

# Renewable Energy Systems: Global status and Prospects

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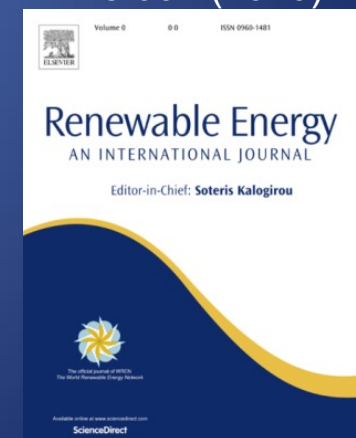
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IF 7.147 (2020)



IF 8.001 (2020)



# Outline

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



# Convincing Evidence

Melting polar ice caps



Melting polar ice caps



Melting polar ice caps



Hurricane Katrina



Coastal flooding - UK



Coastal flooding - UK



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



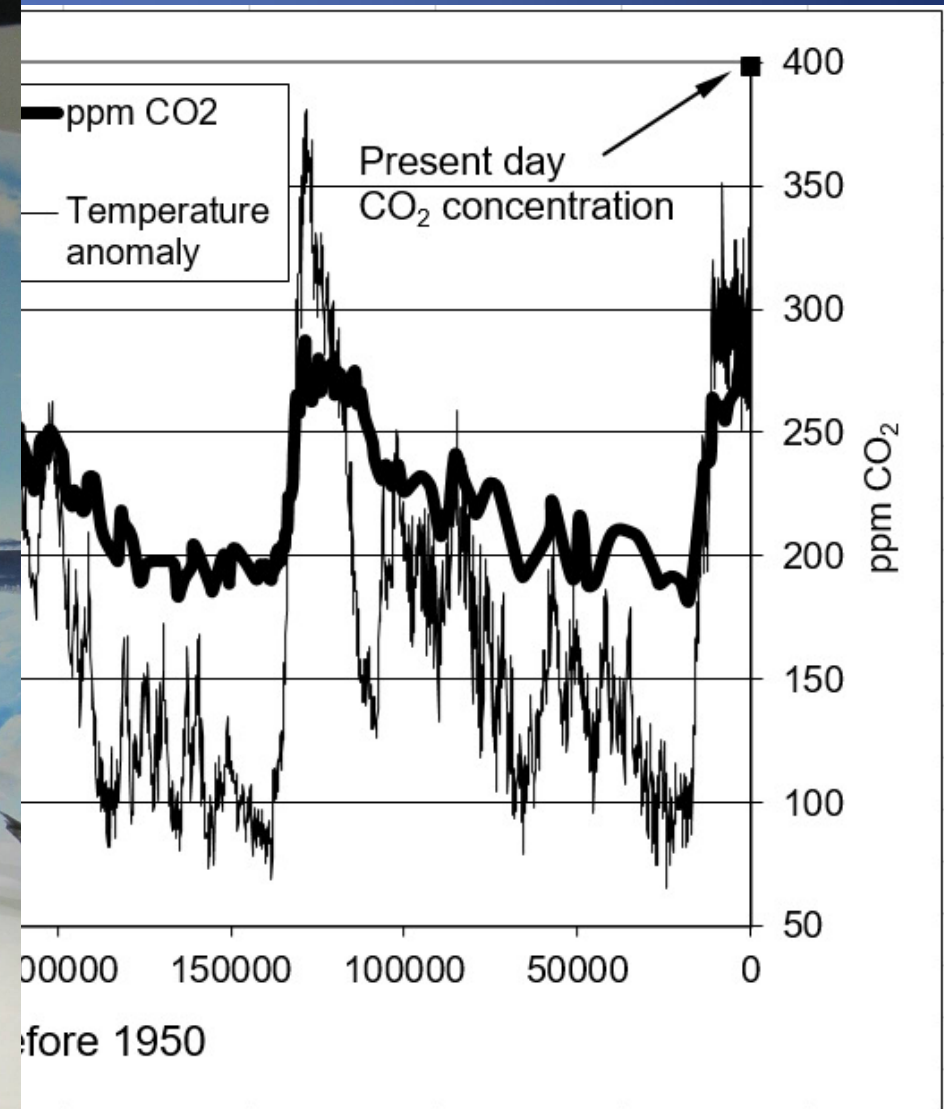
Flooding in India - 2020

## Climate refugees

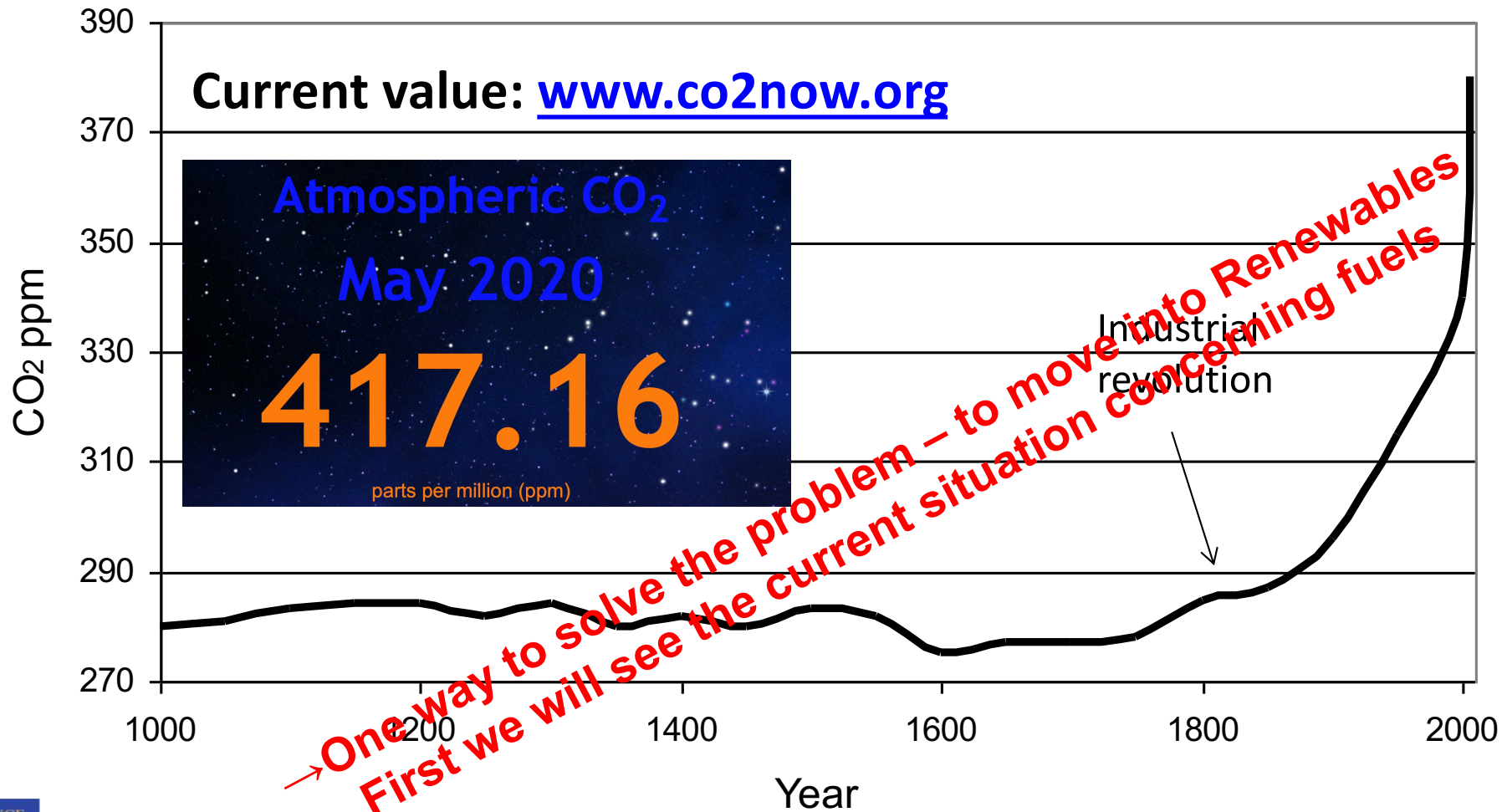


## Effect of Climate Change on India

# Temperature anomaly and CO<sub>2</sub> concentration From Vostok ice-cores (East Antarctica)



# CO<sub>2</sub> 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





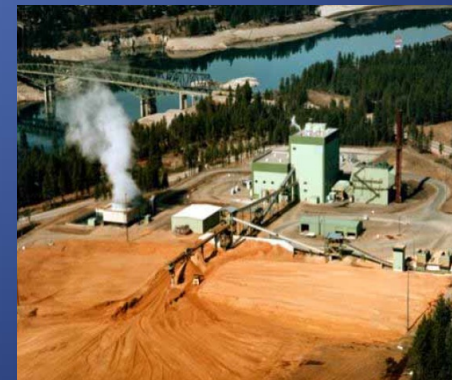
# Renewable Energy Systems

Solar power (solar thermal & PV)

Hydro systems














Wind energy systems



Biomass-Biogas-Biofuels



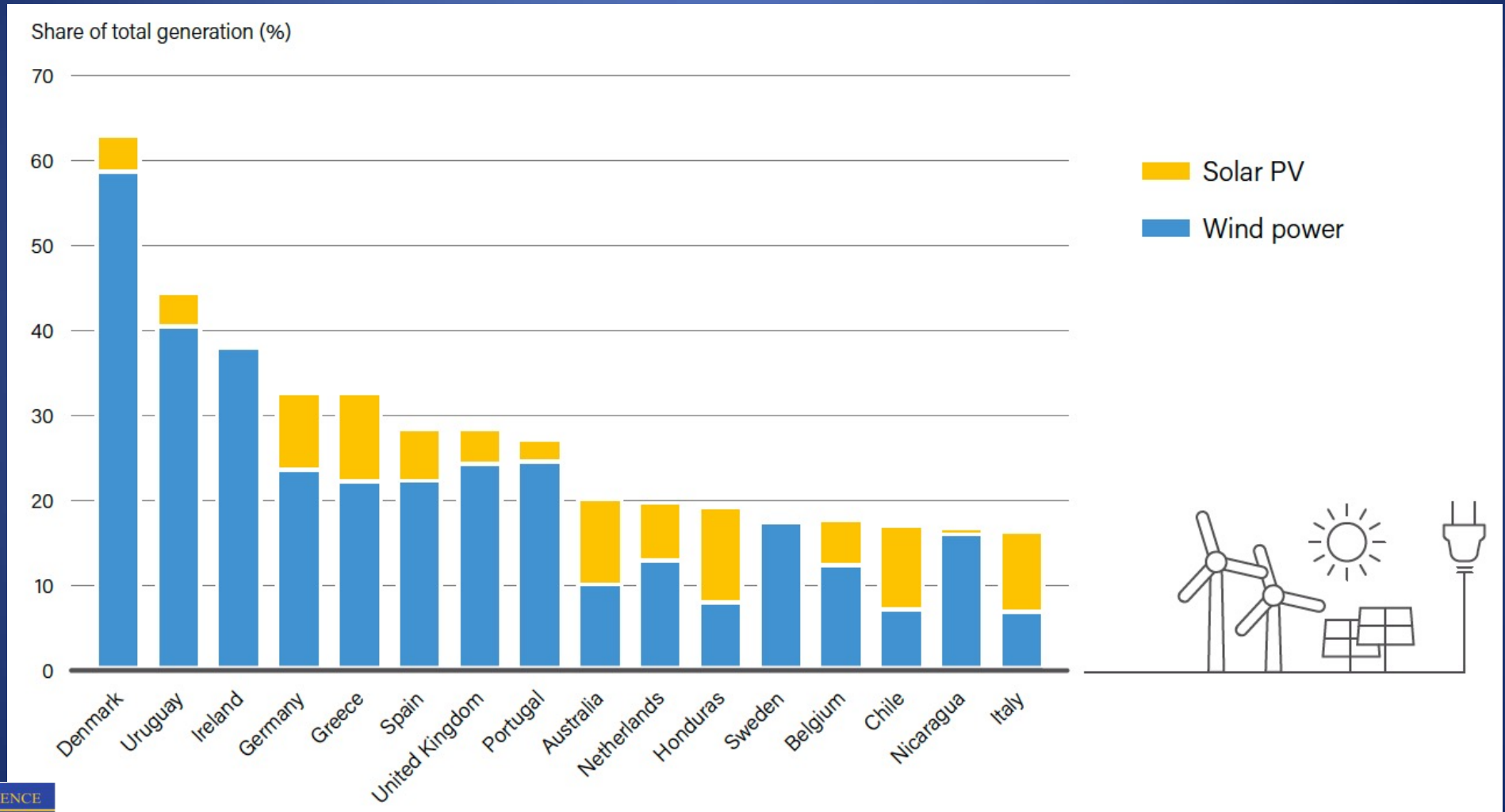


# Renewable Energy Indicators 2020

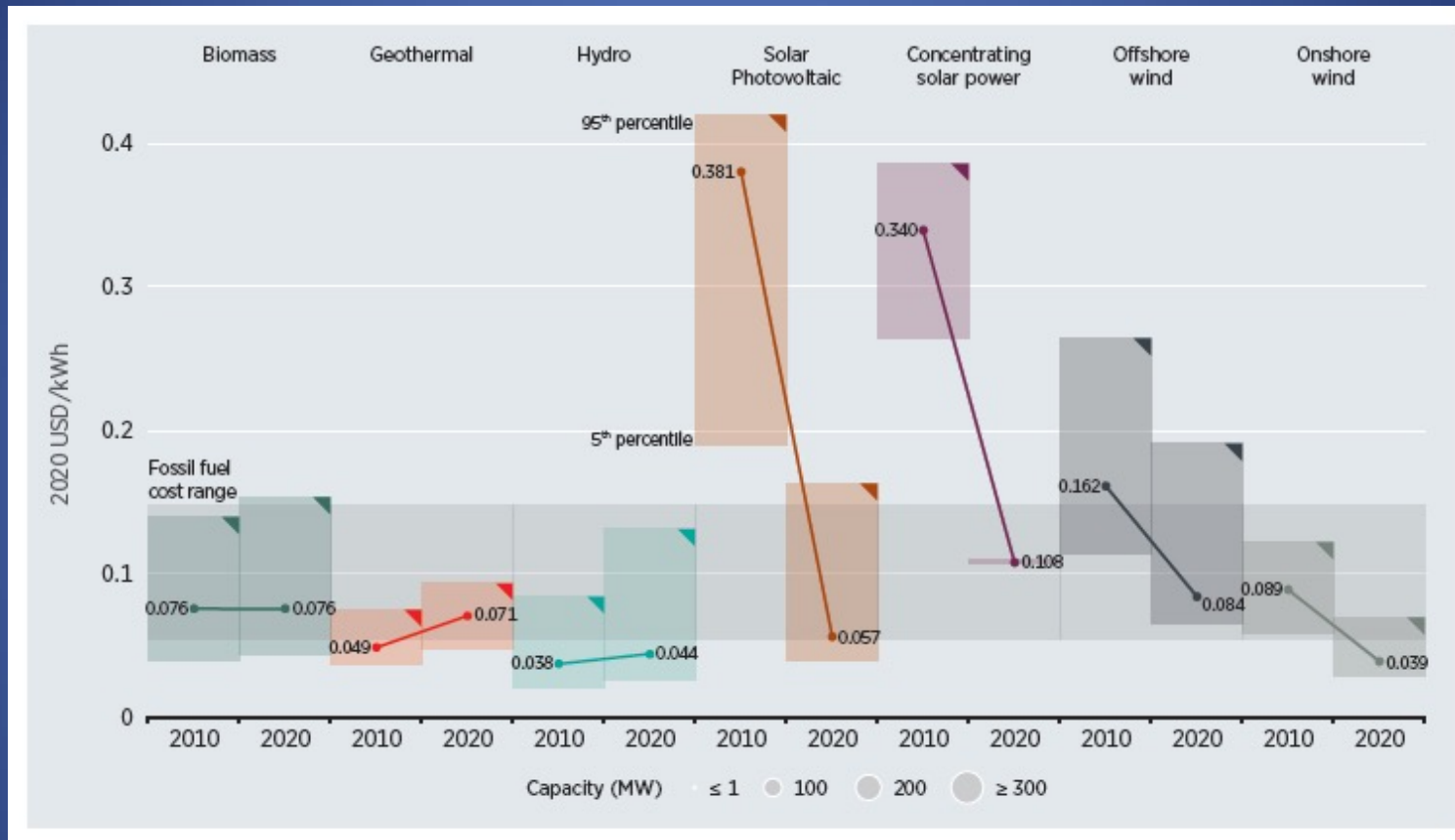
		2019	2020
<b>INVESTMENT</b>			
New investment (annual) in renewable power and fuels <sup>1</sup>	billion USD	298.4	<b>303.5</b>
<b>POWER</b>			
Renewable power capacity (including hydropower)	GW	2,581	<b>2,838</b>
Renewable power capacity (not including hydropower)	GW	1,430	<b>1,668</b>
 Hydropower capacity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

 **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

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



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

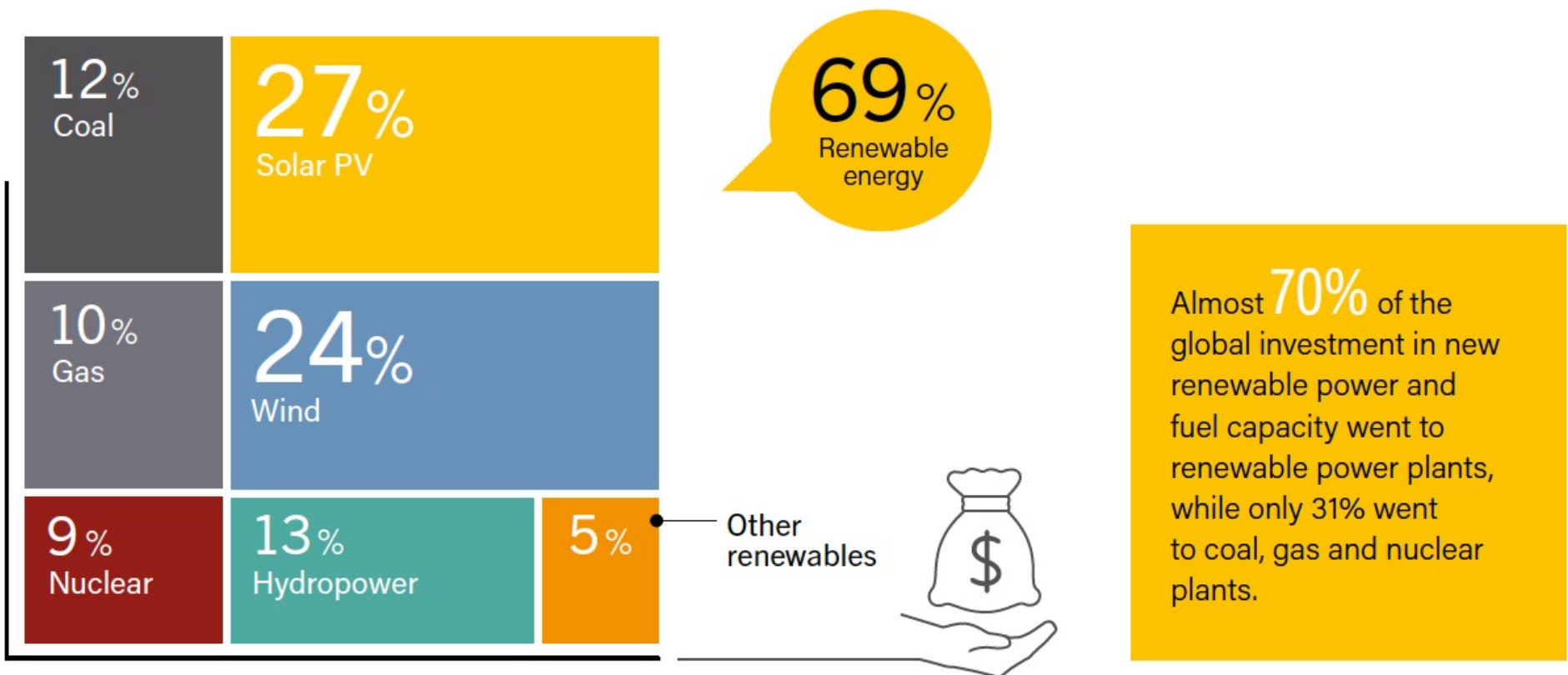


## Obstacles in RES penetration:

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 <sup>l</sup>
Thousand jobs						
 Solar PV	3,605 <sup>e</sup>	2,194	15.6	225	115 <sup>k</sup>	96
 Liquid biofuels	2,063	51	832 <sup>g</sup>	311 <sup>h</sup>	35	208
 Hydropower <sup>a</sup>	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 <sup>m</sup>
 Solid biomass <sup>b, c</sup>	787	186		79 <sup>i</sup>	58	387
 Biogas	334	145		7	85	67
 Geothermal energy <sup>b, d</sup>	94	2.5		35 <sup>j</sup>		23
 Concentrating solar thermal power (CSP)	34	11		5		5
<b>Total</b>	<b>10,983<sup>f</sup></b>	<b>4,078</b>	<b>1,125</b>	<b>855</b>	<b>719</b>	<b>1,235<sup>n</sup></b>

- 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

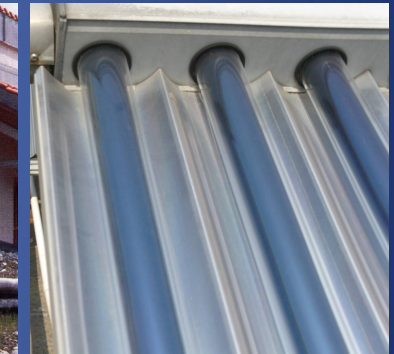


# Low temperature collectors

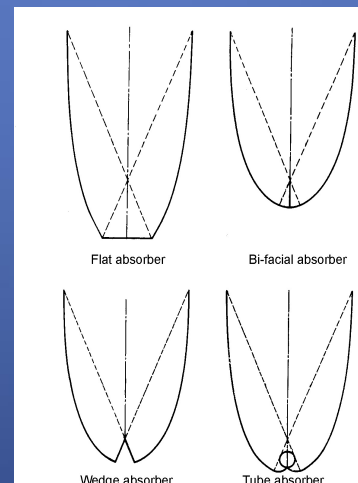
- Flat plate collectors



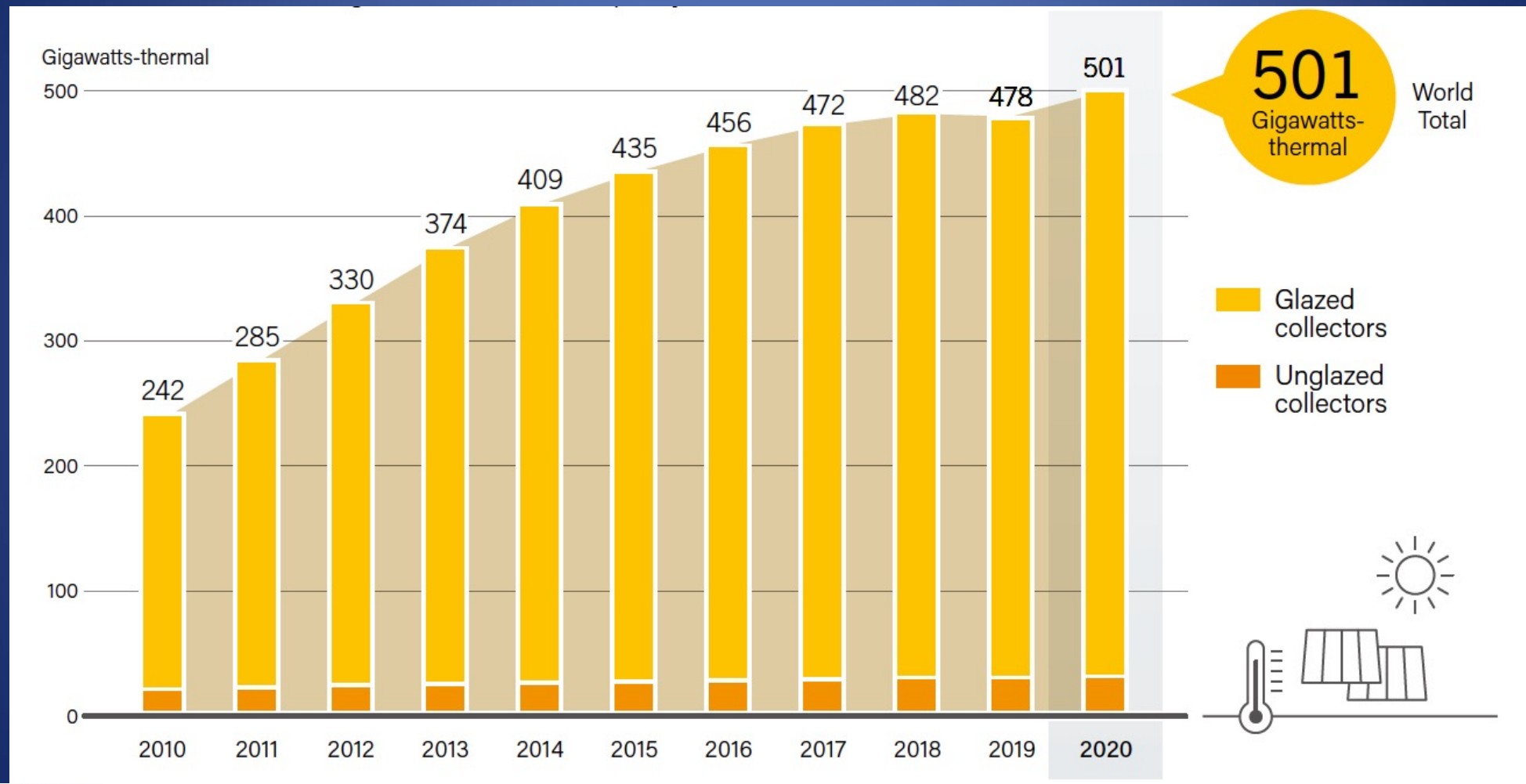
- Evacuated tube collectors



- Compound parabolic collectors



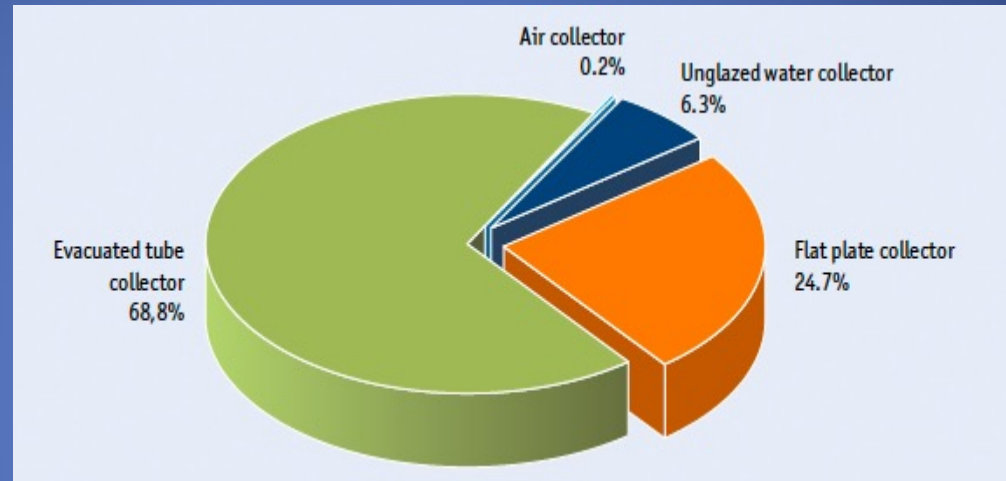
# Solar Water Heating Collectors Global Capacity, 2010–2020



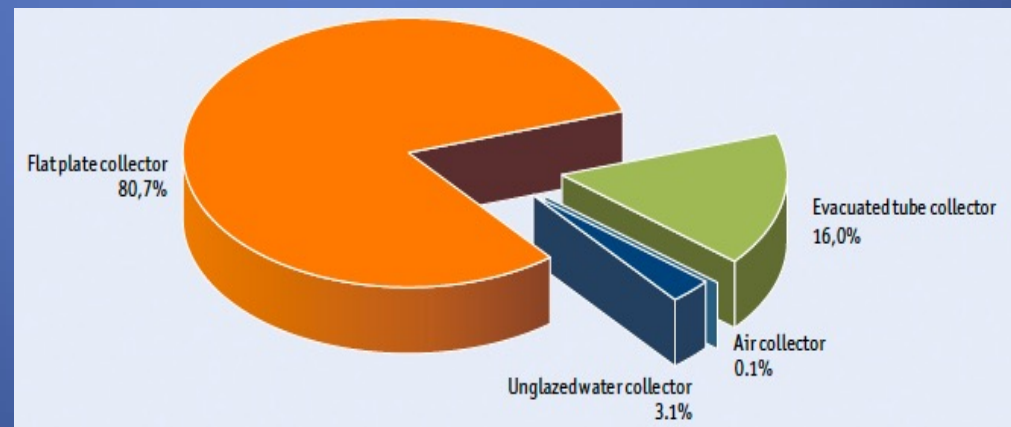


# Distribution of the total installed capacity in operation by collector type in 2020

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.
- 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.
- Vacuum insulation for flat-plate collectors.

# High temperature systems

- Parabolic trough collector



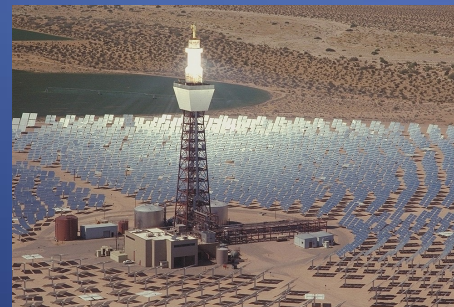
- Linear Fresnel collector



- Solar dish



- Solar tower

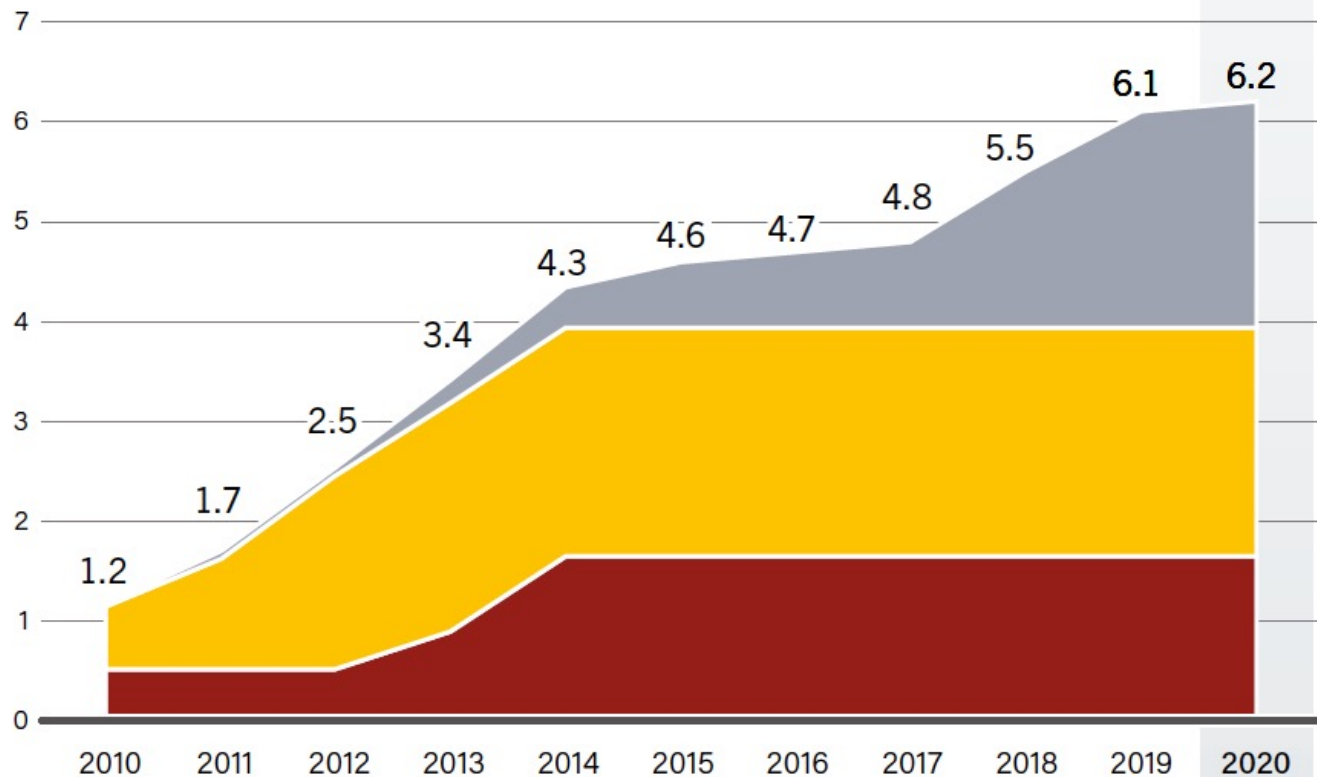


Solar Two

Gemasolar

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

Gigawatts



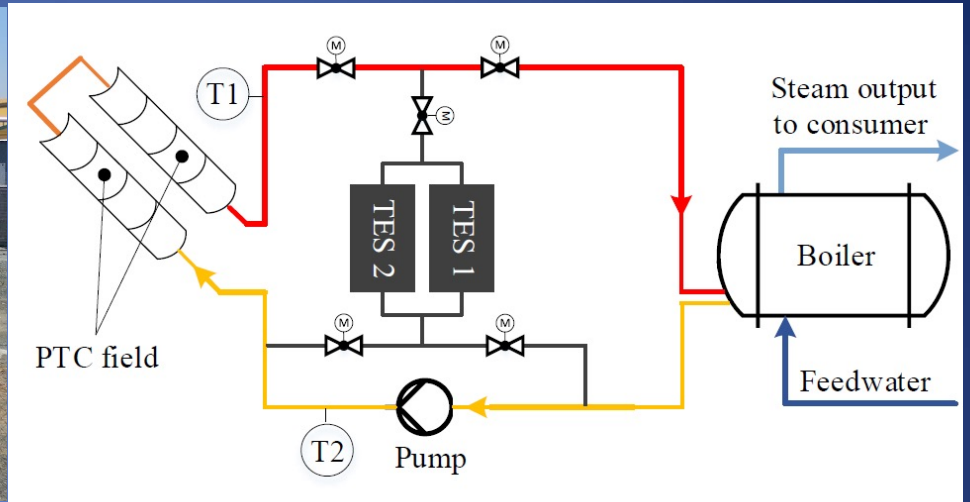
**China**  
was the only country to add new CSP capacity in 2020.

Rest of World  
Spain  
United States



- Many CSP systems are under development in many countries of the world
- All new facilities incorporate thermal ENERGY STORAGE

# Industrial Process Heat-Solar Juice



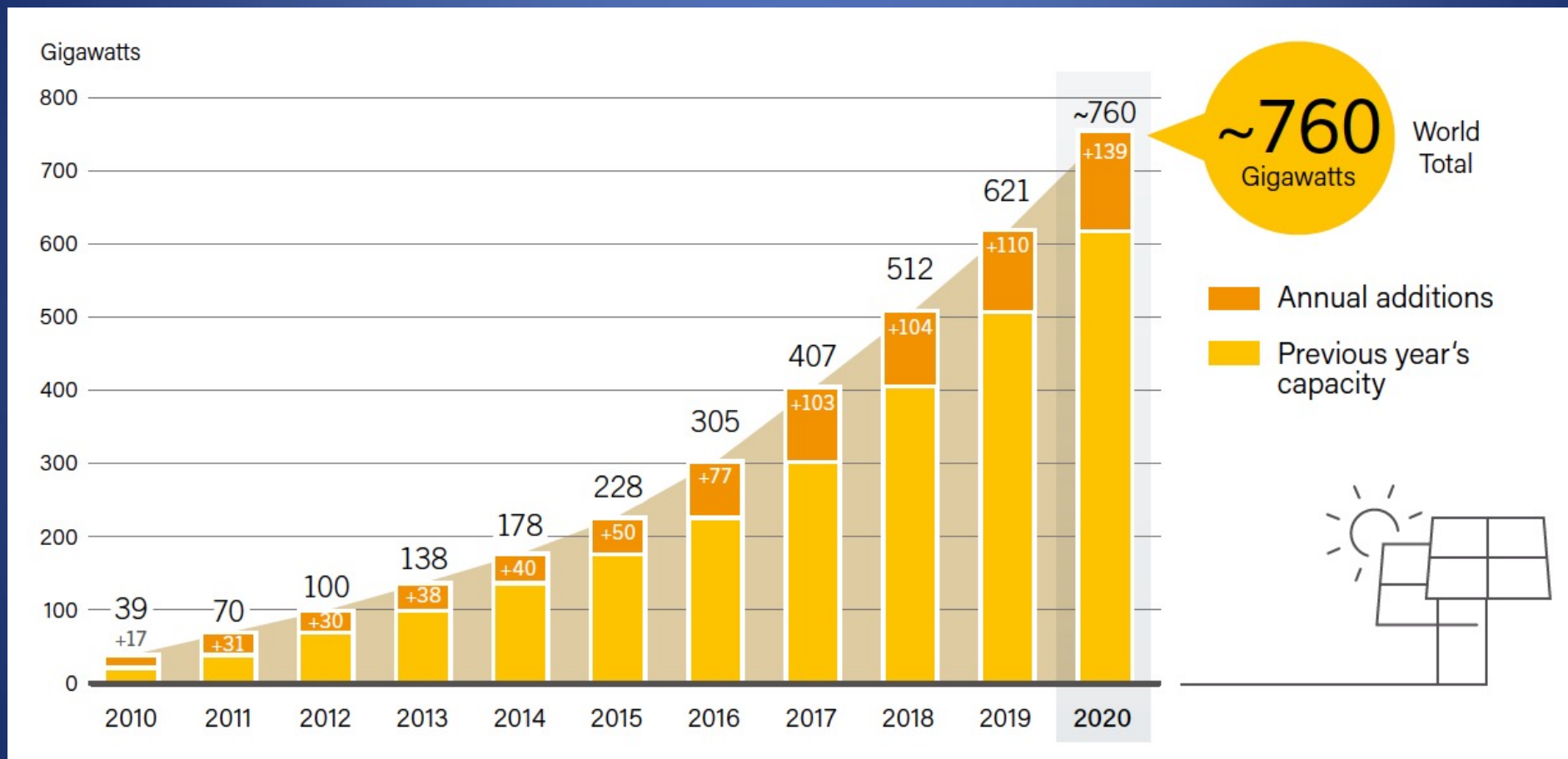
Storage and plantroom containers

Concrete storage

ks

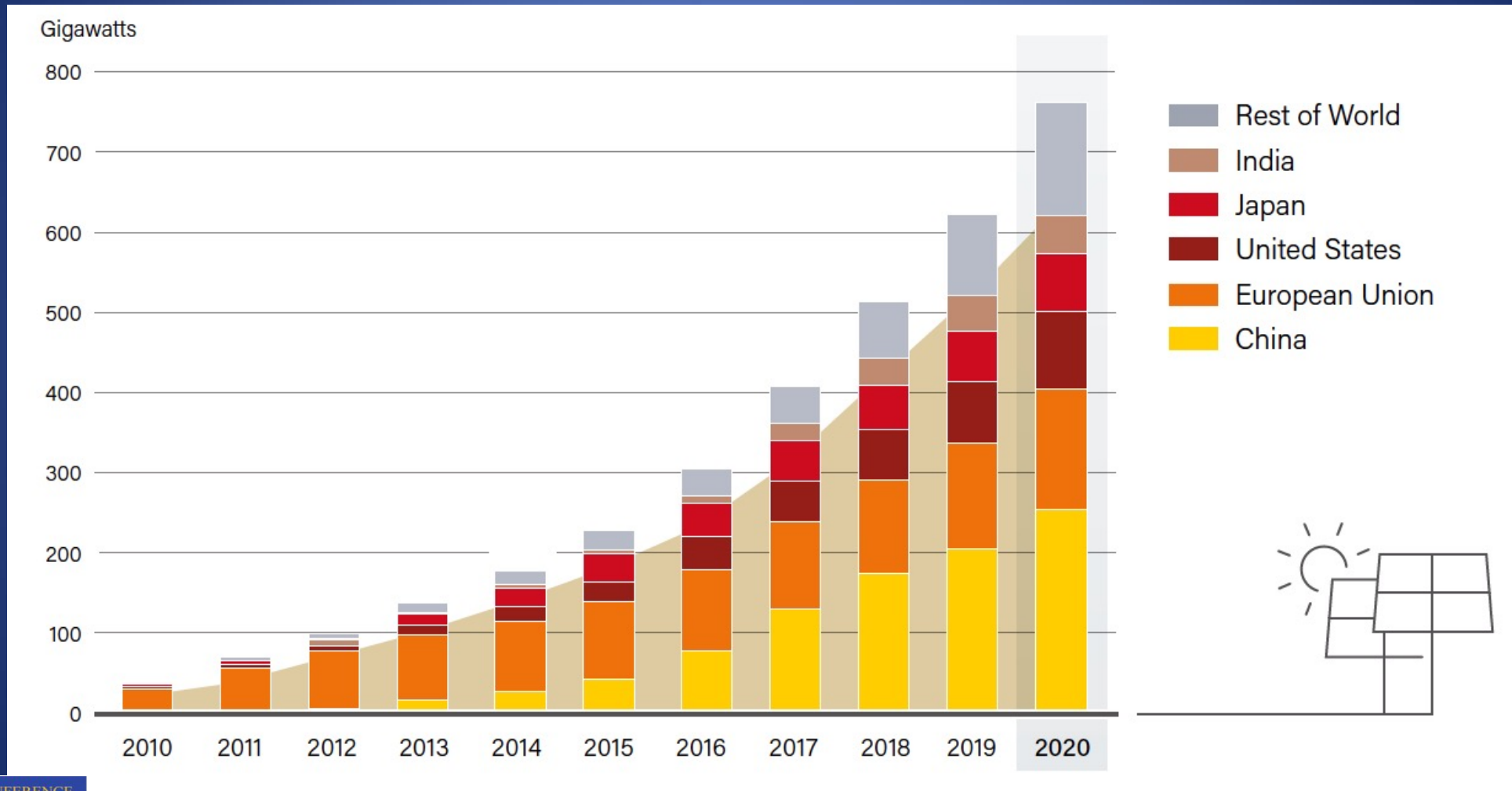


# Solar PV Global Capacity and Annual Additions, 2010-2020

























→ 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.

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





# 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

## 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<sup>2</sup>

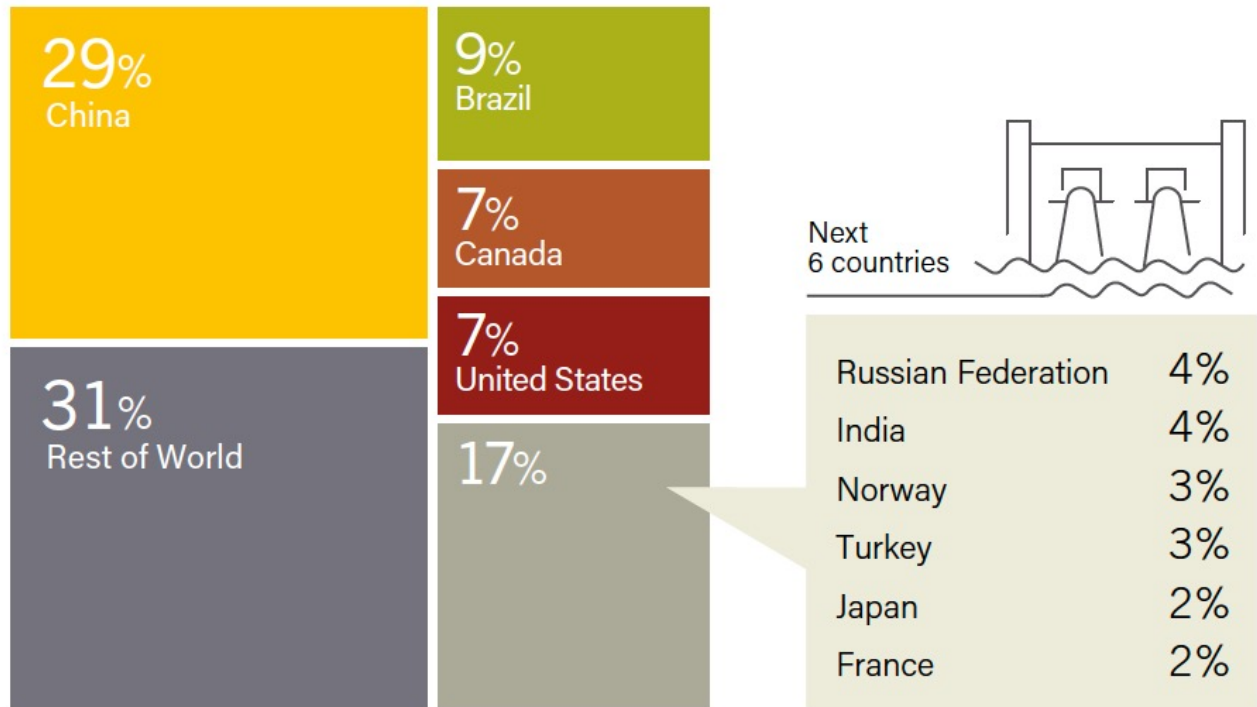


# Hydro Power

- 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)...

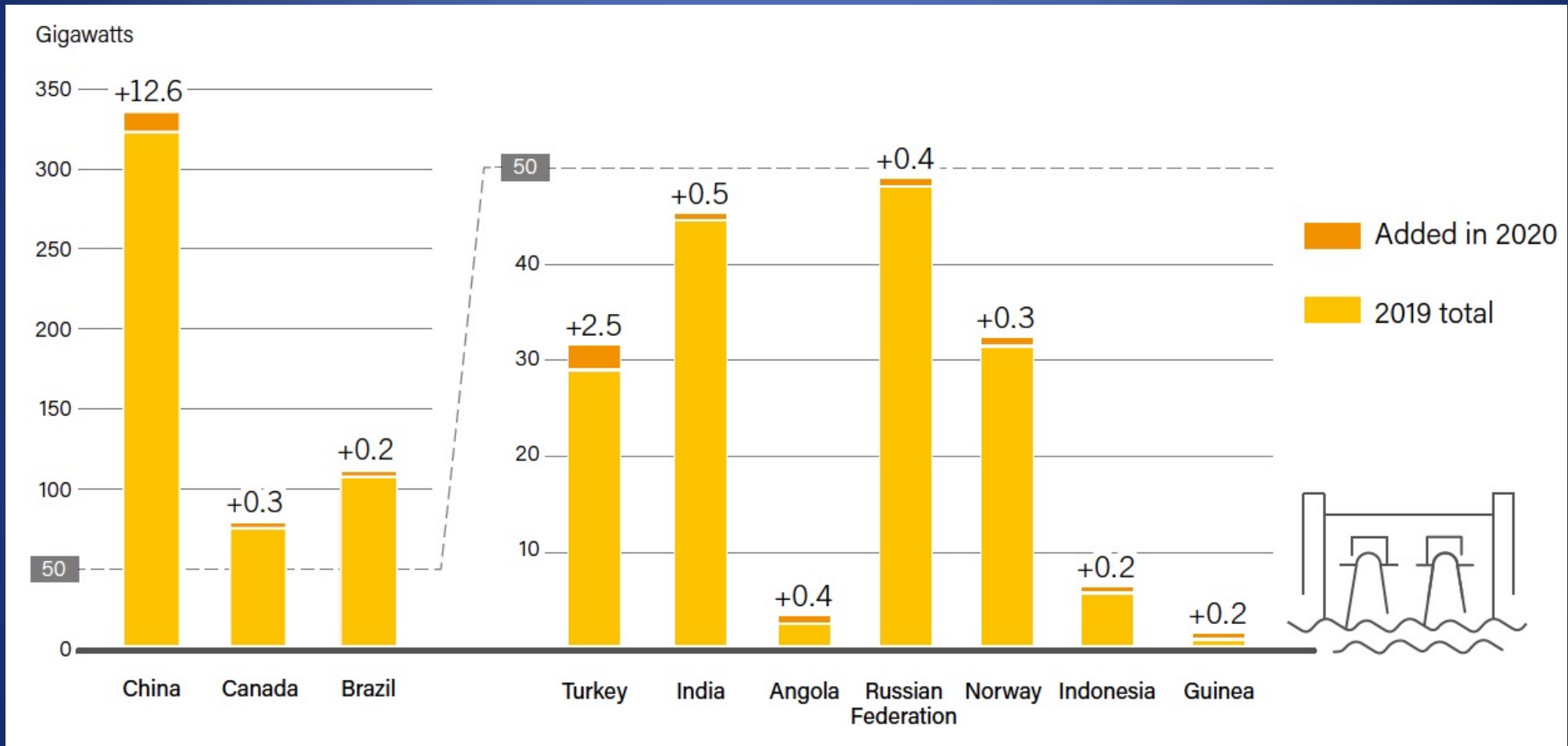


# Hydropower Global Capacity



Source: Renewable 2021: Global Status Report, REN21

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

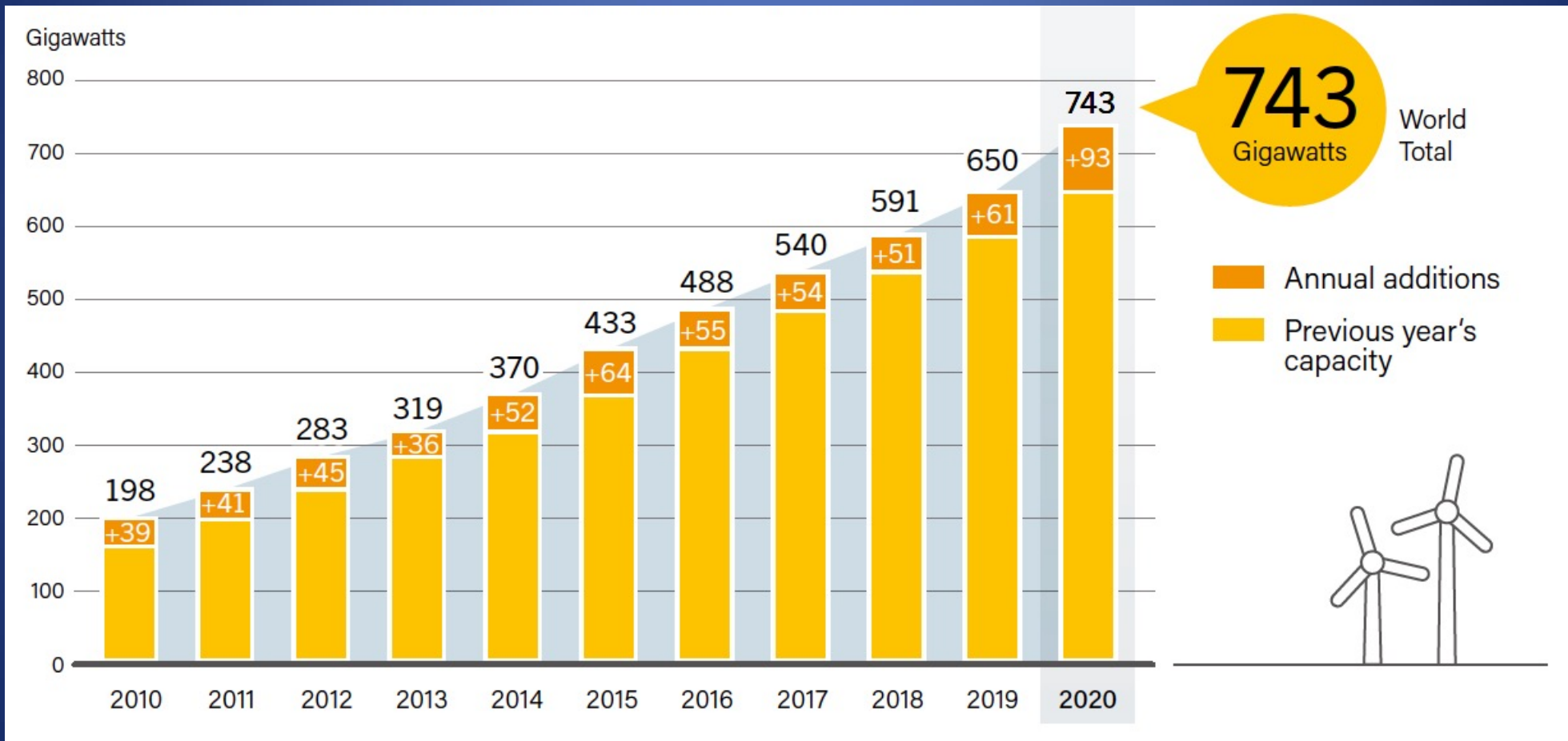


# Wind Power

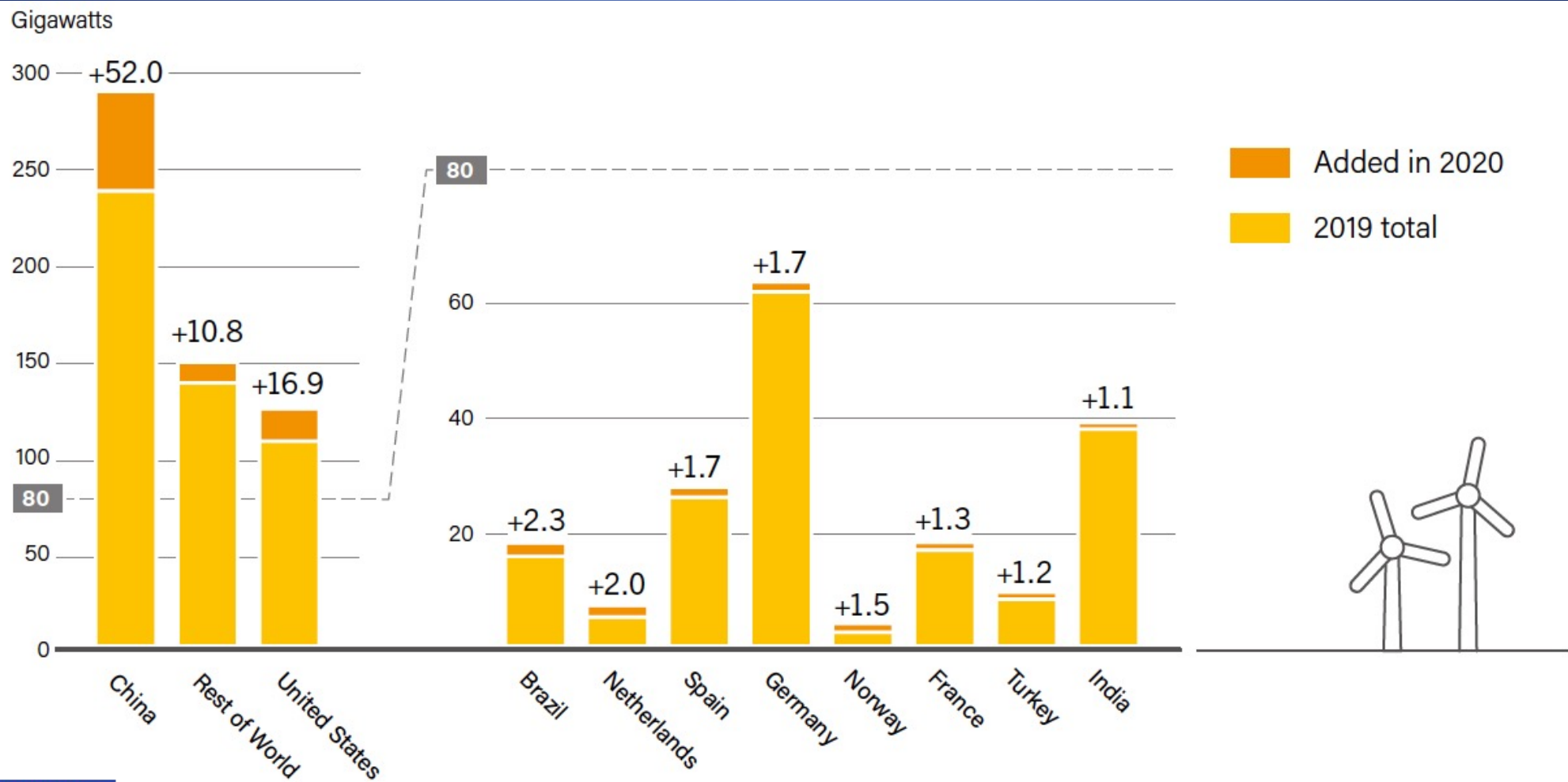




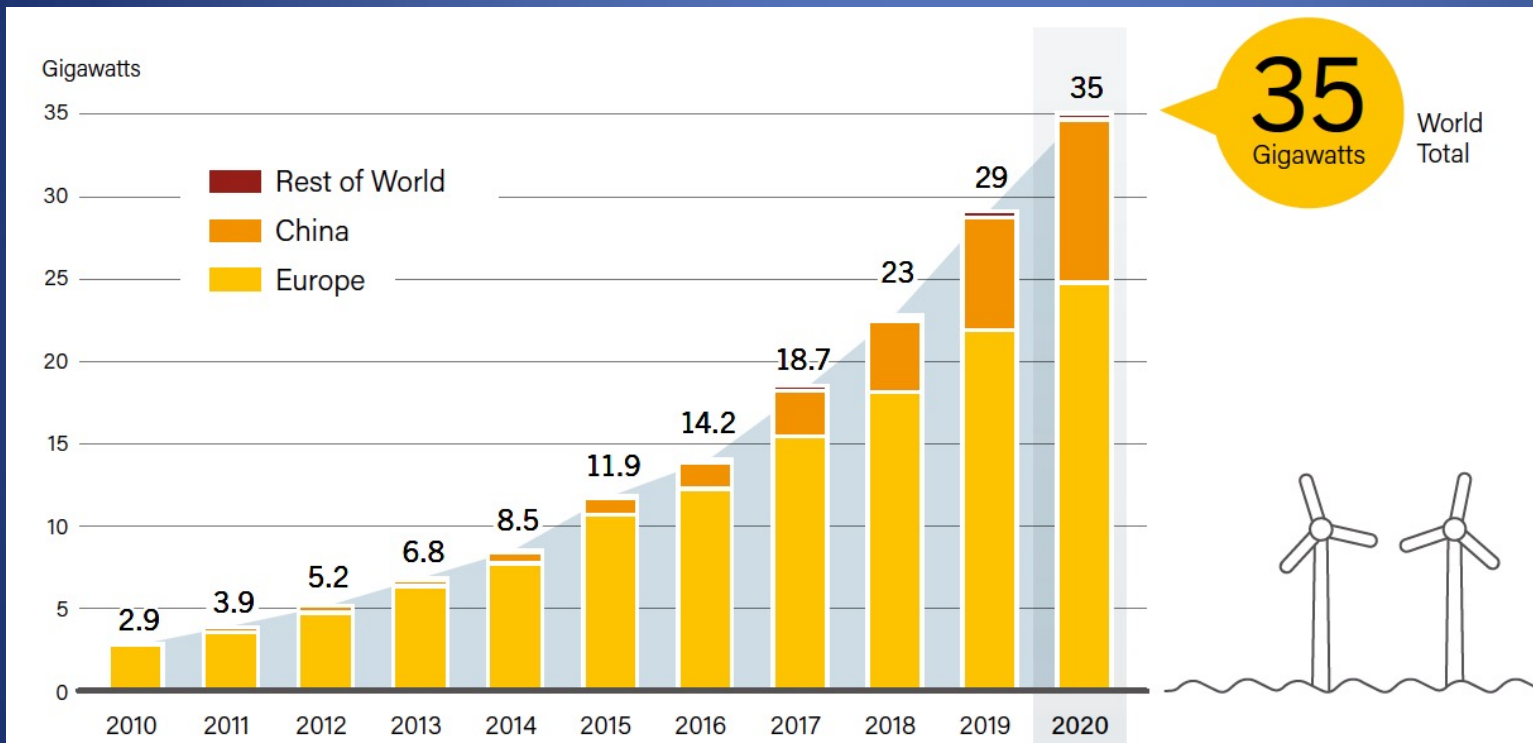
# Wind Power Global Capacity and Annual Additions, 2010–2020



# Wind Power Capacity and Additions, Top 10 Countries, 2020



# 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.

# Biomass

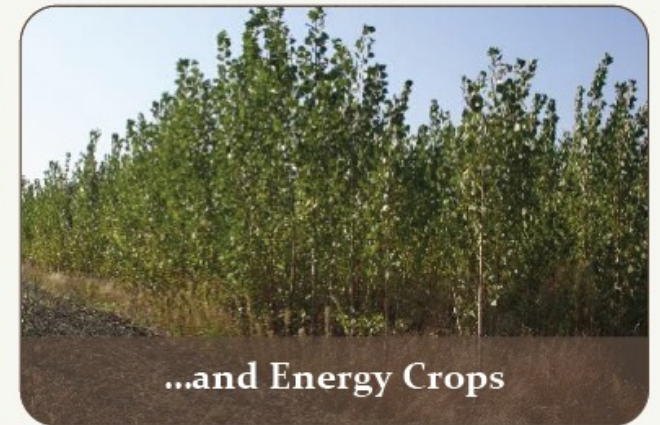
- Main areas:
  - Biomass
  - Biogas
  - Biofuels (biodiesel)
  - Waste (MSW, landfills [?])



Supplying Renewable Energy...

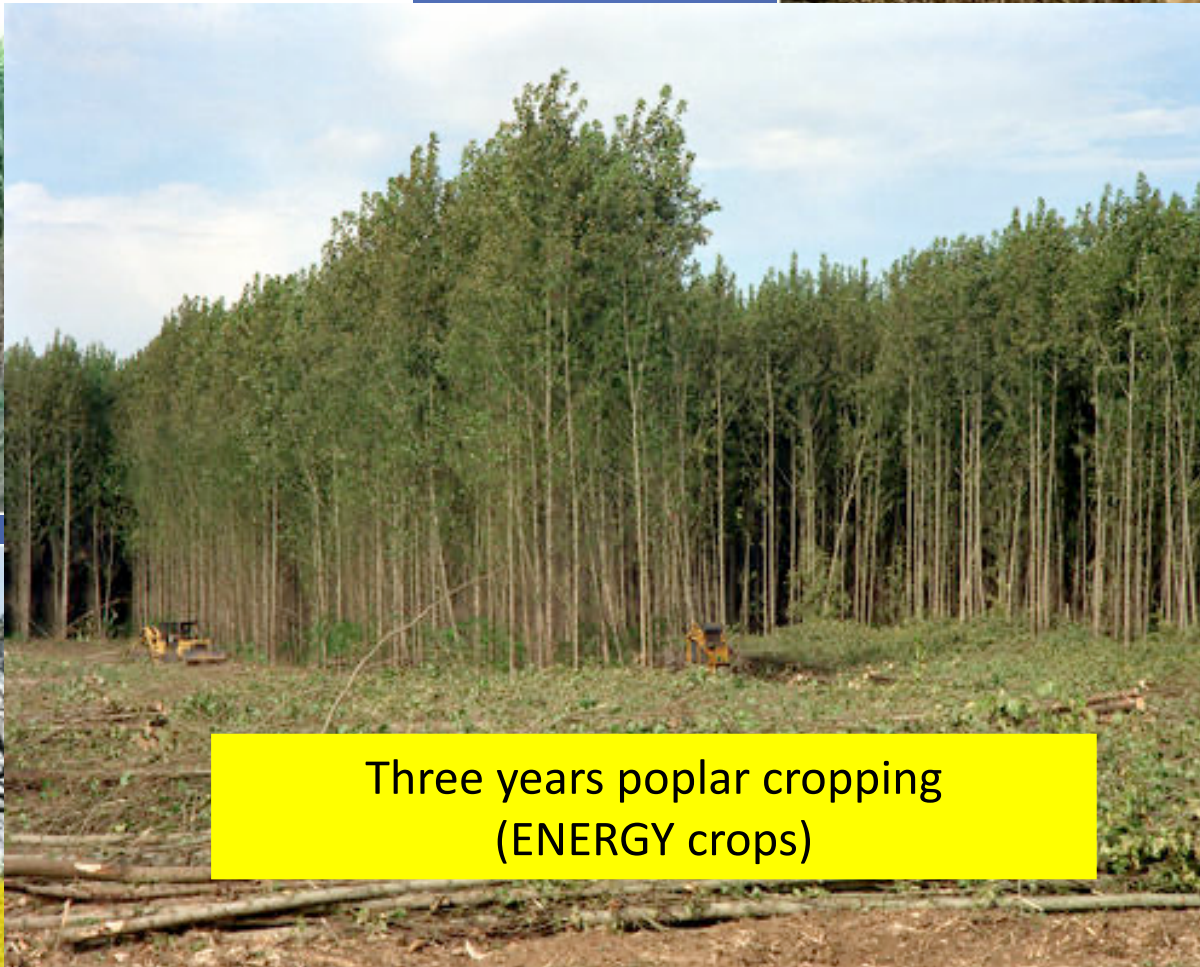


...from Forest Residues...



...and Energy Crops

# Biomass – Question food for fuel?



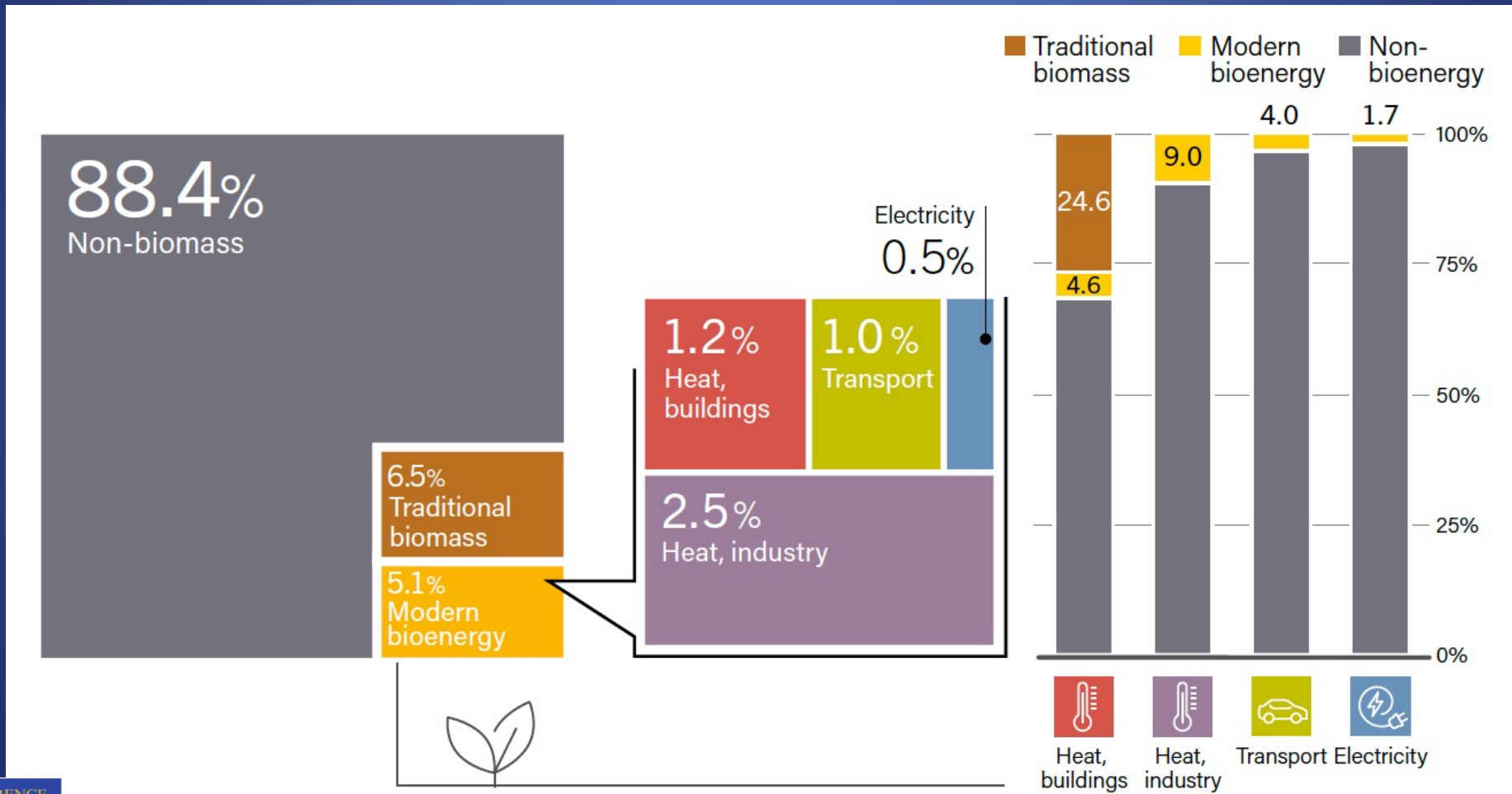
Three years poplar cropping  
(ENERGY crops)



**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**

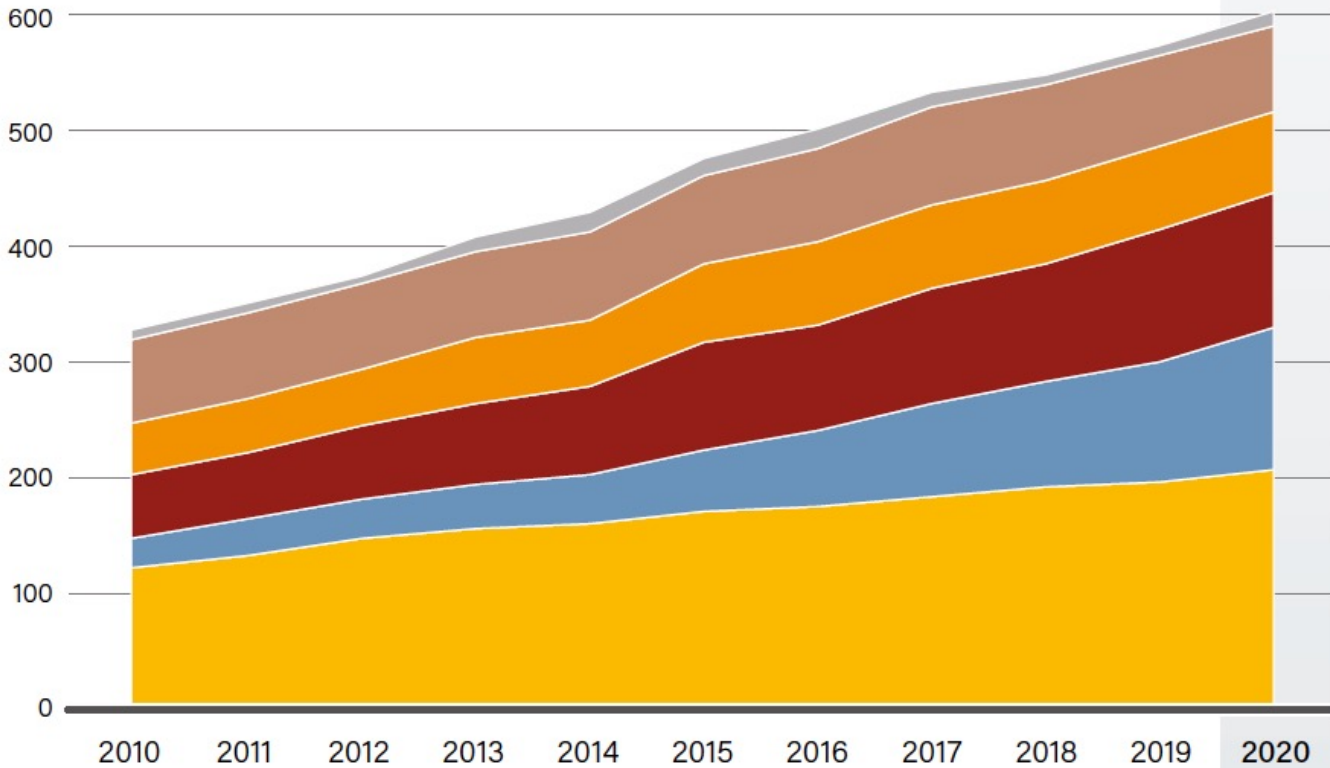


# Shares of Bioenergy in Total Final Energy Consumption, Overall and by end-use sector, 2019



# Global Bioelectricity Generation, by Region, 2010-2020

Terawatt-hours



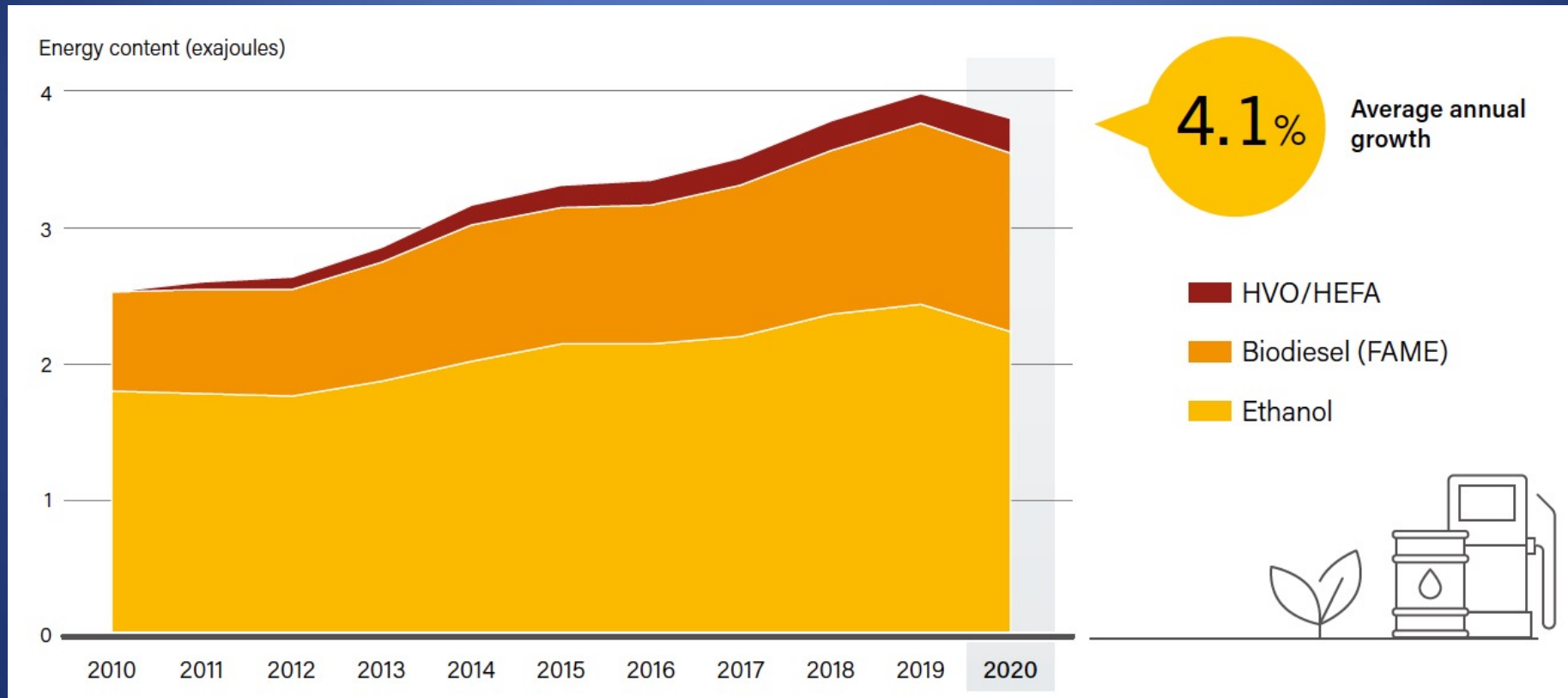
**6.3%** Average annual growth

- Rest of World
- South America
- North America
- Rest of Asia
- China
- EU-28



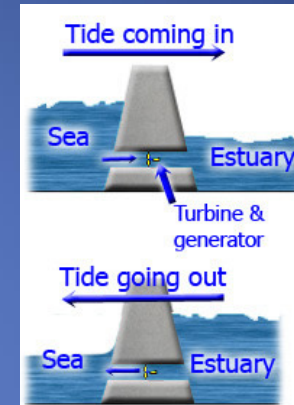


# Global trends in ethanol, biodiesel and HVO production 2010-2020

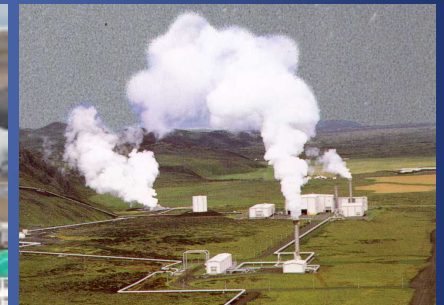
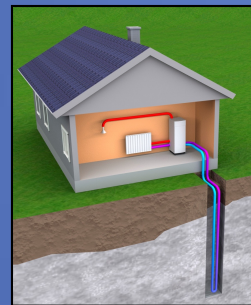


# Other areas of renewables

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

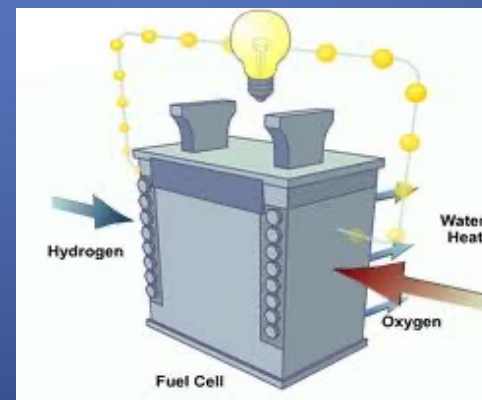


- Geothermal



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

- Hydrogen – Fuel Cells

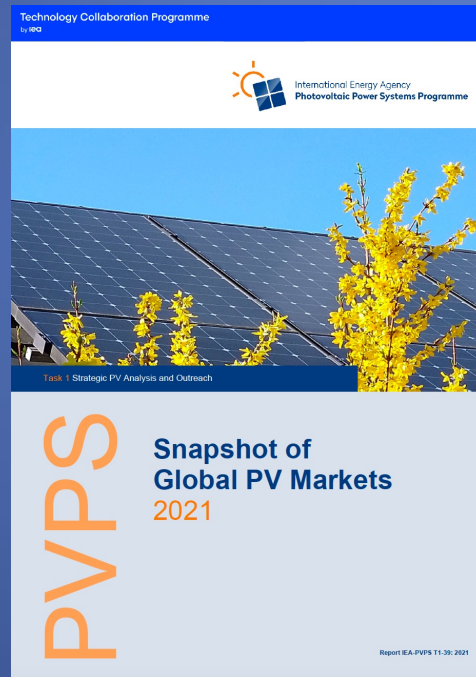
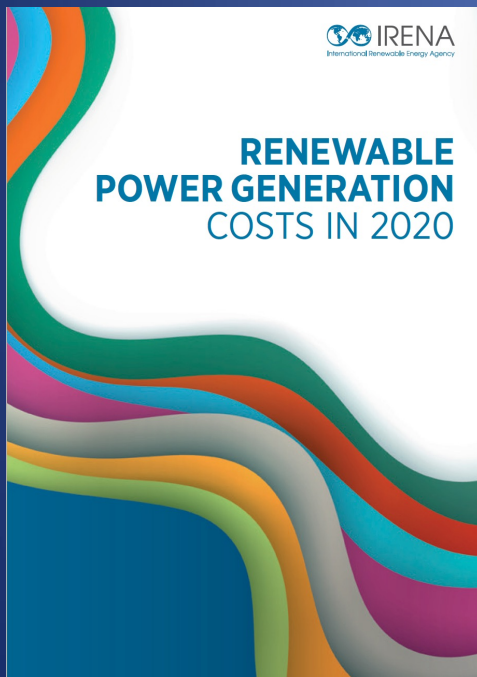


# Prospects - Hot research areas

- 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

# 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



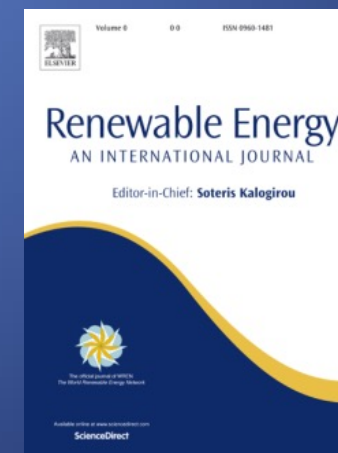
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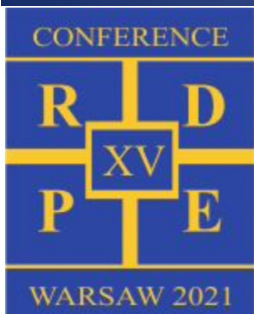


Thank you for your attention....

# Thank you for your attention



## I will be happy to answer questions...



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