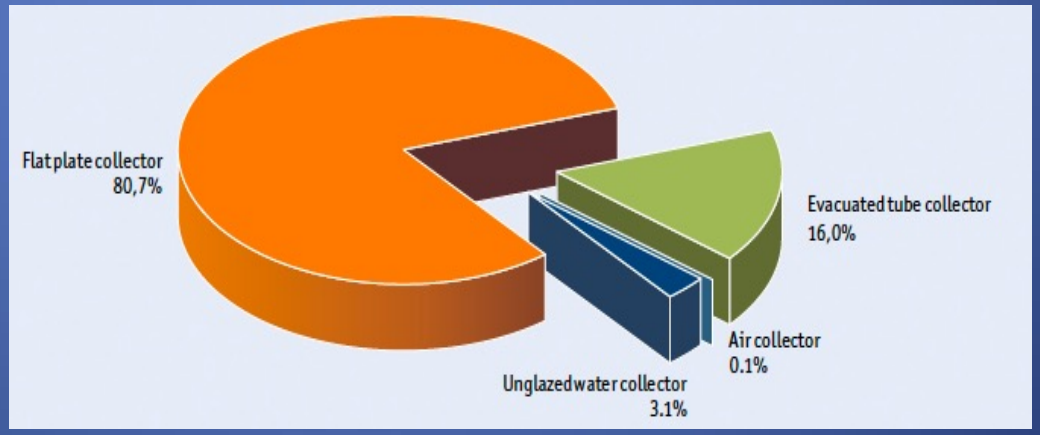
Solar water heating in Cyprus
A success story

Distribution of the total installed capacity in operation by collector type in 2020

World



Europe



Source: Solar Heat Worldwide: Global Market Development and Trends in 2020, Edition 2021

Research lead to several new innovations

- Use of polymeric materials for the manufacture of solar thermal absorbers to:
  - reduce cost due to lower raw material and manufacturing costs.
  - reduce weight compared to copper or aluminium.
- Improved heat transfer with the use of nanofluids.
- New transparent covers with anti-reflective coatings for high optical transmission, and the use of high vacuum or noble gases.
- Switchable coatings to reduce stagnation temperatures.
- Development of new selective absorber with low emission coatings.
- Development of temperature-resistant super-insulating materials.
- Vacuum insulation for flat-plate collectors.

High temperature systems

- Parabolic trough collector

- Linear Fresnel collector

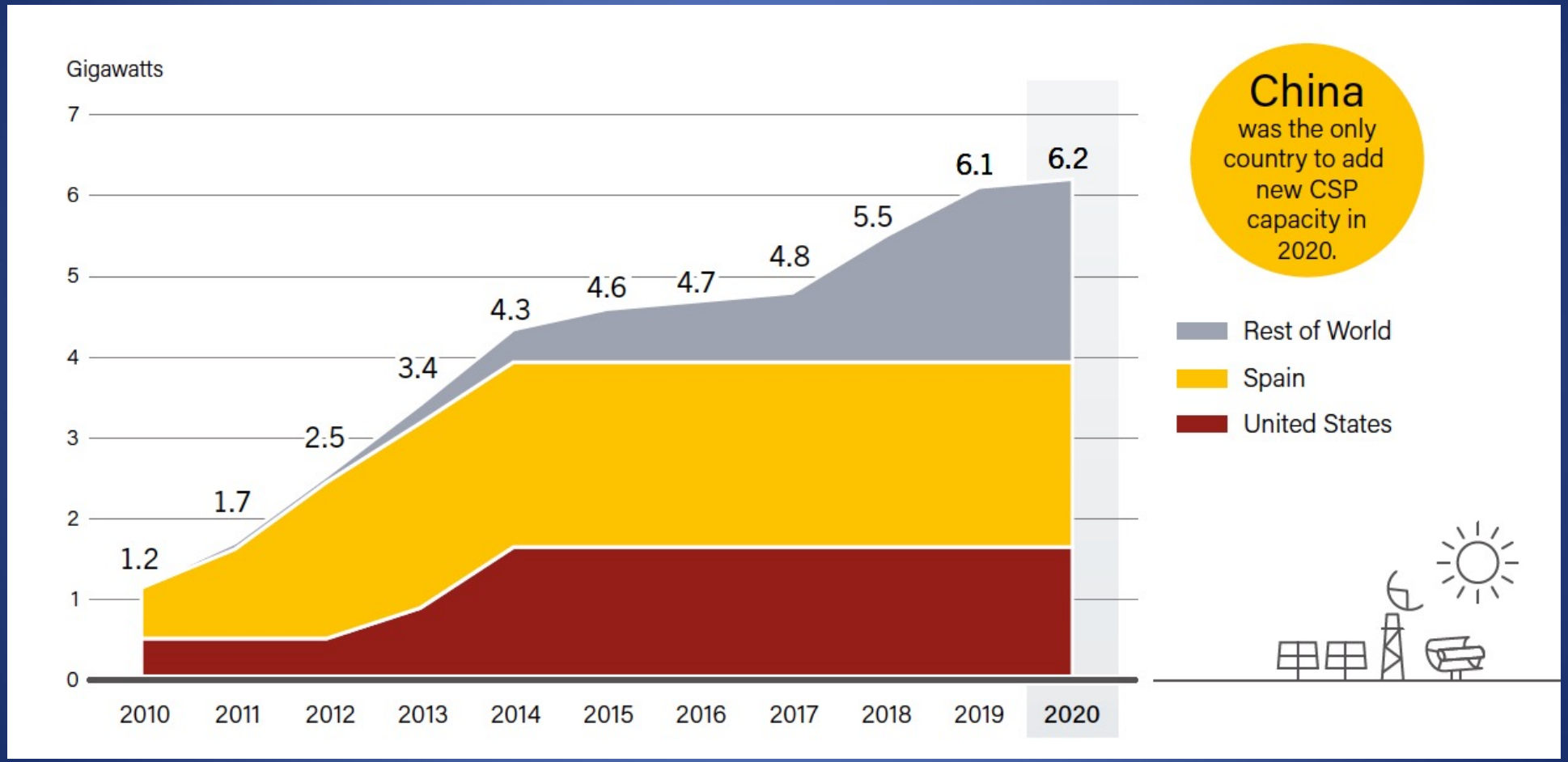
- Solar dish

- Solar tower

Solar Two

Gemasolar

Concentrating Solar Thermal Power Global Capacity, by Country/Region, 2010–2020



→ **Many CSP systems are under development in many countries of the world**

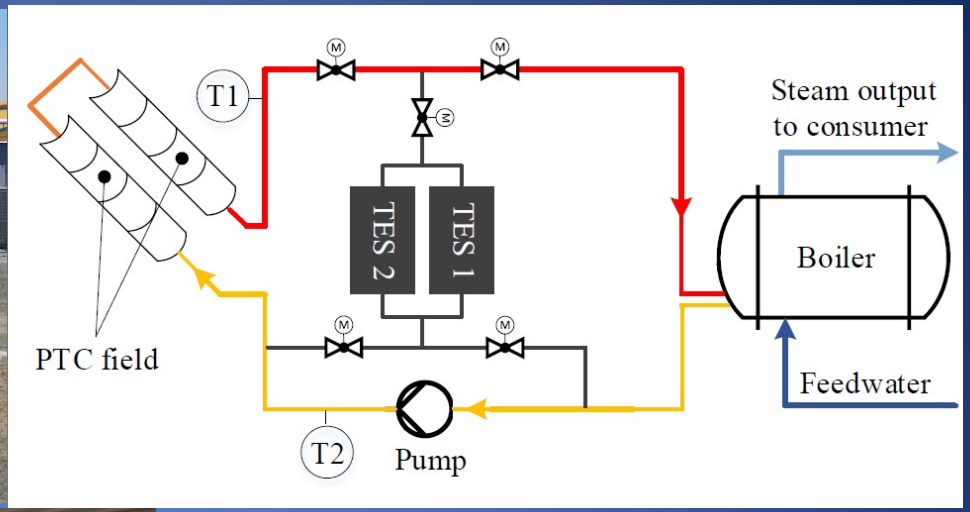
→ **All new facilities incorporate thermal ENERGY STORAGE**

Source: Renewable 2021: Global Status Report, REN21

16th sdewes Conference DUBROVNIK 2021

Cyprus University of Technology

Industrial Process Heat-Solar Juice



Storage and plantroom containers

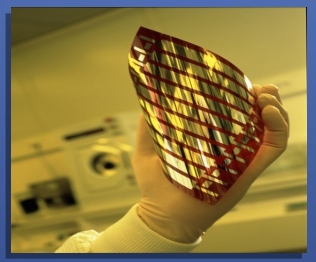
Concrete storage

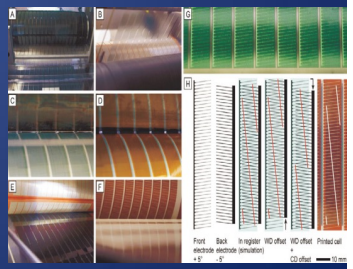
ks

Photovoltaics

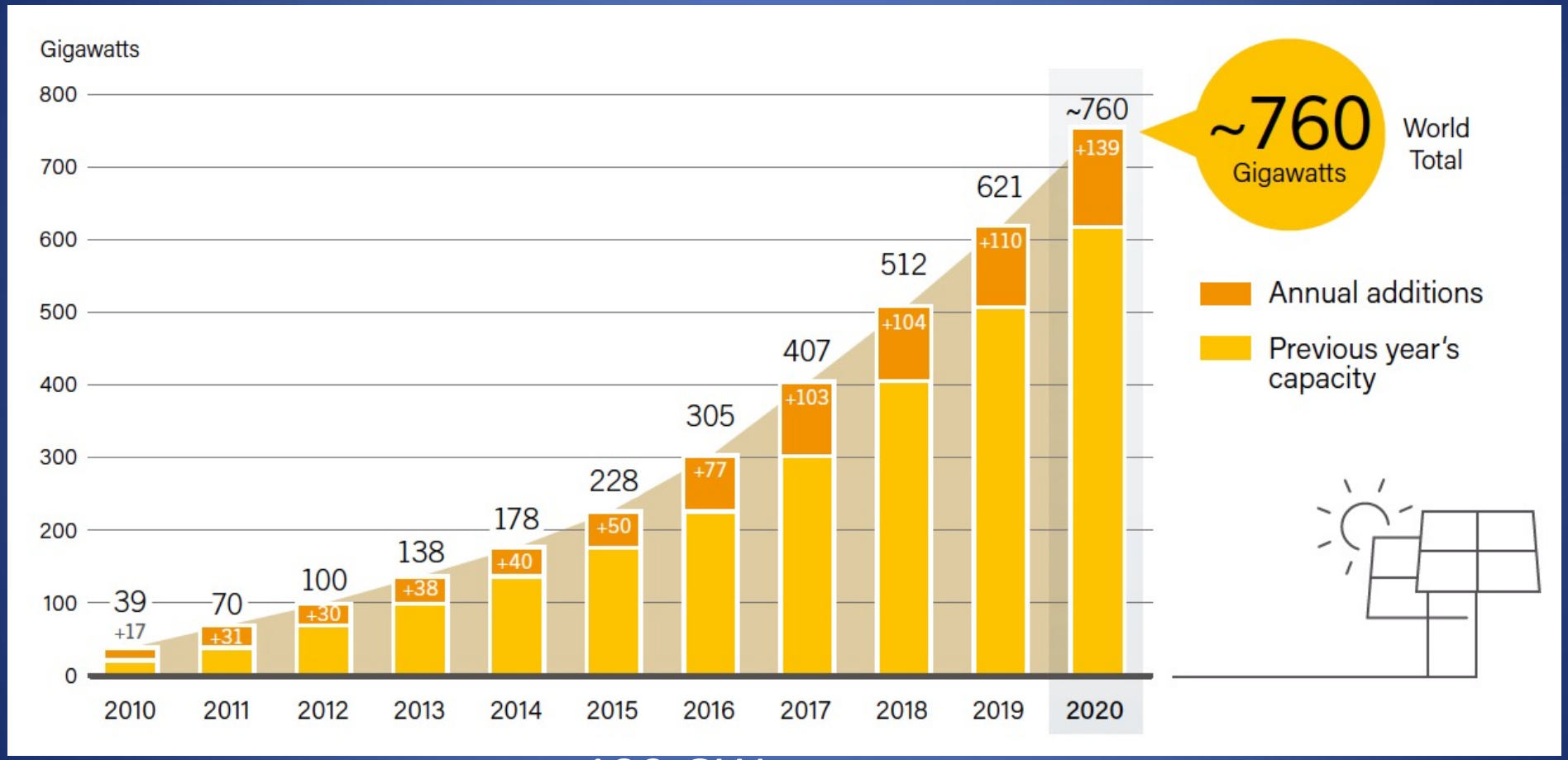
- Four basic technologies:
  - Polycrystalline silicon cells
  - Monocrystalline silicon cells
  - Amorphous silicon cells

  - Other thin film cells





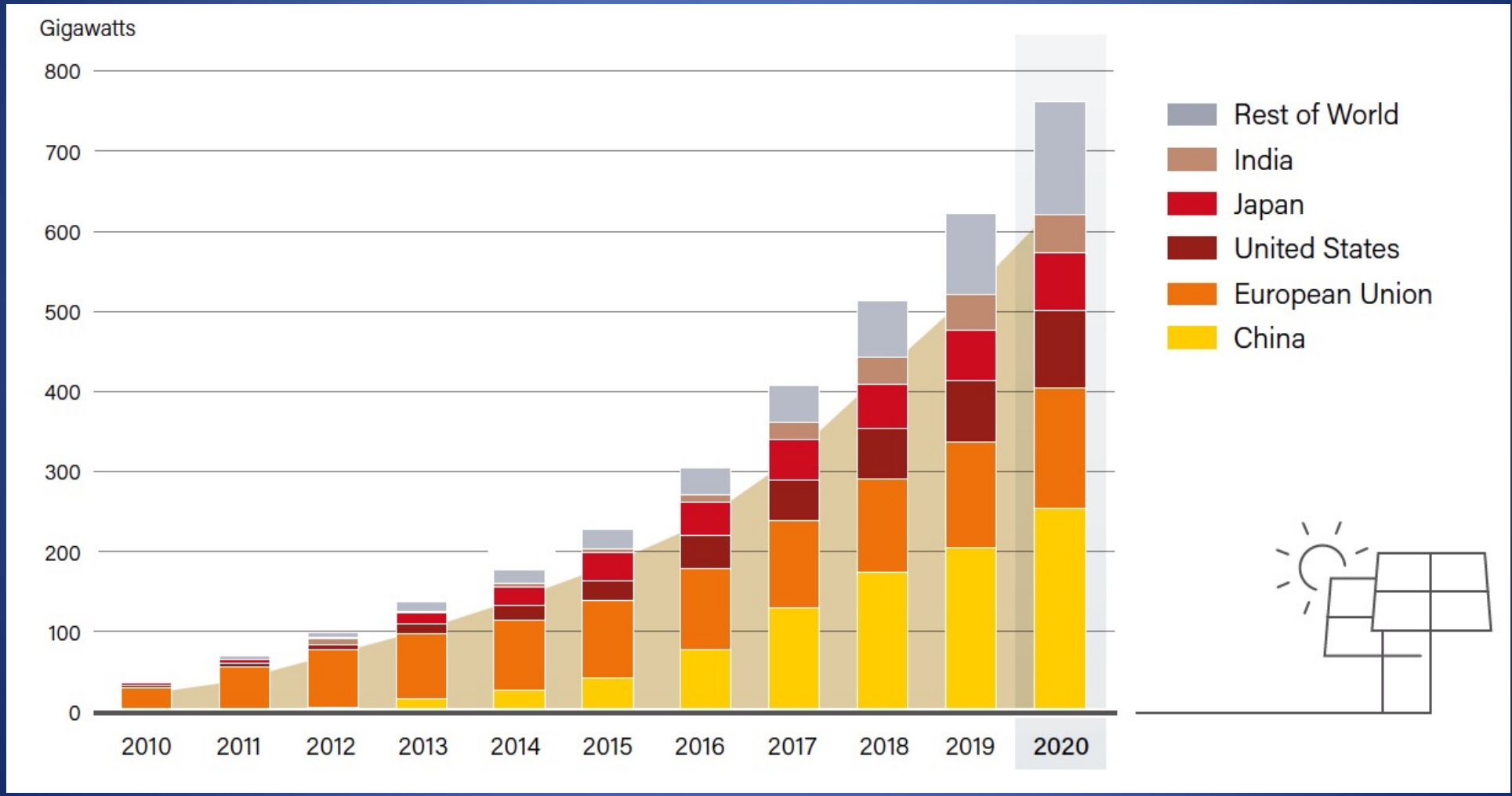
Solar PV Global Capacity and Annual Additions, 2010-2020



→ During 2020, at least 139 GW of solar PV capacity was added worldwide – equivalent to the installation of more than 60,000 SOLAR PANELS EVERY HOUR.

Source: Renewable 2021: Global Status Report, REN21

Solar PV Global Capacity by Country and Region, 2010-2020



Source: Renewable 2021: Global Status Report, REN21

Top 10 countries for PV Installations and Total Installed Capacity 2020

FOR ANNUAL INSTALLED CAPACITY			FOR CUMULATIVE CAPACITY		
1	China	48,2 GW	1	China	253,4 GW
(2)	*European Union*	19,6 GW	(2)	*European Union*	*151,3 GW*
2	United States	19,2 GW	2	United States	93,2 GW
3	Vietnam	11,1 GW	3	Japan	71,4 GW
4	Japan	8,2 GW	4	Germany	53,9 GW
5	Germany	4,9 GW	5	India	47,4 GW
6	India	4,4 GW	6	Italy	21,7 GW
7	Australia	4,1 GW	7	Australia	20,2 GW
8	Korea	4,1 GW	8	Vietnam	16,4 GW
9	Brazil	3,1 GW	9	Korea	15,9 GW
10	Netherlands	3 GW	10	UK	13,5 GW

16th sdewes Conference DUBROVNIK 2021

Source: Snapshot of Global PV markets 2021: IEA PVPS

Cyprus University of Technology


Current PV Research
• Higher performance cells/modules
• New nanomaterials applications
• Advanced manufacturing techniques
8.22 MW Alamosa, Colorado, PV solar plant

Very Large Scale PV 66MW-China

Tengger Desert Solar Park – 1547MW – China

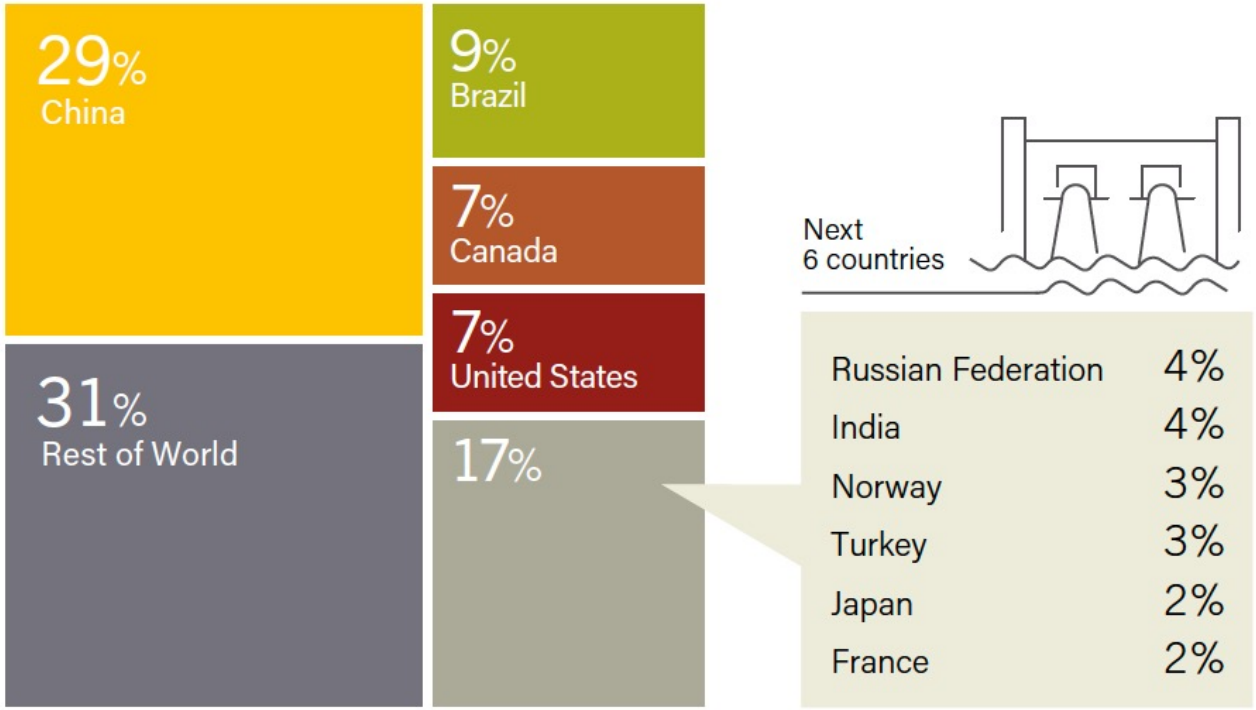
The largest solar power plant in the world right now.
Installed in Zhongwei, Ningxia.
Tengger desert (Inner Mongolia).
The area of the solar field is 1,200 km^2

Hydro Power

- **Comes in a variety of sizes:**
- **Large Hydro (>10 MW)**
  - 18 GW scheme at the Three Gorges, China (largest)
  - An example of Large Hydro (> 10 MW)
- **Small Hydro (1 – 10 MW)**
- **Mini Hydro (100 kW – 1 MW)**
- **Micro Hydro (< 100 kW)**

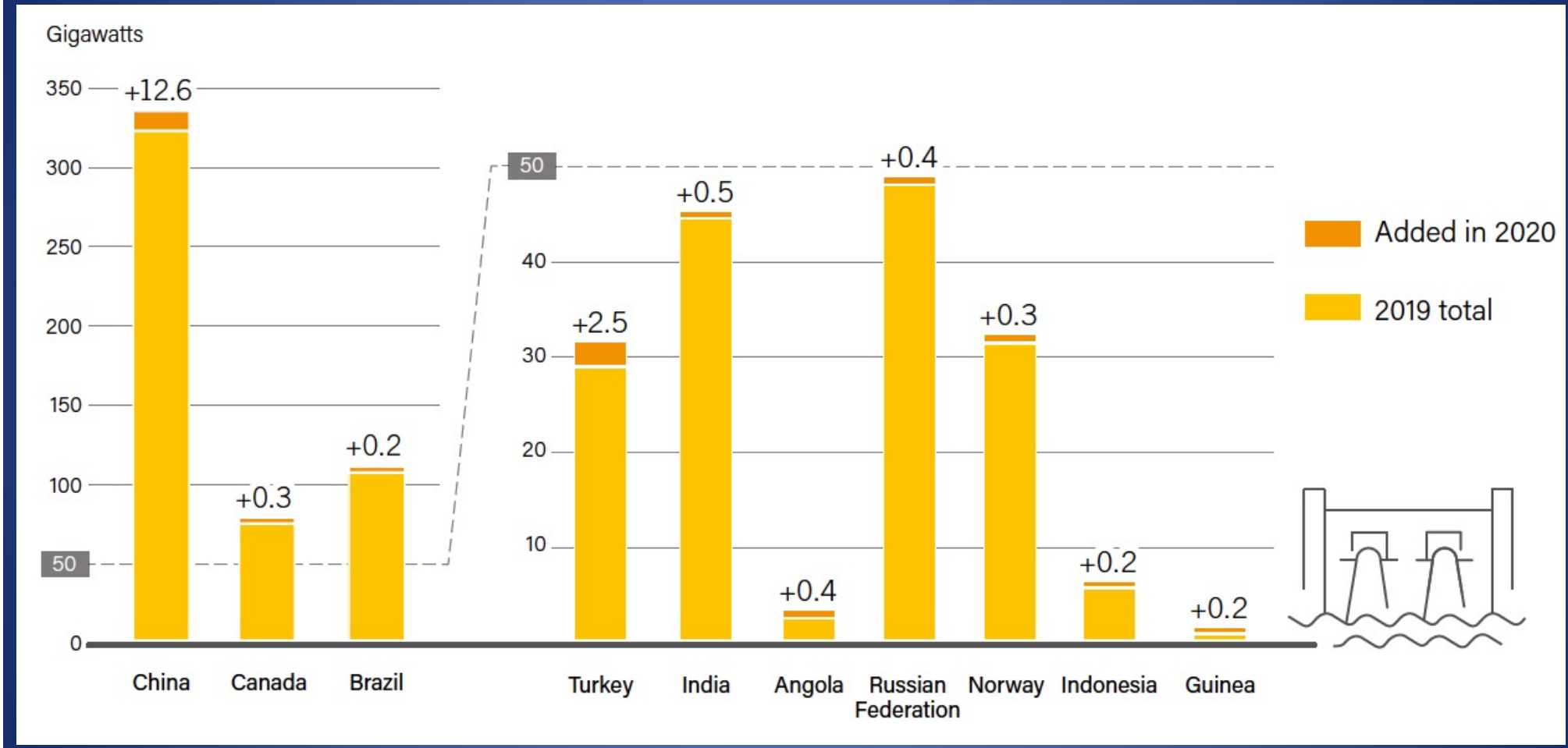
- **And finally Pico Hydro (< 5 kW)…**

Hydropower Global Capacity



Source: Renewable 2021: Global Status Report, REN21

Hydropower Capacity and Additions, Top 10 Countries for Capacity Added, 2020



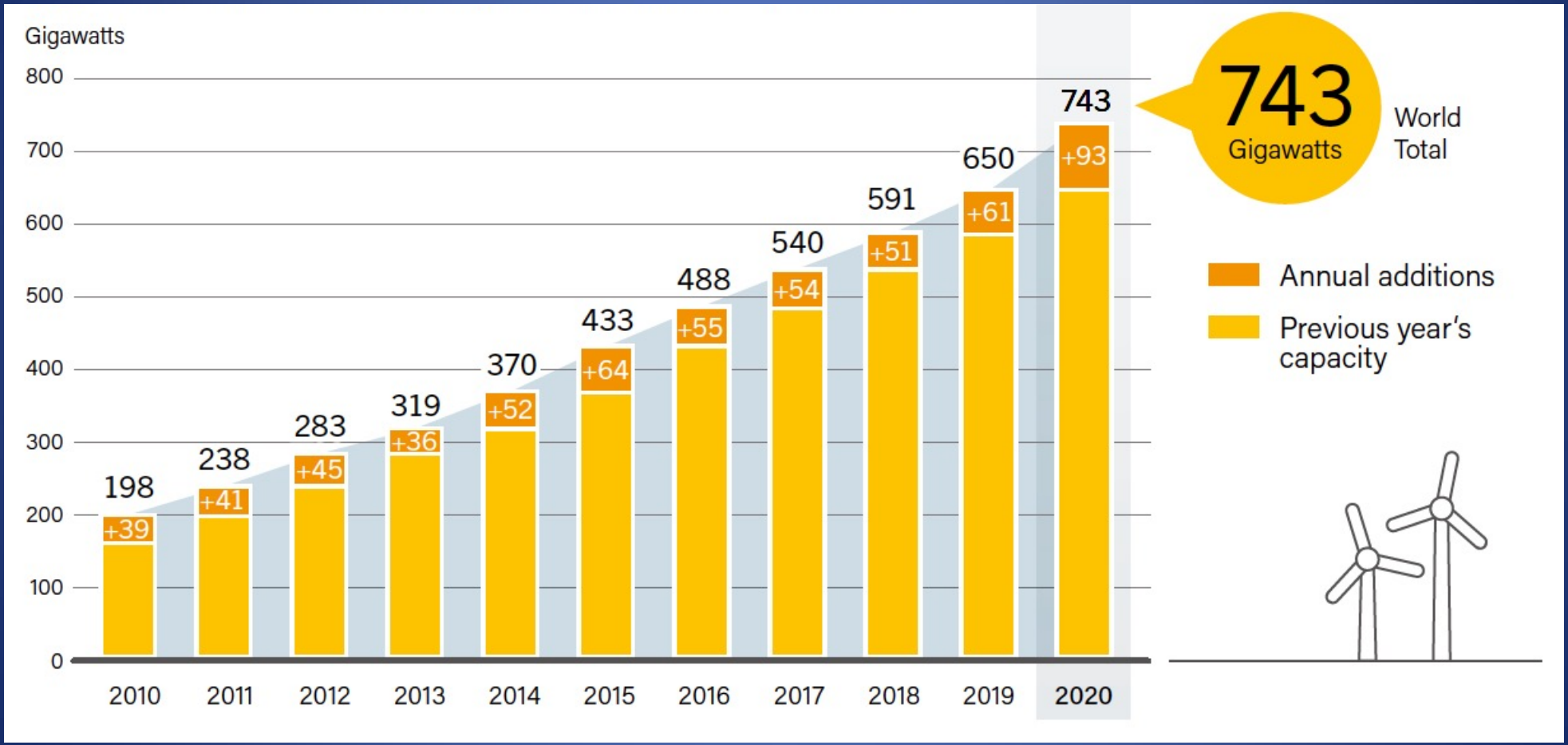
Source: Renewable 2021: Global Status Report, REN21

Wind Power

16th sdewes Conference DUBROVNIK 2021

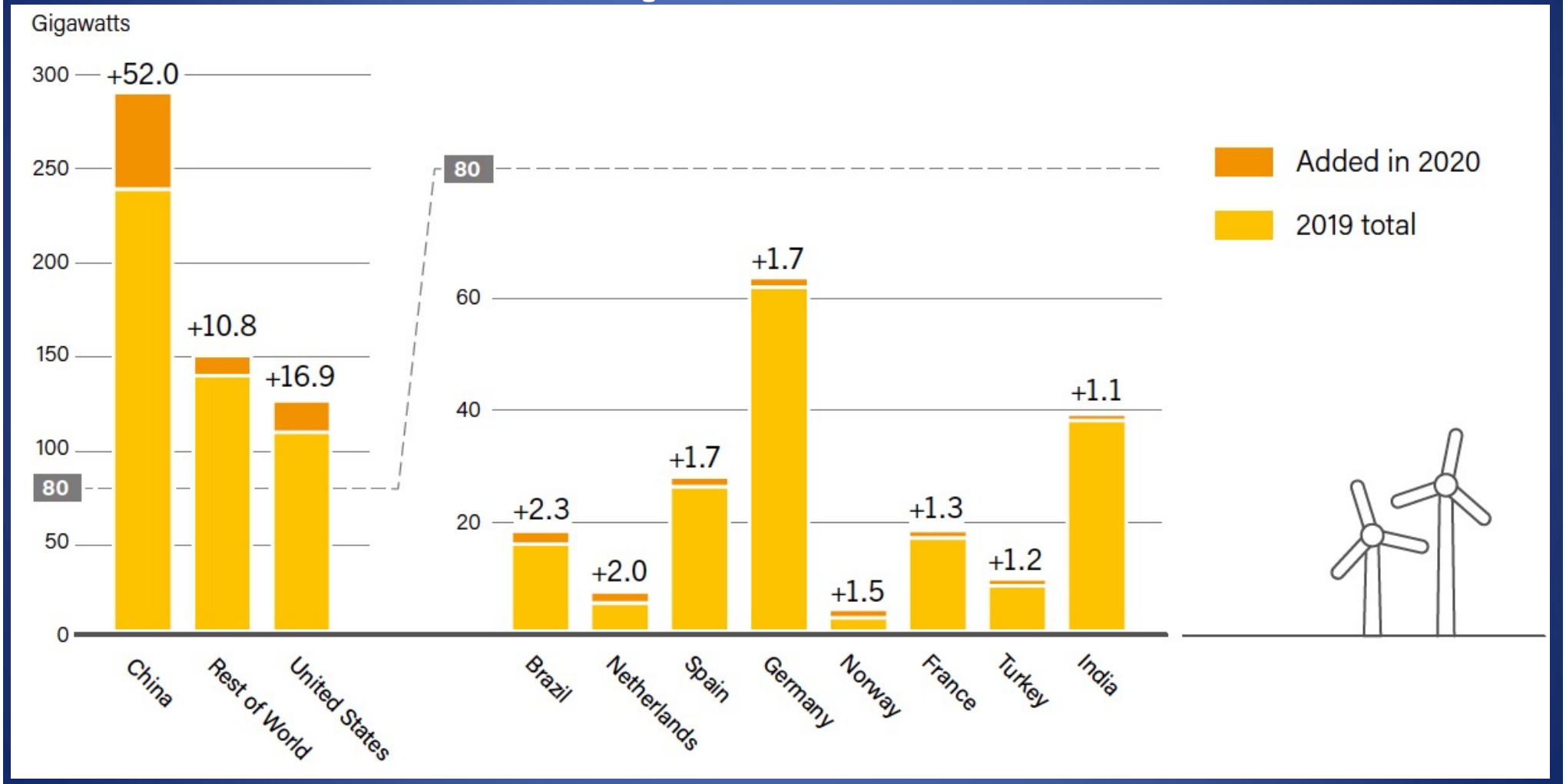
Cyprus University of Technology

Wind Power Global Capacity and Annual Additions, 2010–2020



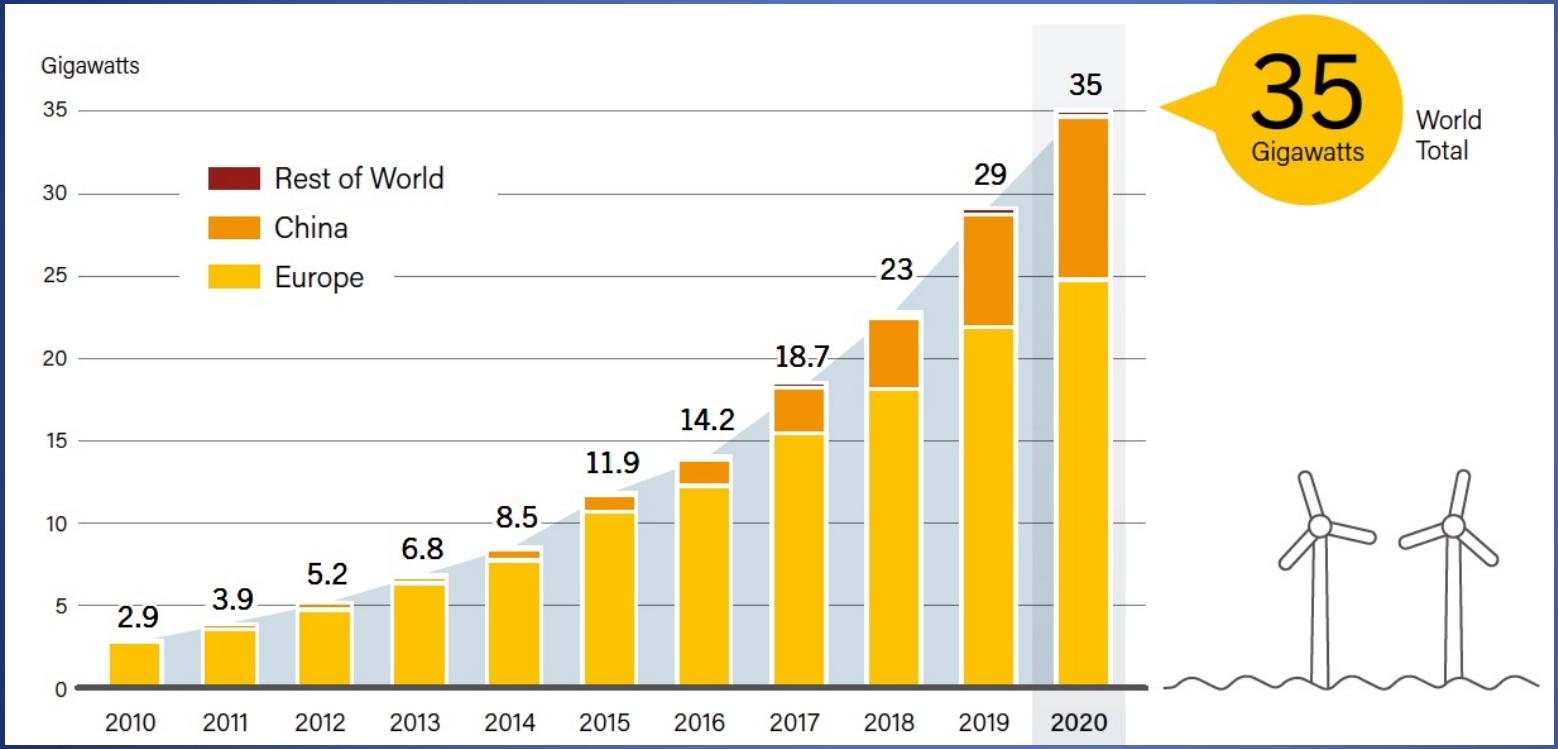
Source: Renewable 2021: Global Status Report, REN21

Wind Power Capacity and Additions, Top 10 Countries, 2020



Source: Renewable 2021: Global Status Report, REN21

Wind Power Offshore Global Capacity by Region, 2010-2020

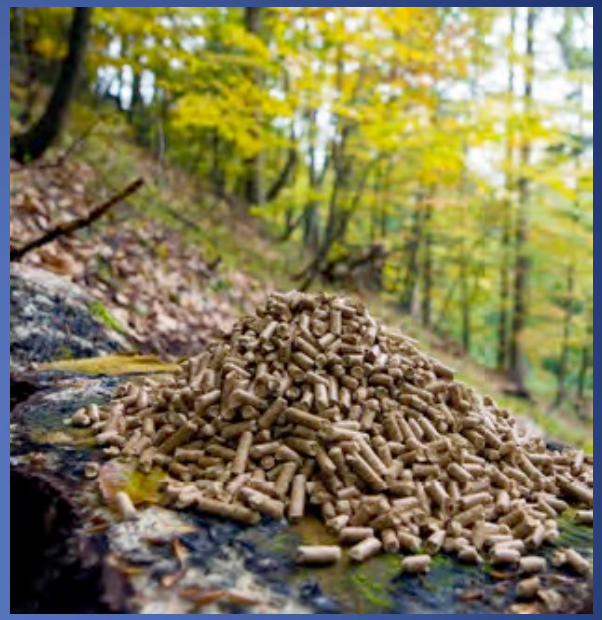


→ WIND has become the LEAST-COST option for new power generating capacity in an increasing number of markets.

Source: Renewable 2021: Global Status Report, REN21

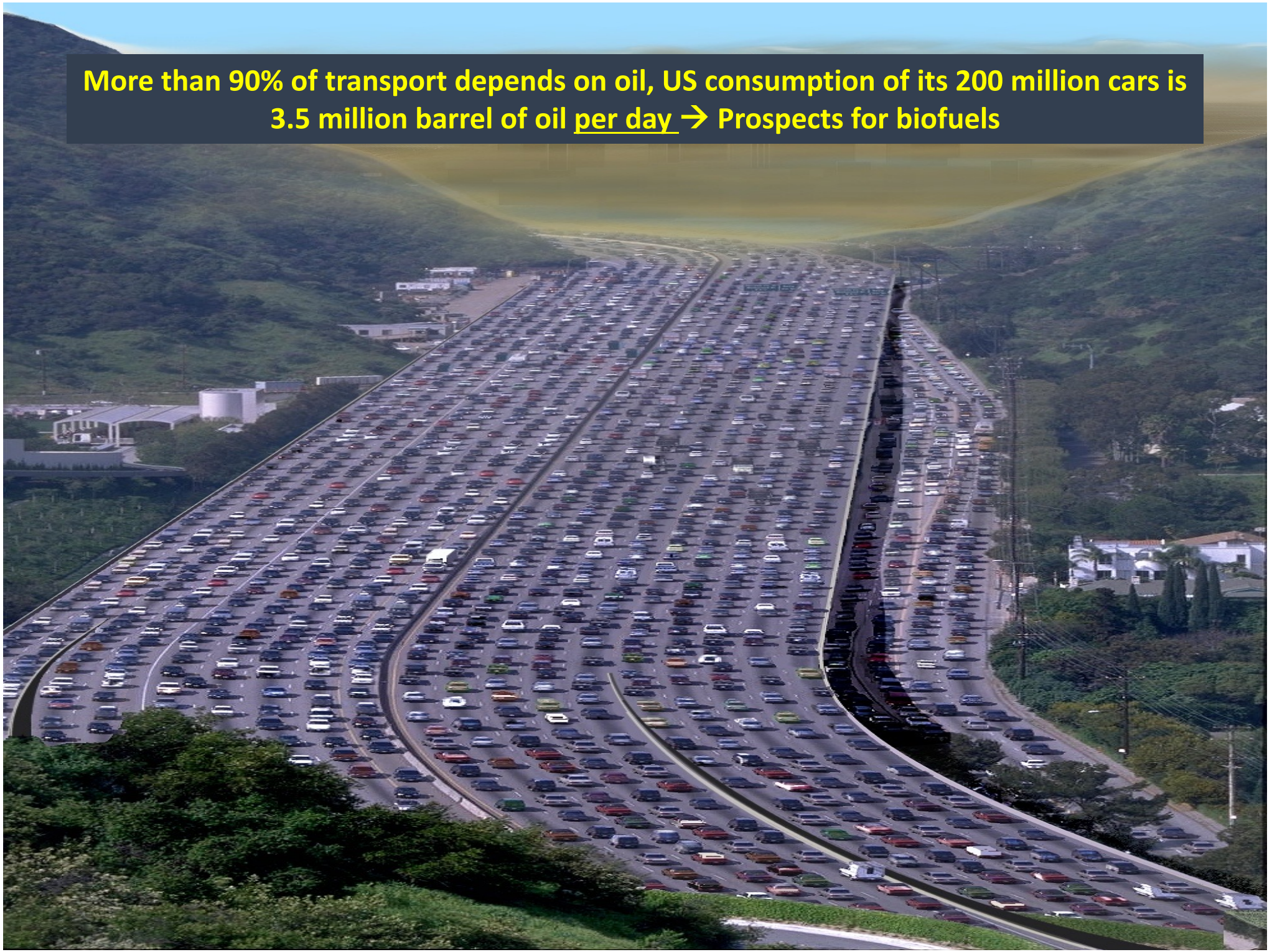
Biomass

- Main areas:
  - Biomass
  - Biogas
  - Biofuels (biodiesel)
  - Waste (MSW, landfills [?])

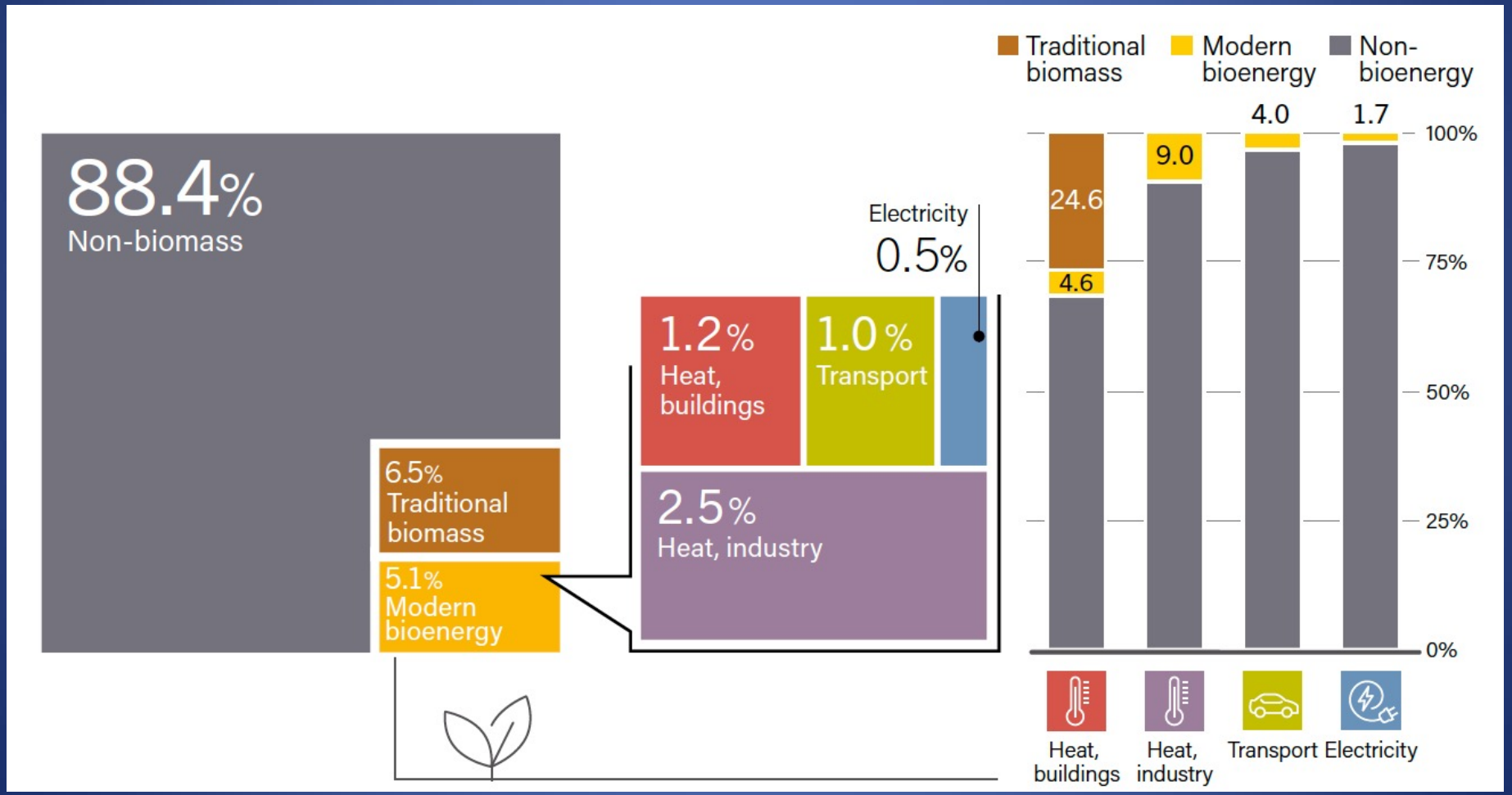


Biomass – Question food for fuel?

→ Land availability for energy crops

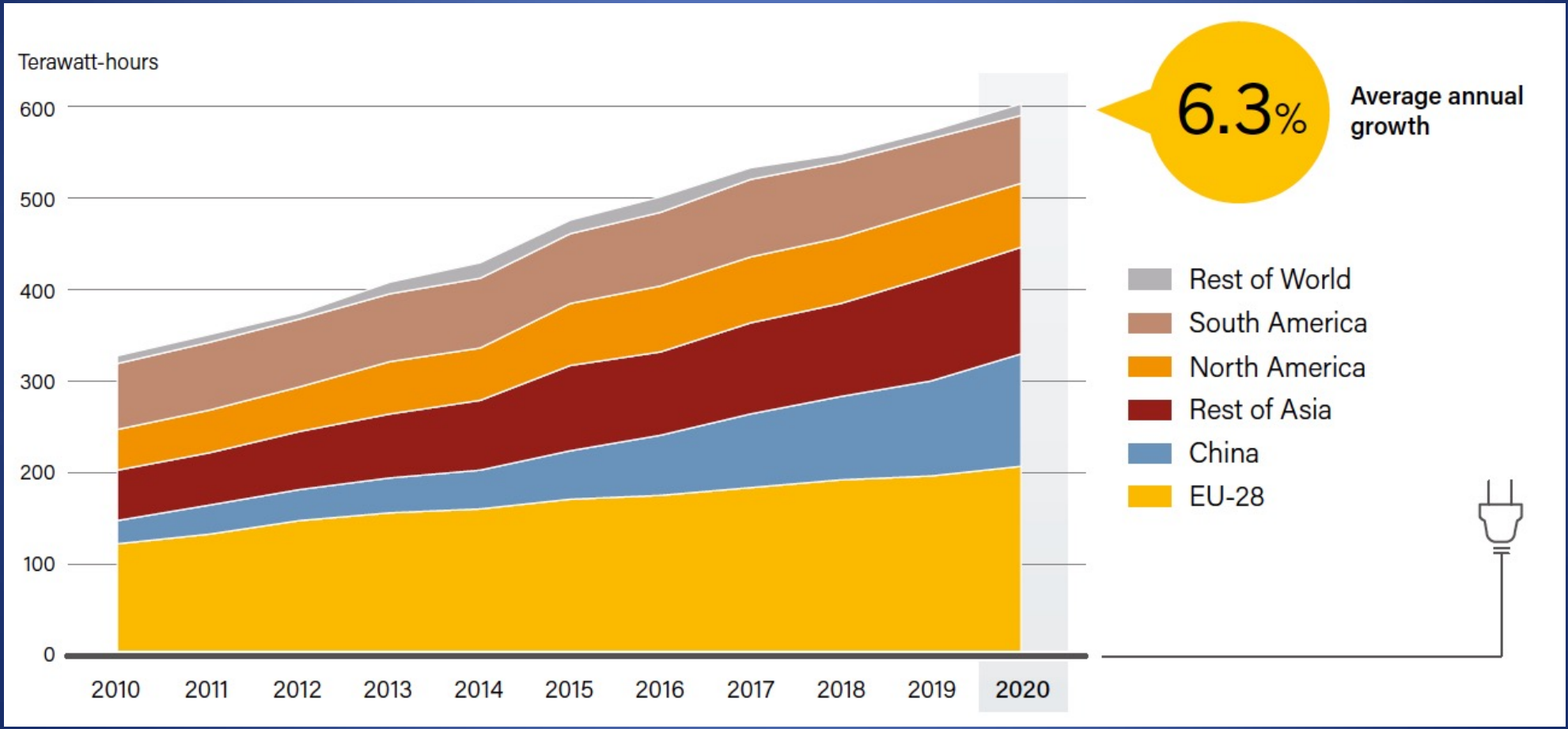

More than 90% of transport depends on oil, US consumption of its 200 million cars is 3.5 million barrel of oil per day → Prospects for biofuels

Shares of Bioenergy in Total Final Energy Consumption, Overall and by end-use sector, 2019



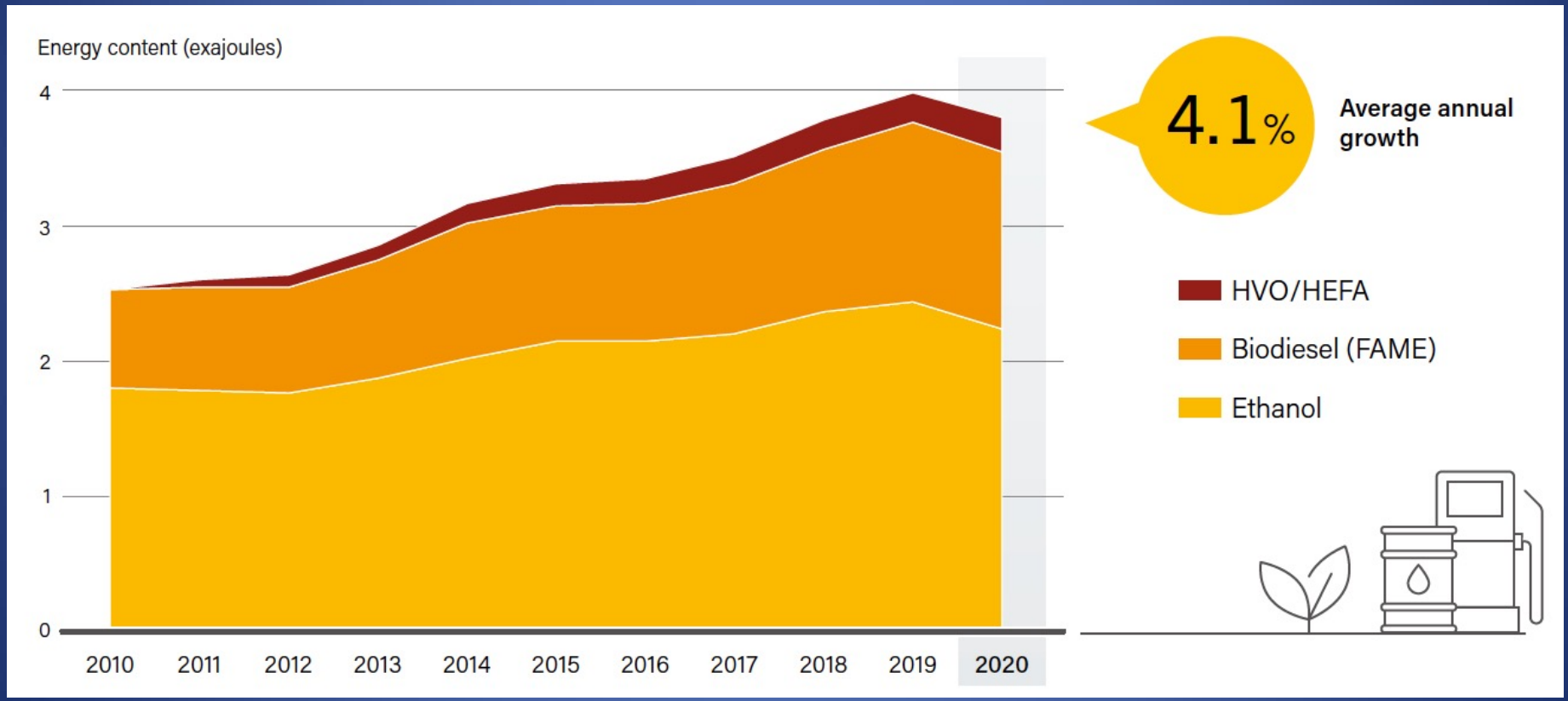
Source: Renewable 2021: Global Status Report, REN21

Global Bioelectricity Generation, by Region, 2010-2020



Source: Renewable 2021: Global Status Report, REN21

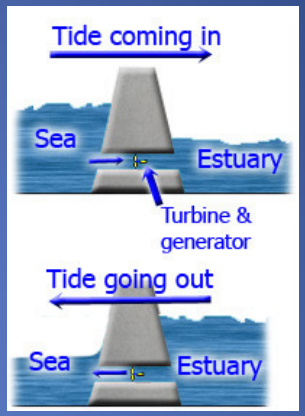
Global trends in ethanol, biodiesel and HVO production 2010-2020

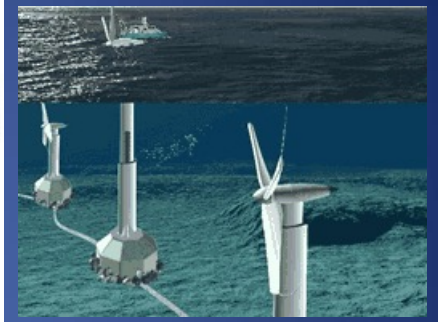


Source: Renewable 2021: Global Status Report, REN21

Other areas of renewables

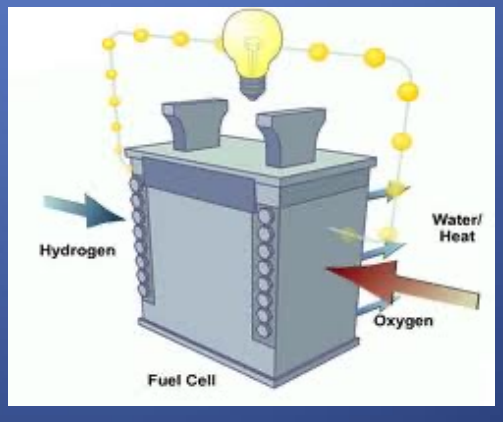
- Ocean energy systems
  - Wave, tidal energy conversion, OTEC
  - Total capacity: 535 MW (2019)





- Geothermal
  - Global capacity: 13.9 GW (power), 421 PJ (heat) [2019]

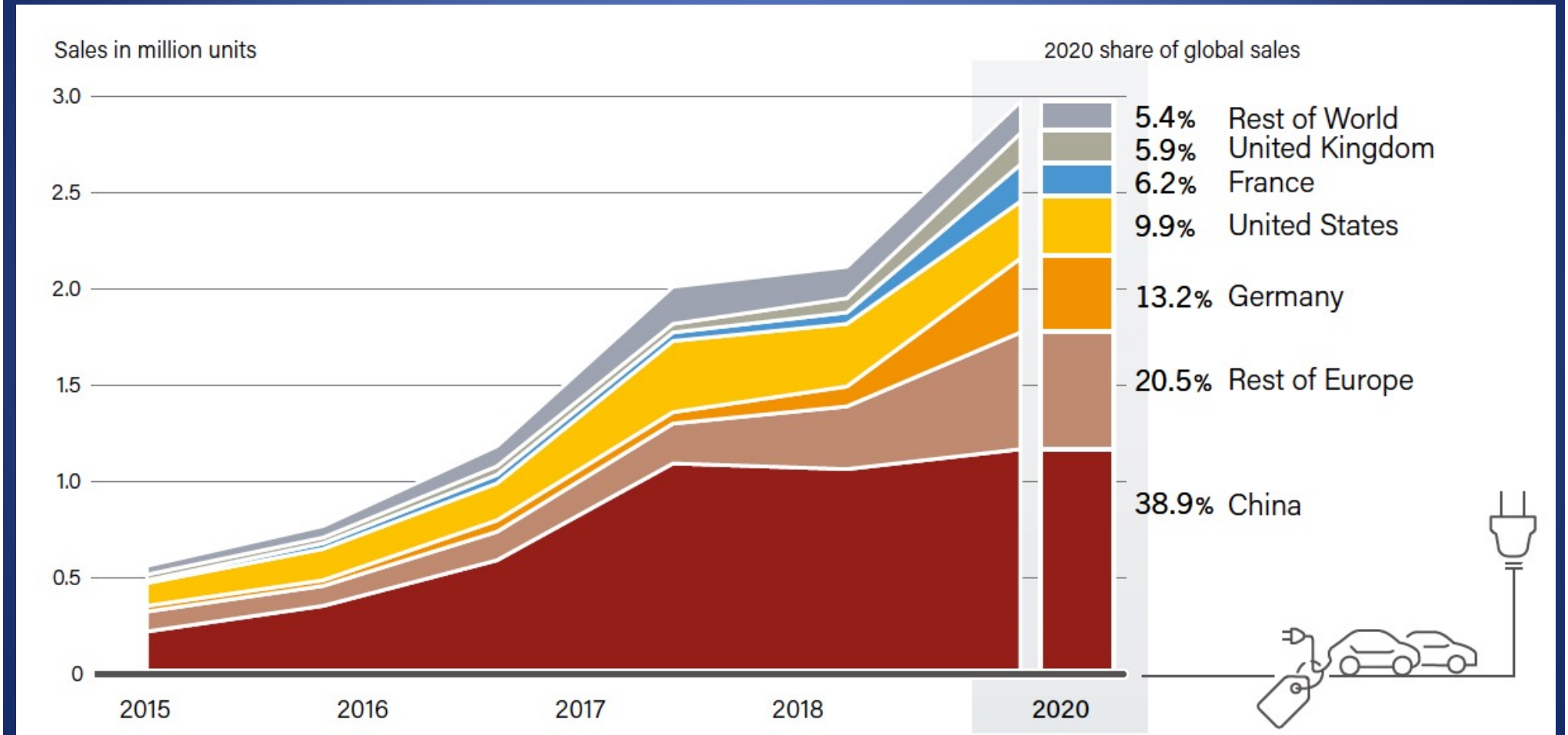
- Hydrogen – Fuel Cells



Prospects - Hot research areas

- Increase efficiency of various RE technologies
- Design renewable energy components at lower cost
- Extensive use of RES (many regions, even countries consider transformation into 100% renewables)
  - High shares of renewables
  - Power system transformation
  - Storage/integration (smart energy systems)
- Effective coupling not only for electricity but also heating + cooling and transportation

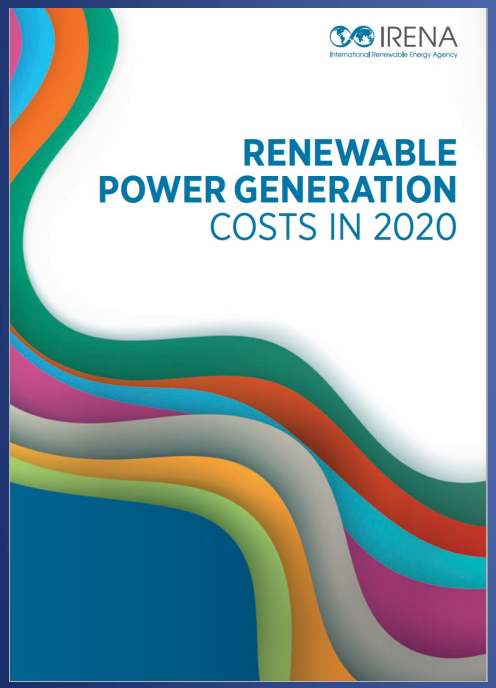
Electric Car Global Stock 2015-2020

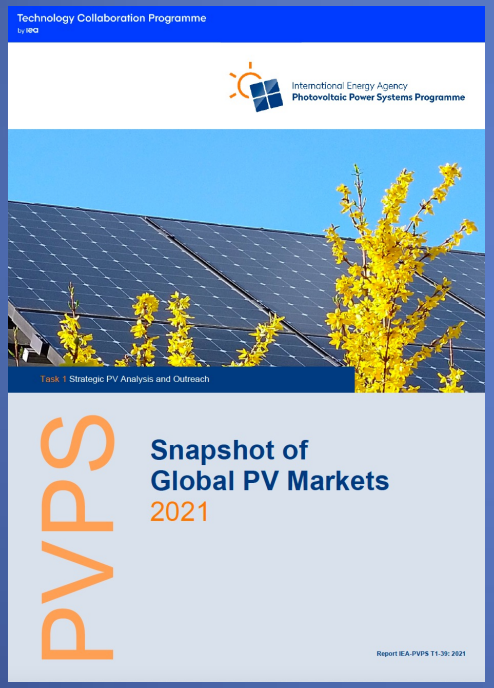


Source: Renewable 2021: Global Status Report, REN21

Acknowledgements

- Main reports used for this survey:





Concluding:

- → There are a lot of possibilities to utilise effectively renewable energy technologies
- → These are nowadays more cost-effective options than conventional fuels
- → We should never underestimate the climate problem
- → It is in our hands to utilise renewables effectively

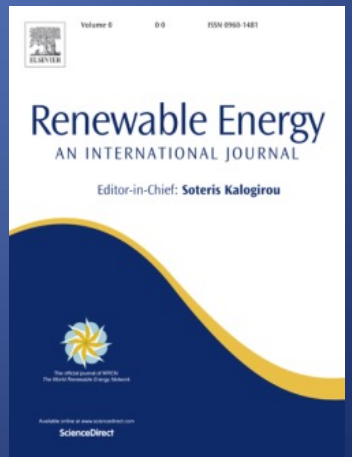
Thank you for your attention….

Soteris Kalogirou

email: soteris.kalogirou@cut.ac.cy

Cyprus University of Technology

Journal: RENE-Editor@cut.ac.cy



16th sdewes Conference DUBROVNIK 2021

Thank you for your attention

I will be happy to answer questions…

16th sdewes Conference DUBROVNIK 2021

Cyprus University of Technology