RENEWABLE ENERGY TECHNOLOGIES

PART I: TECHNICAL FUNDAMENTALS

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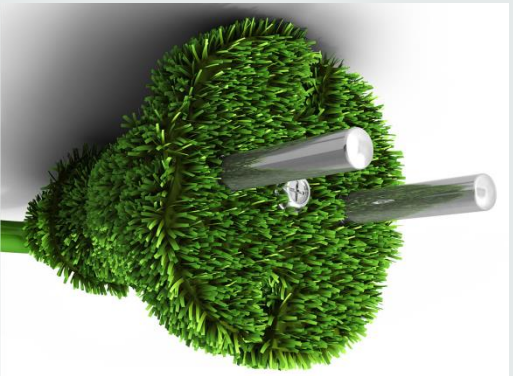
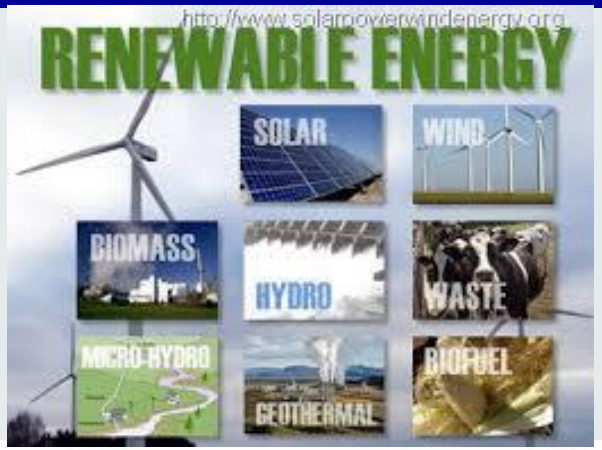
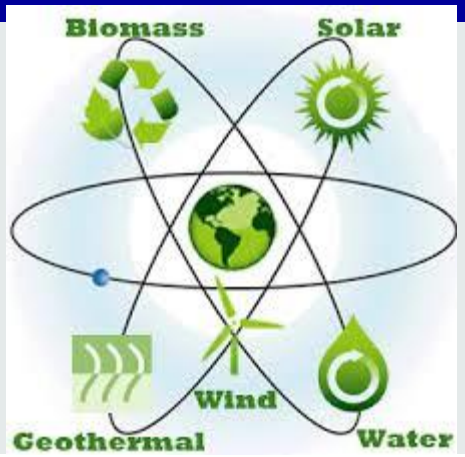
OCTOBER 12, 2015







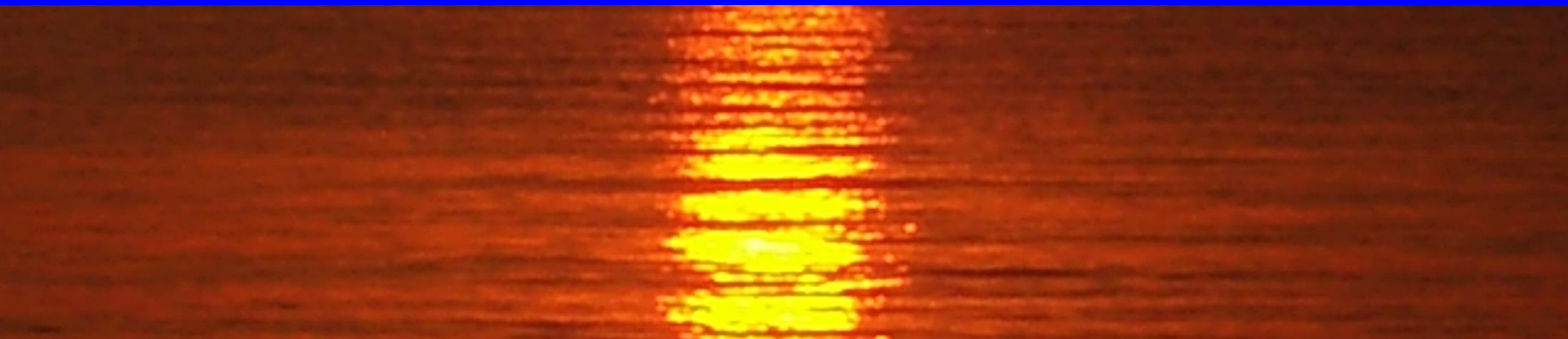
RTU

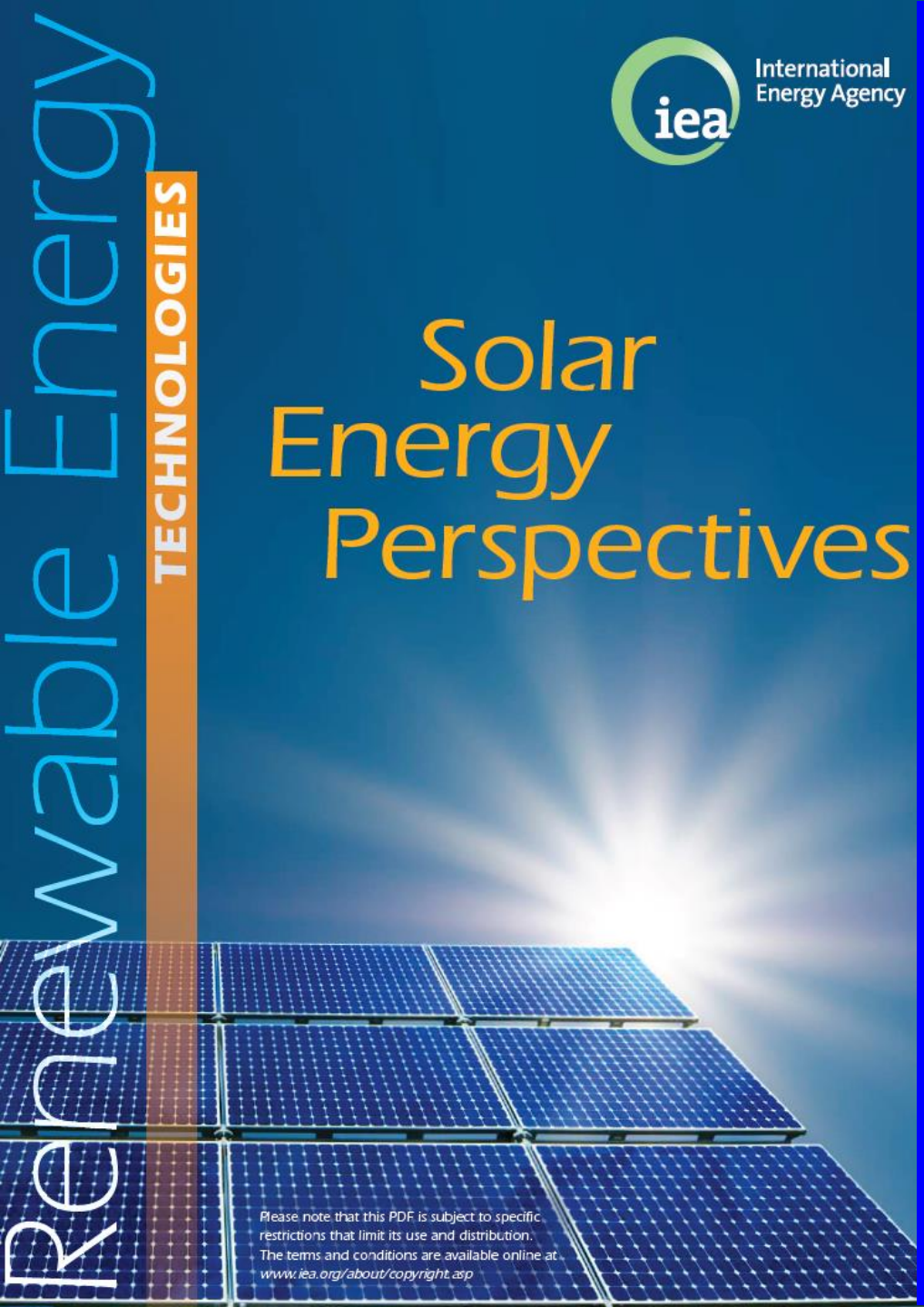
RTU VASSI

Baltic-American Freedom Foundation

ASU Ira A. Fulton Schools of Engineering
ARIZONA STATE UNIVERSITY

“The sun will be the Fuel of the Future”
Anonymous, 1876, *Popular Science*

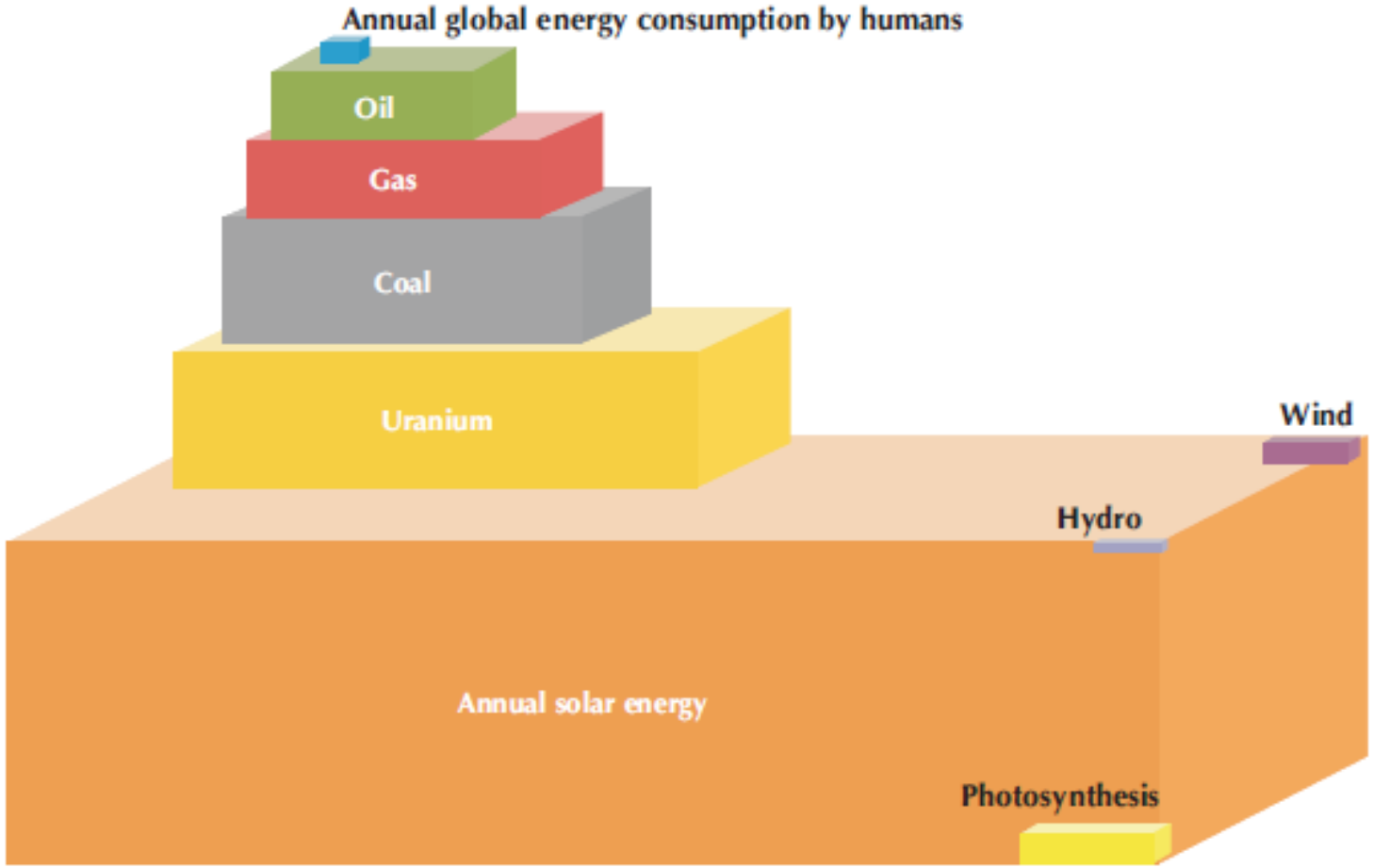




- In 90 minutes, enough sunlight strikes the earth to provide the entire planet's energy needs for one year.
- While solar energy is abundant, it represents a tiny fraction of the world's current energy mix.
- This is changing rapidly & is being driven by global action to improve energy access and supply security, and to mitigate climate change.

Total Energy Resources

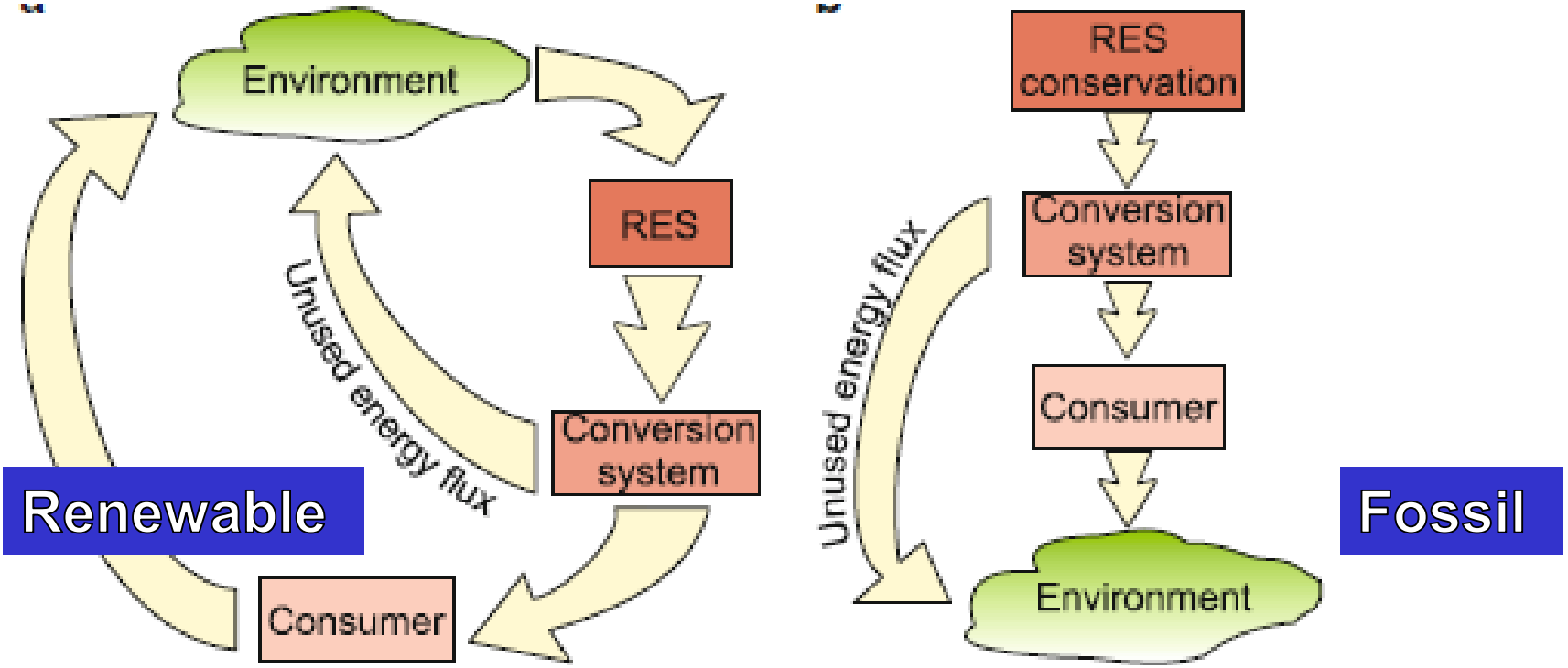
- Solar Energy is the largest Energy Resource and it is inexhaustible



Source: National Petroleum Council, 2007, after Craig, Cunningham and Saigo (republished from IEA, 2008b).

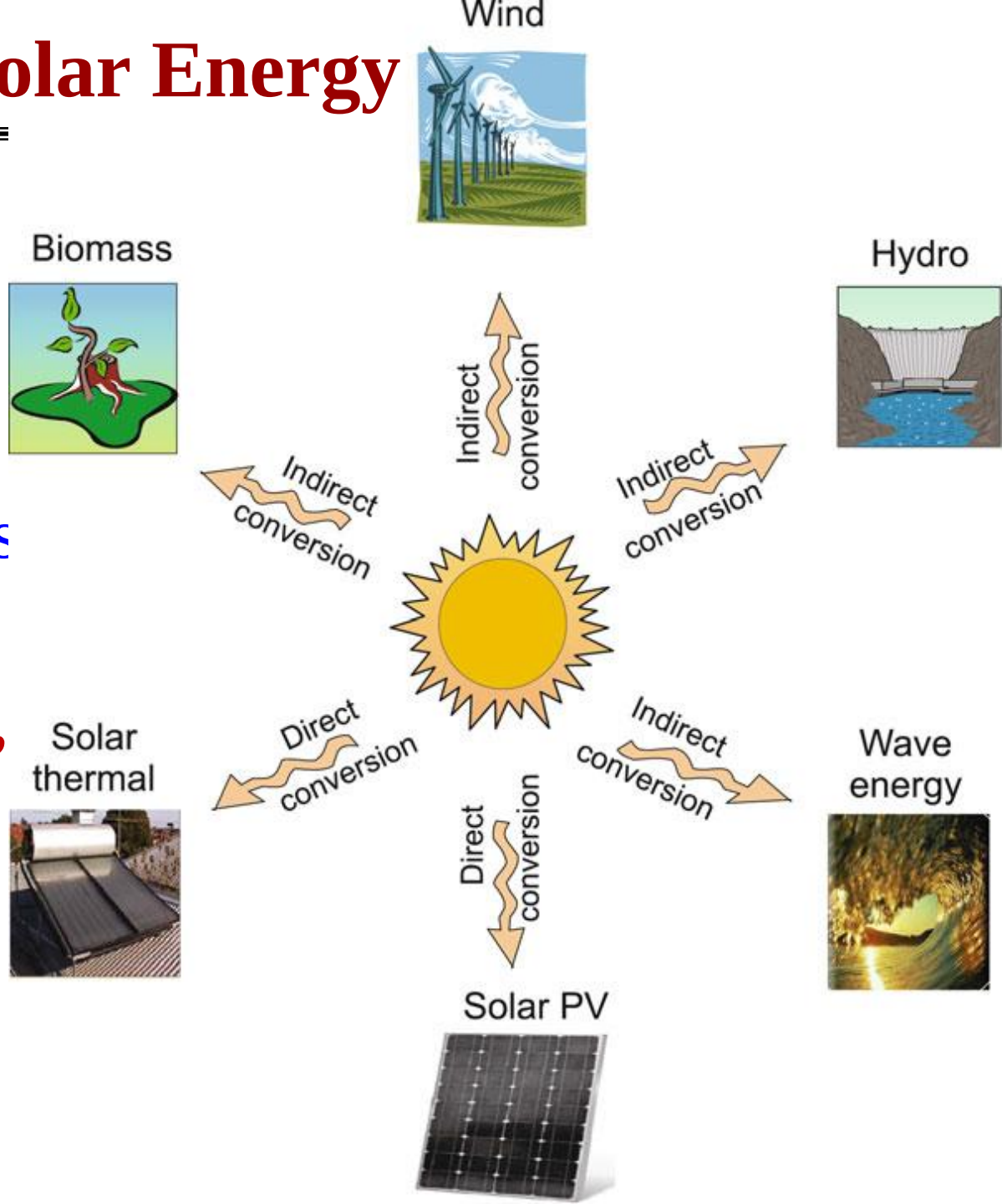
Energy Fluxes Circulation

- **Renewable energy flux has a closed character while the fossil energy has an open character.**
- In the case of RES use the energy flux generated by the environment is transformed with the help of conversion unit into another form of energy necessary for the consumer. Then it reverses in the same environment and its thermal balance remains unvaried.



Main Forms of Solar Energy

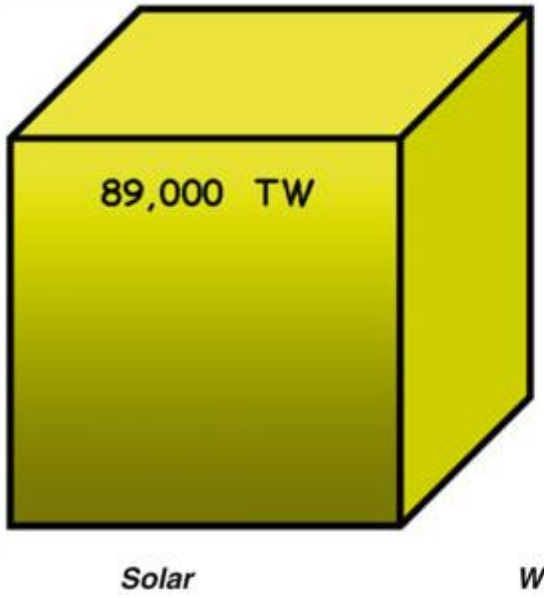
- Depending on the origin, RES are divided into groups include **Solar energy** & its derivatives –
- **Wind, Hydraulic, Biomass energy, Tide energy, Thermal energy** of the planet's ocean.

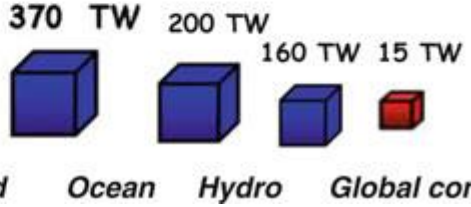


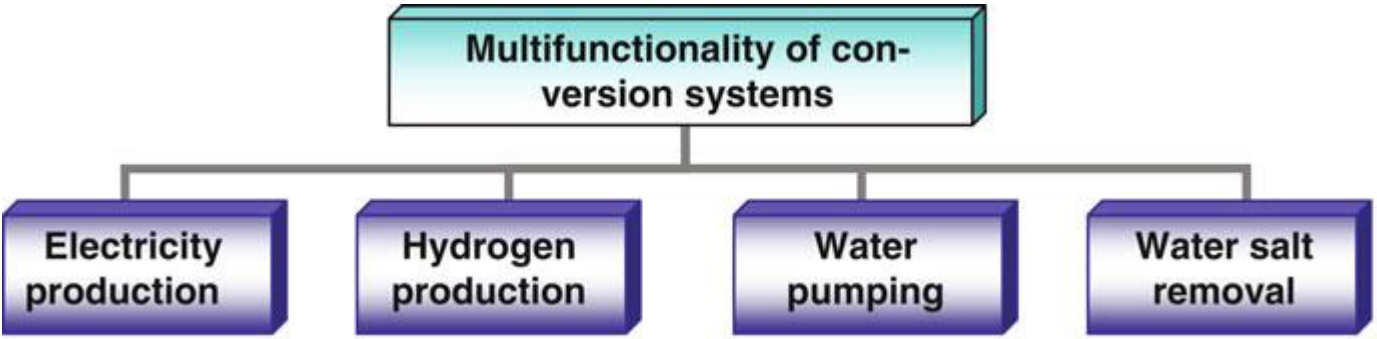
Renewable Energy Sources

- RES are "*energy of the future*".
- World reserves of renewable energy are enormous.
- But, only part of this energy can be converted.

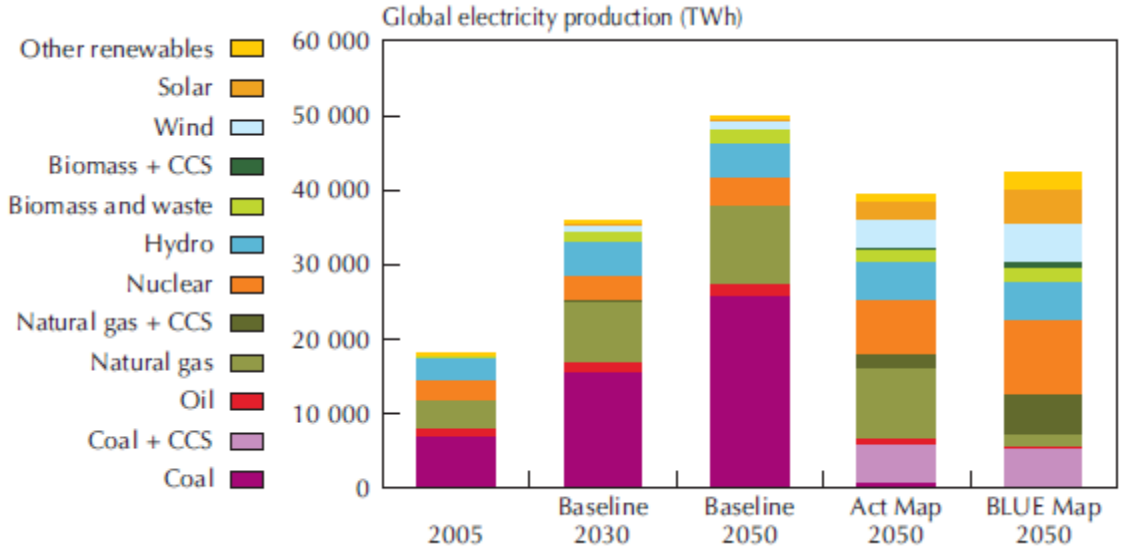
- **Renewable energy conversion systems possess multi-functionality, in the case of remote consumers, particularly.**
- **For example, water pumping into storage tanks when electricity is not demanded, hydrogen production, etc.).**





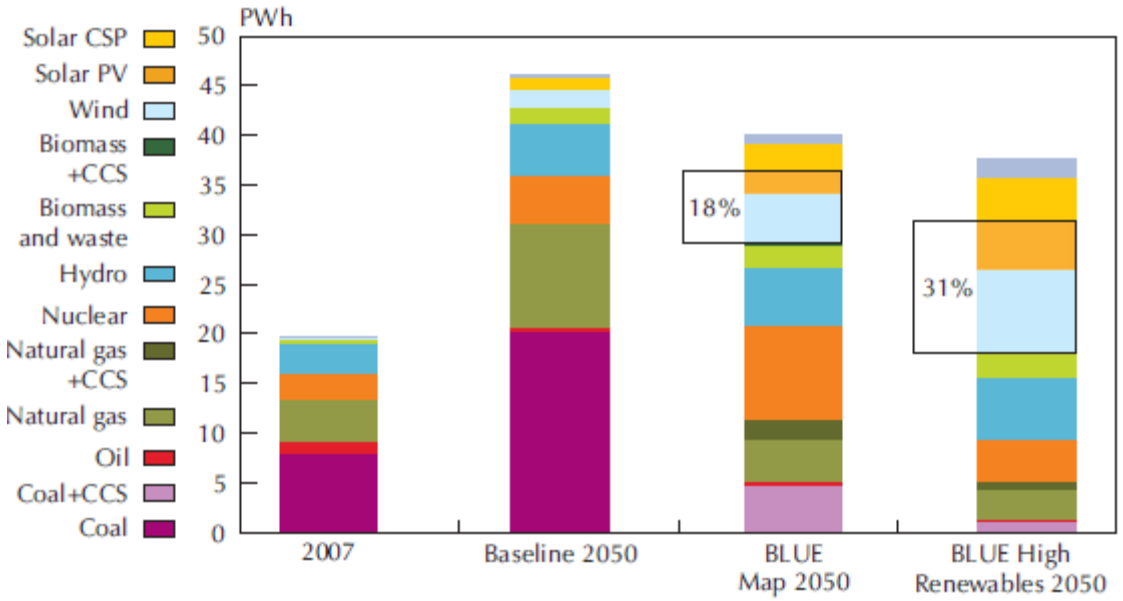


Global electricity production in 2050

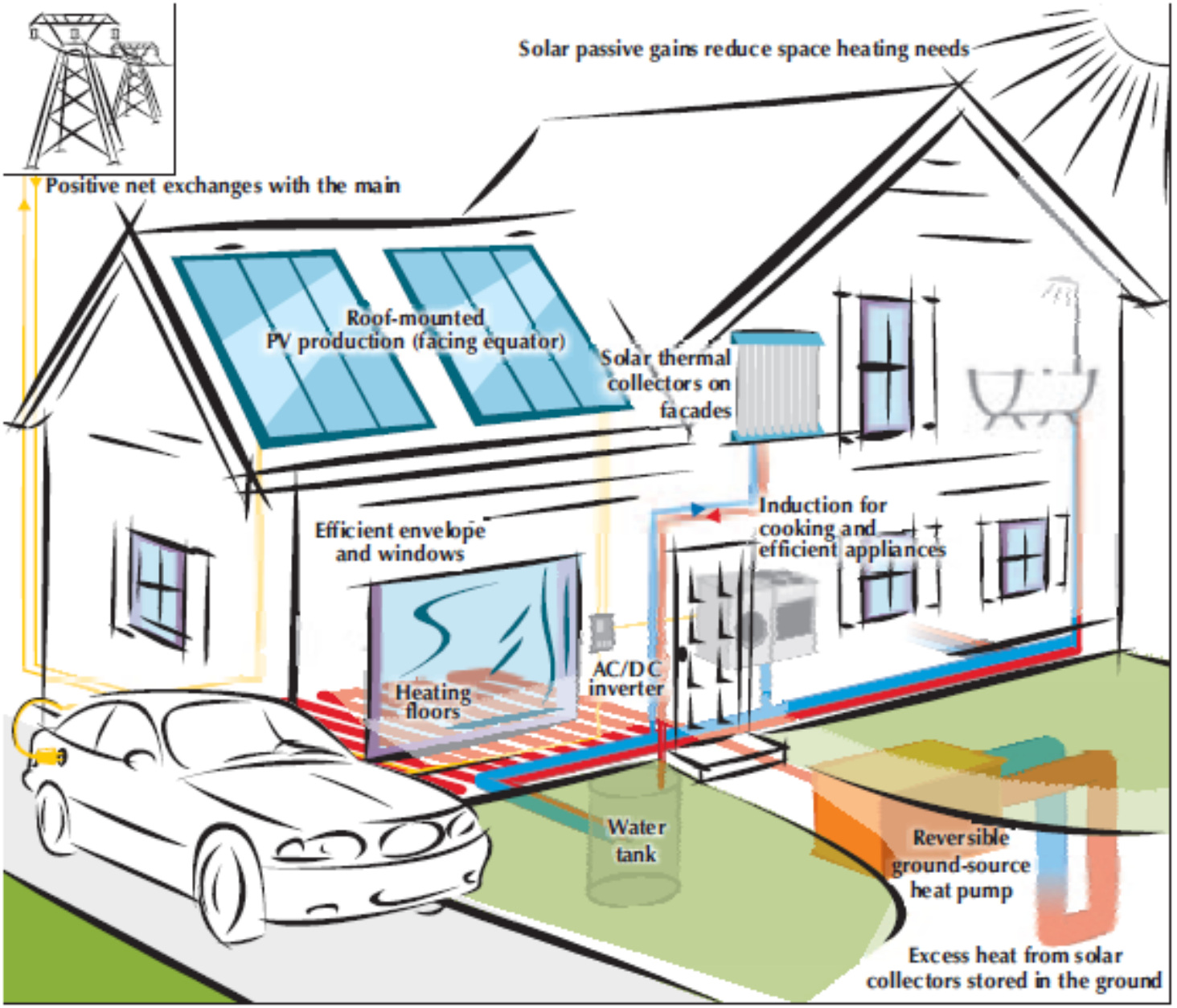


Clean electricity can replace many fossil fuel uses.

Variable renewables could represent one-third of total electricity generation by 2050.



An Integrated Approach to the Development of Solar Energy in Buildings

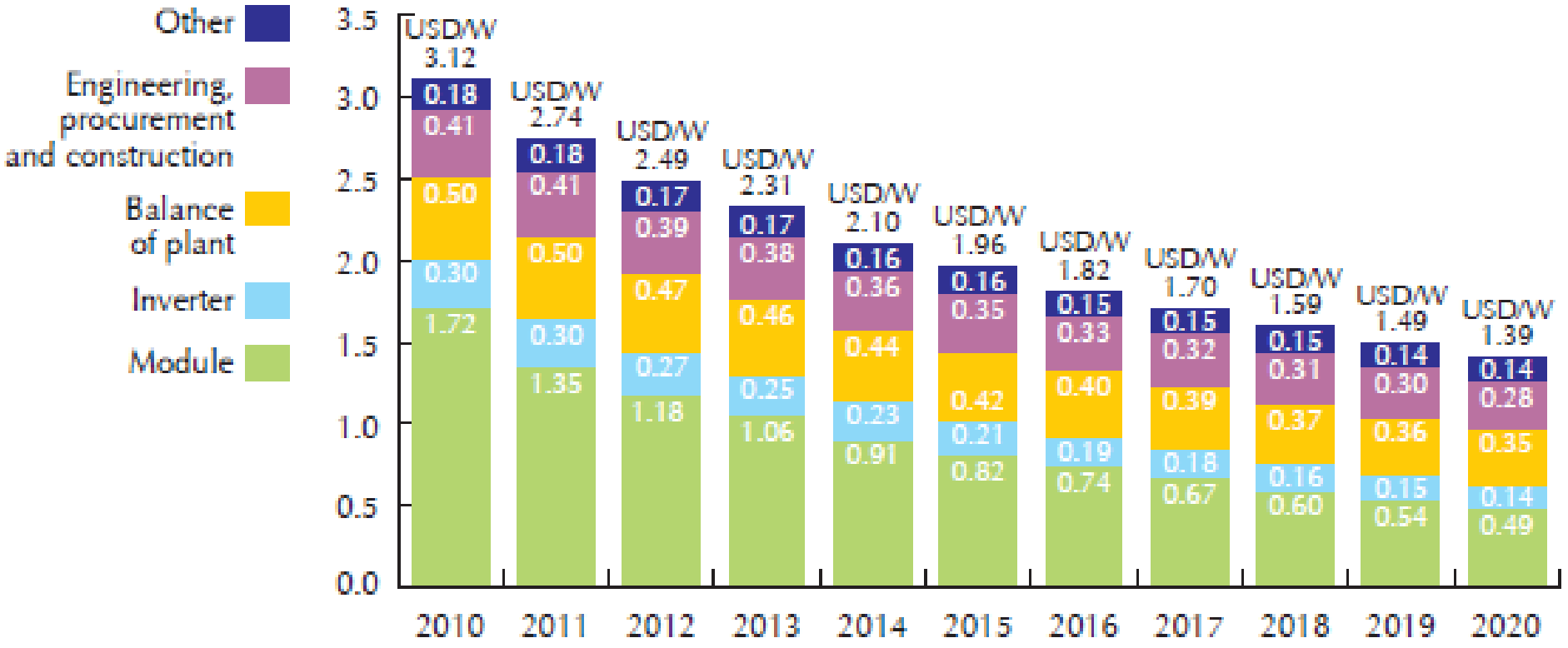


Energy Efficiency and the Solar Energy Technologies should be closely associated

There is nothing that you cannot do with SOLAR

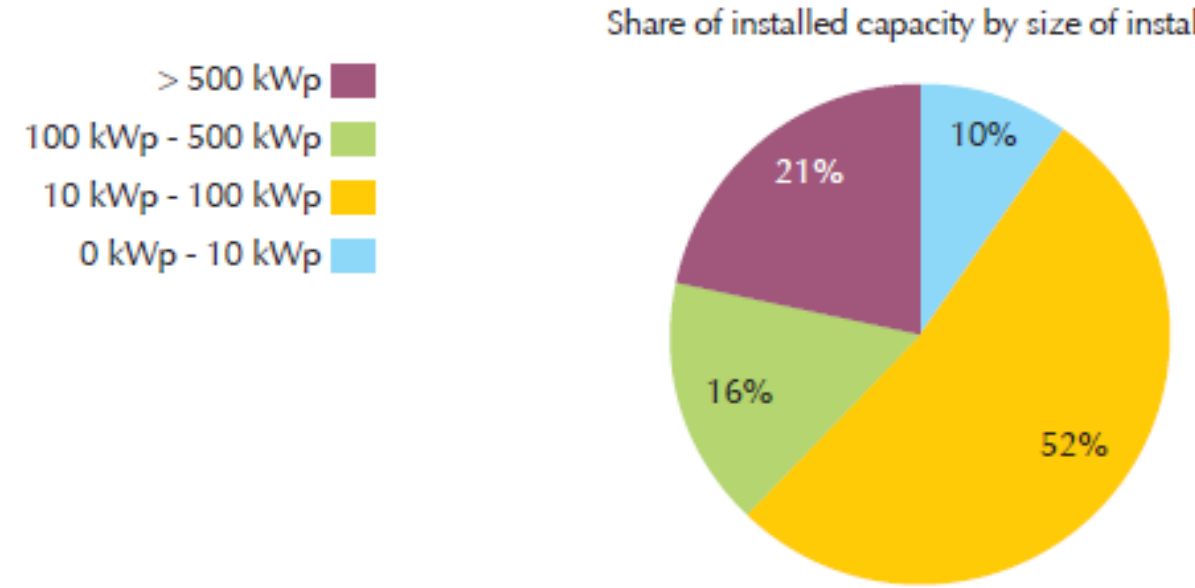
Utility Scale PV Price Forecast

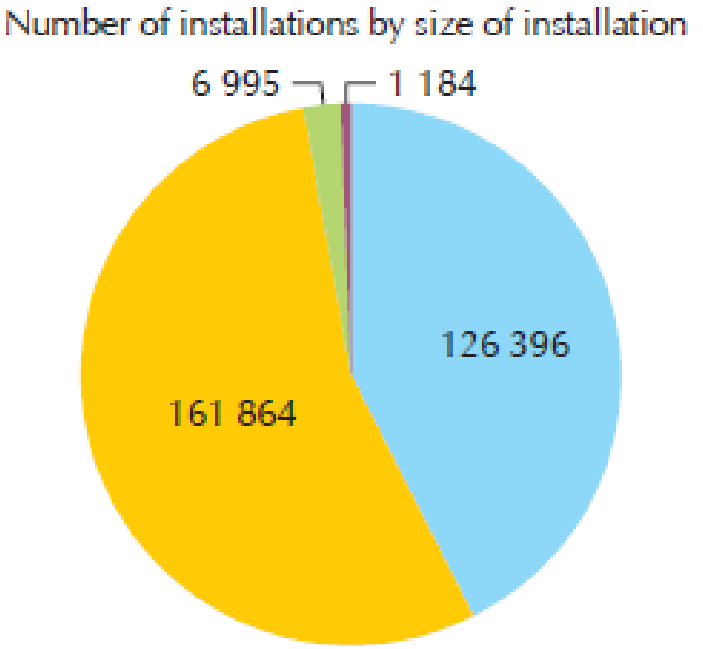
- **Module costs will soon represent only one-third of utility-scale PV systems.**



Note: Module price derives from experience curve + margin; system price in markets with cost-based, rather than value-based pricing

New PV installations in Germany, from October 2009 to October 2010

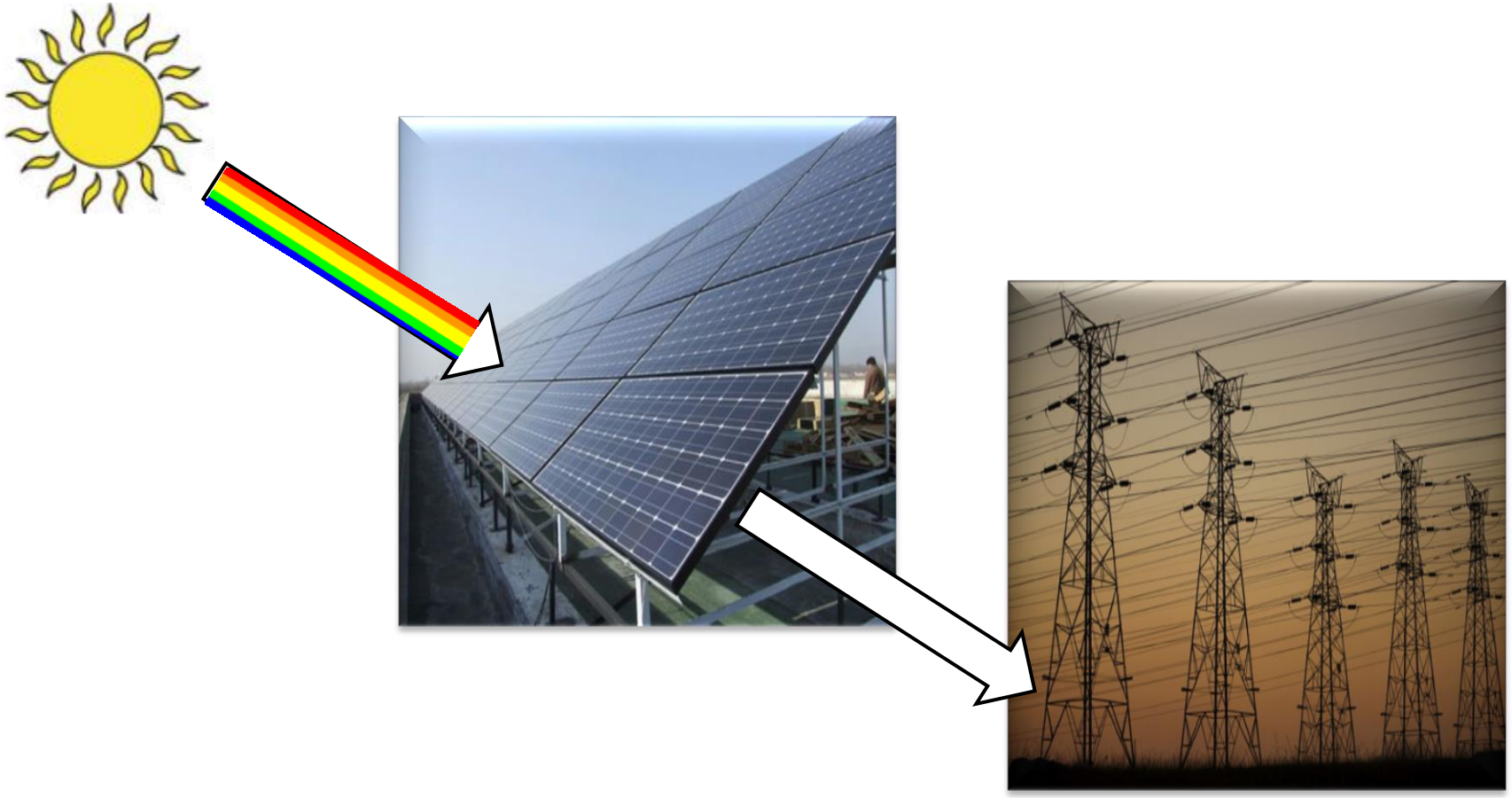




In Germany, where some 8.5 GW were installed in 2010, the growth rate still exceeds that which would be consistent with the 2020 targets (about 3.6 GW/y)

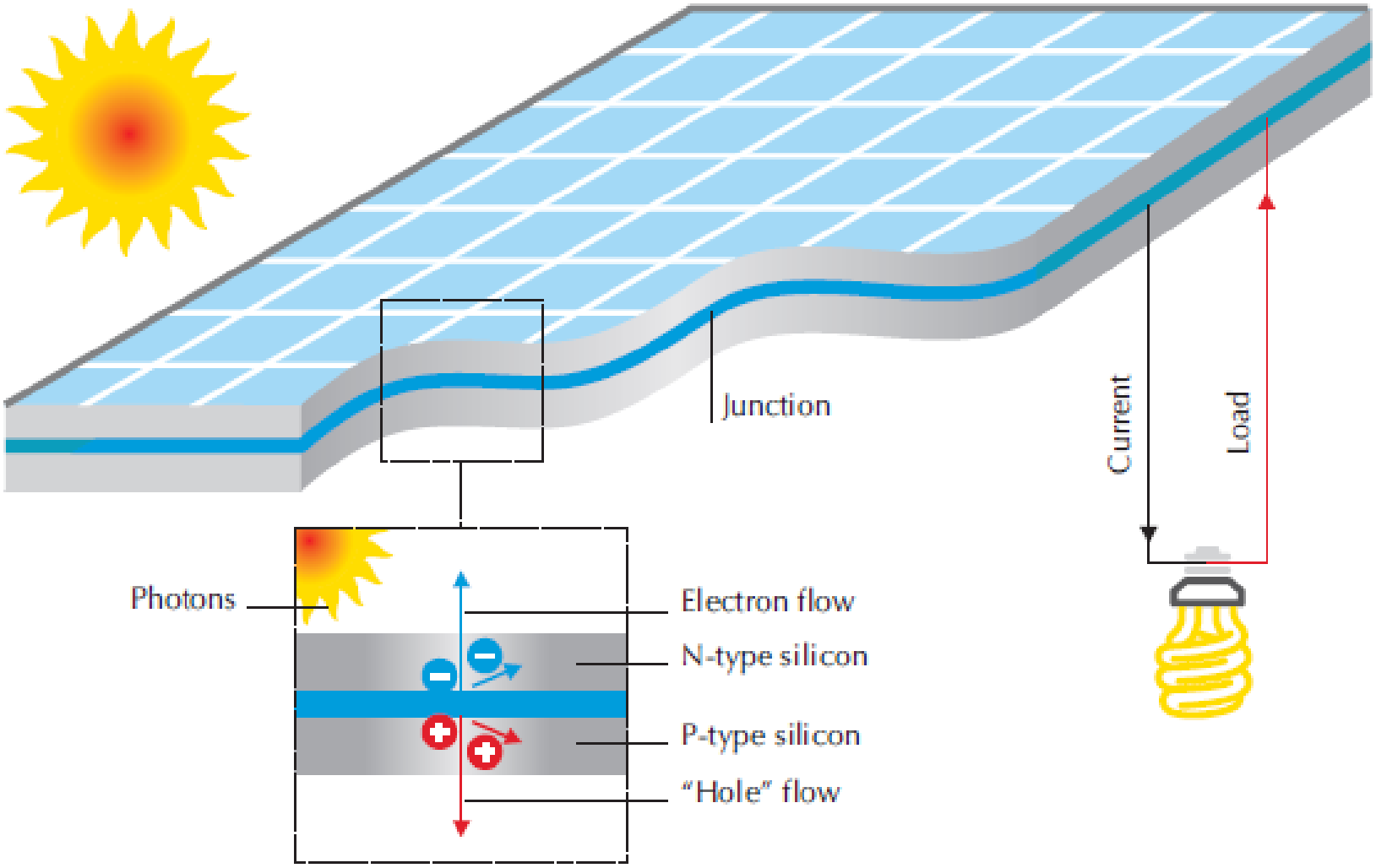
Generating Electricity from Sunlight

Sunlight → PV Module → Electricity



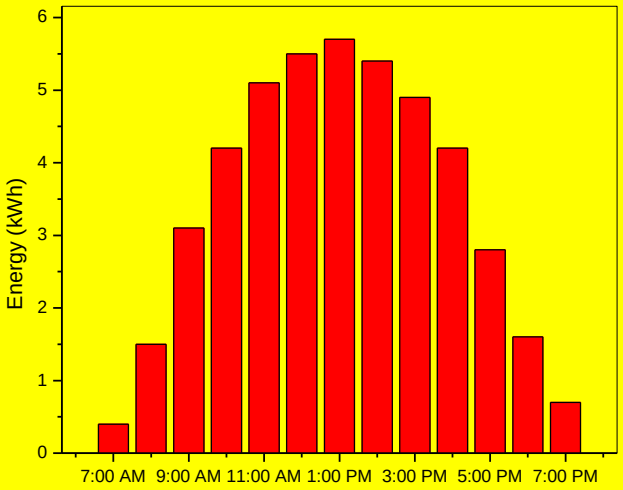
Photovoltaics Effect

PV Systems directly convert Light into Electricity



PV Markets & Applications Module

- Photovoltaics (PV) markets
- Advantages and disadvantages of PV systems
- Different PV terminologies (panel, module, array)
- Types of PV Applications


Energy (kWh)
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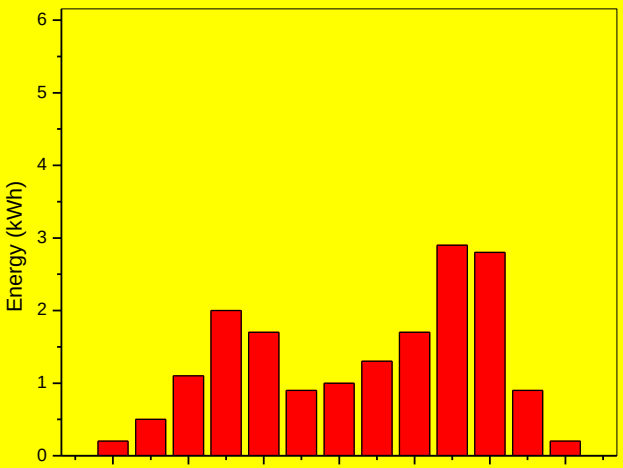
Time on August 13, 2013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Global Renewable Energy Development

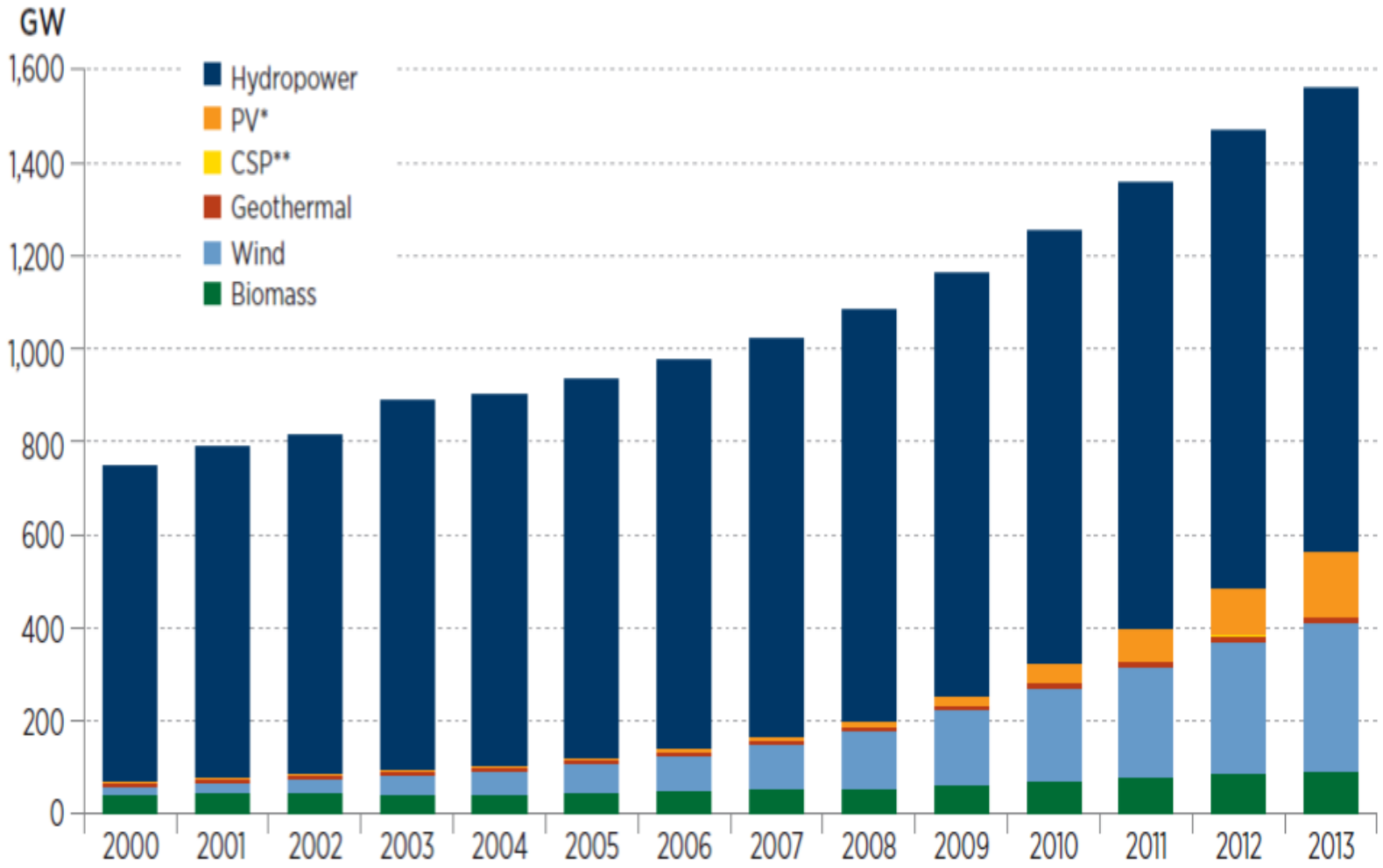
Renewable Energy Growth in USA

- The overall energy consumption grew to 97.3 quadrillion Btu in 2013, a 2.4% increase from 2012.
- Electric power sector energy consumption grew to 38.4 quadrillion Btu in 2013, a 0.6% increase from 2012.
- Installed renewable electricity capacity exceeded 171 gigawatts (GW) in 2013, generating 534 TWh.
- In 2013, solar electricity was the fastest growing electricity generation technology, with cumulative installed capacity increasing by nearly 66% from the previous year.
- Wind electricity generation increased 20% in 2013, while wind electricity capacity grew 1.8%.

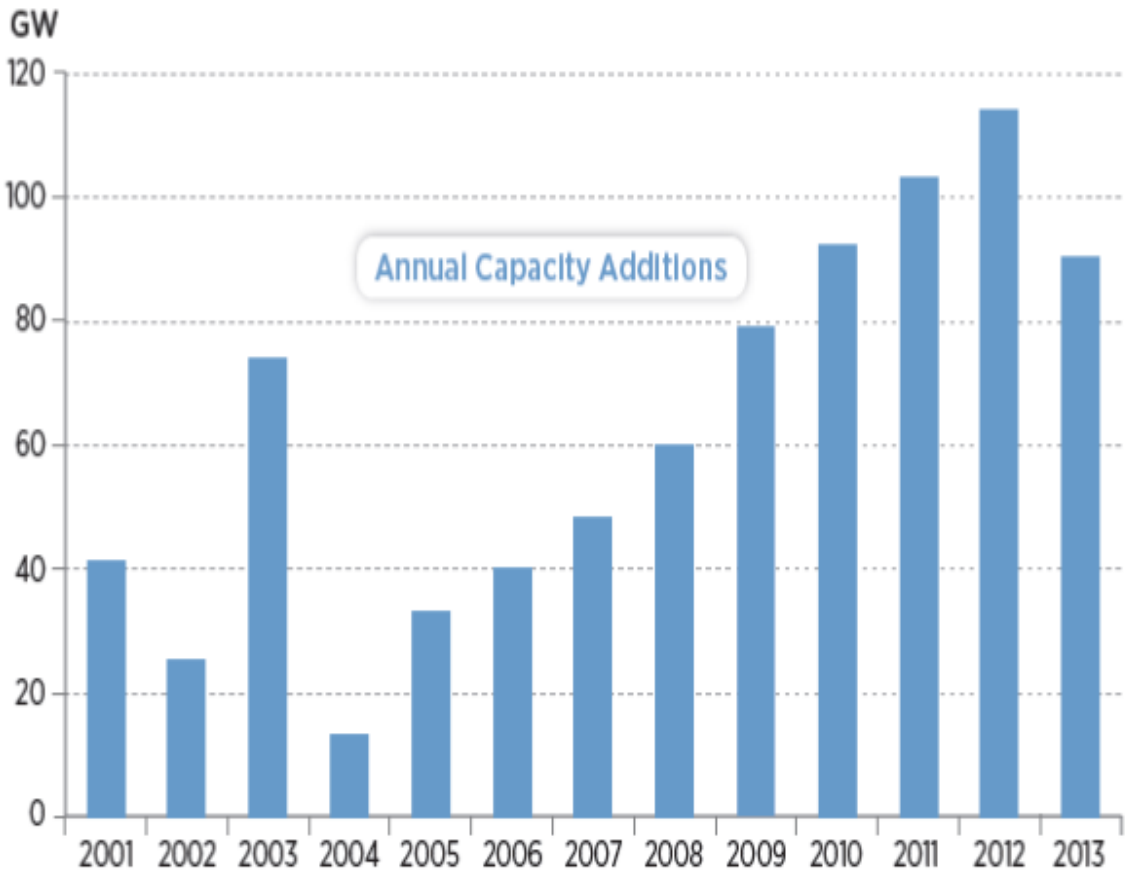
Global Renewable Energy Development

- Cumulative global renewable electricity installed capacity grew by 108% from 2000 to 2013 (from 748 GW to 1,560 GW).
- Renewable sources accounted for 23% of all electricity generation worldwide (5,095 TWh) in 2013.
- Wind and solar electricity have been the fastest growing renewable electricity technologies worldwide. Wind electricity generation grew by a factor of 18 and solar electricity generation grew by a factor of 68 between 2000 and 2013.
- In 2013, China led the world in cumulative total renewable electricity installed capacity, as well as cumulative wind and hydropower capacity. Germany led the world in cumulative PV installed capacity.
- The United States led the world in geothermal and biomass installed capacity.

Global Renewable Energy Capacity



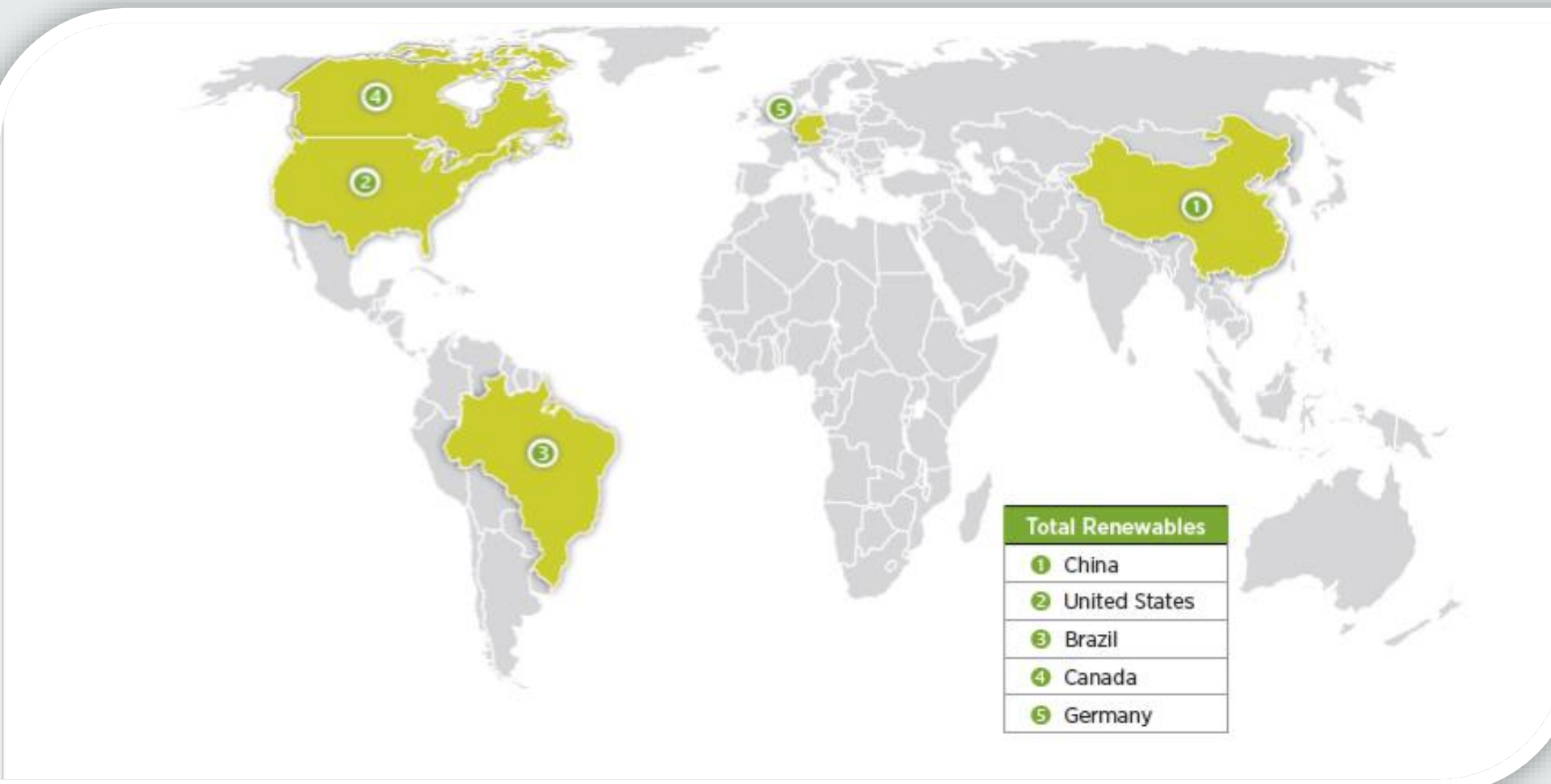
Global Annual Installed Renewable Electricity Capacity Growth



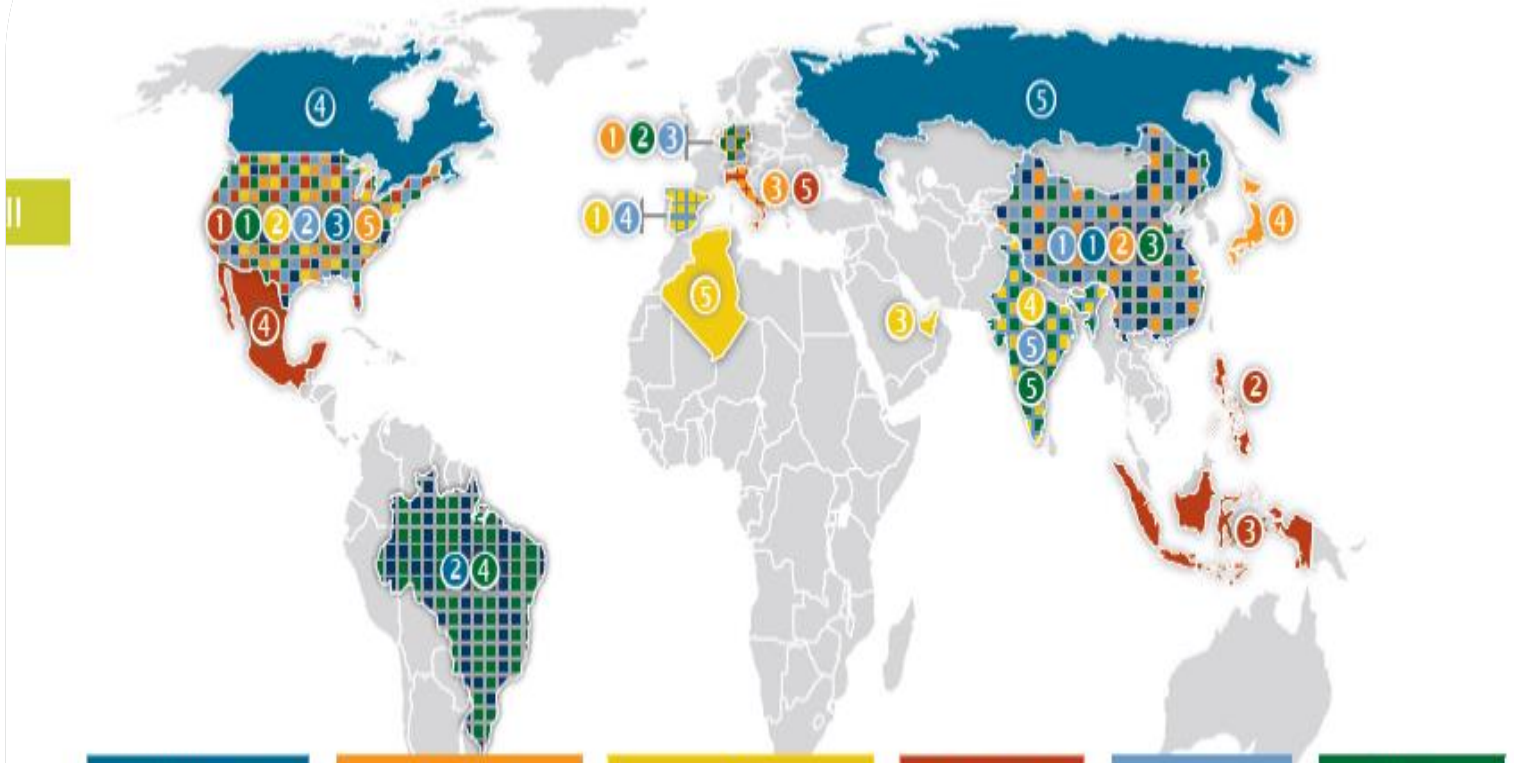
	Compounded Annual Growth Rate (2000–2013)
Wind	23.0%
PV*	46.8%
CSP	23.3%
Geothermal	3.0%
Biomass	8.5%
Hydropower	2.3%
All Renewables	5.8%

Source: REN21

Top countries for Renewable Electricity Installed Capacity (2013)



Top Countries with Installed Renewable Electricity by Technology (2013)



Hydropower	Solar PV*	CSP	Geothermal	Wind	Biomass
1 China	1 Germany	1 Spain	1 United States	1 China	1 United States
2 Brazil	2 China	2 United States	2 Philippines	2 United States	2 Germany
3 United States	3 Italy	3 United Arab Emirates	3 Indonesia	3 Germany	3 China
4 Canada	4 Japan	4 India	4 Mexico	4 Spain	4 Brazil
5 Russia	5 United States	5 Algeria	5 Italy	5 India	5 India

Sources: REN21

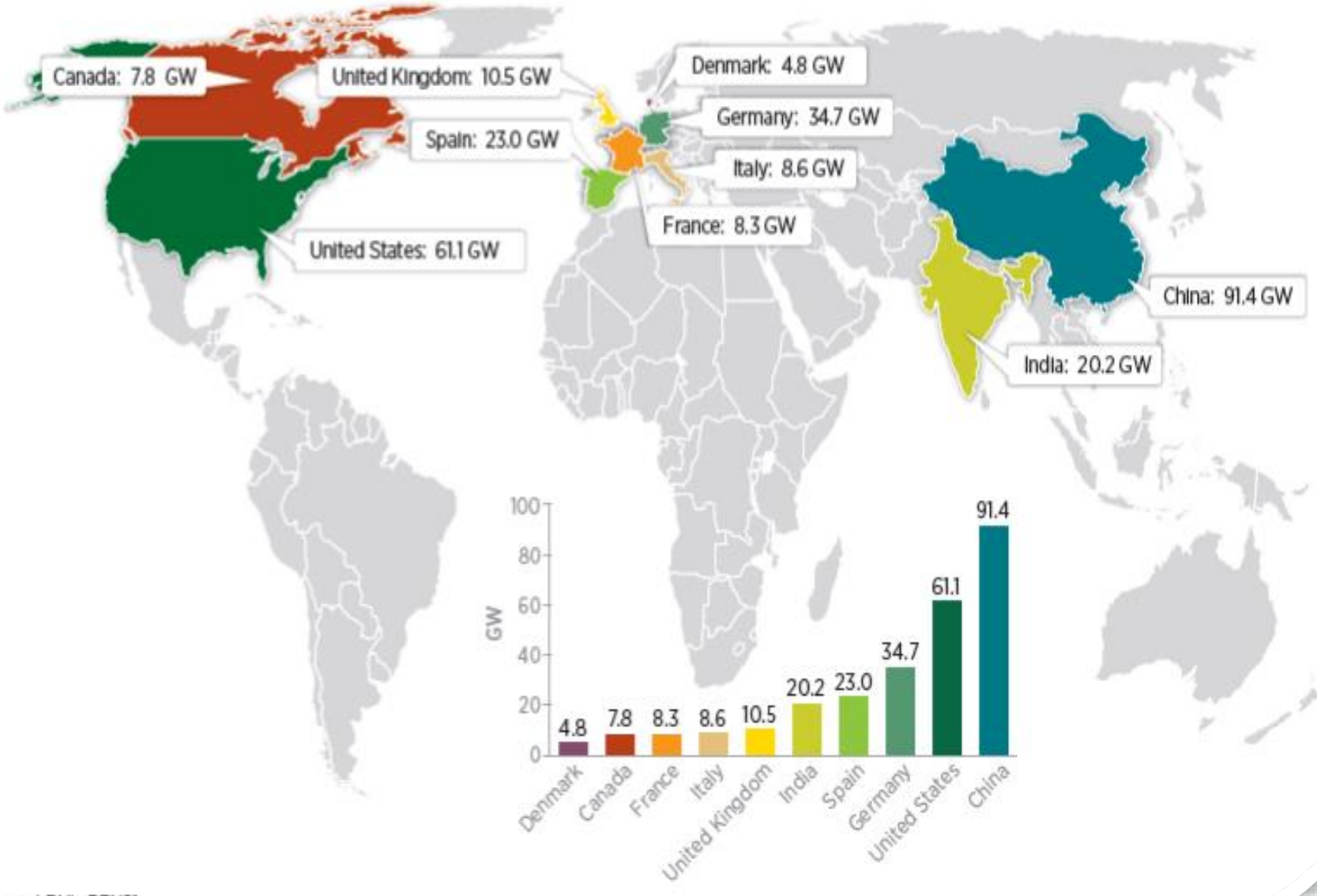
*Grid-connected only


Wind

Wind Electricity

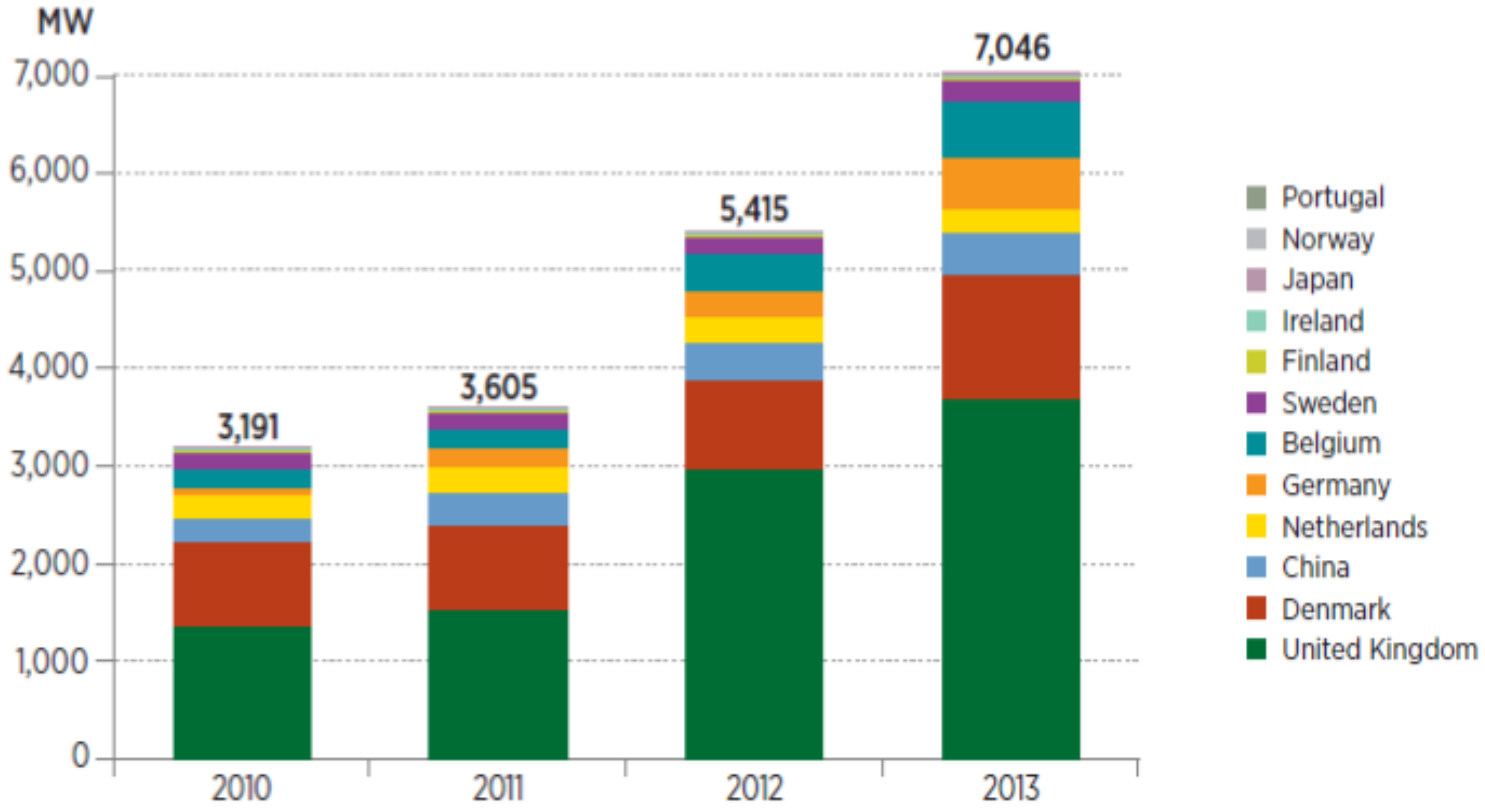
- In the United States, wind electricity experienced limited growth, with only 1.1 GW of new capacity added, a 92% reduction from the record-setting 13.1 GW installed in 2012.
- At the end of 2013, there was more U.S. wind power capacity under construction than at any time previously: construction activity was started on more than 12.0 GW of projects .
- China continued in 2013 to lead the world in cumulative installed wind capacity, with more than 91 GW installed as of the end of 2013.
- **Global cumulative installed offshore wind capacity surpassed 7 GW in 2013.**
- While projects have been proposed, no commercial offshore wind turbines have yet been commissioned in the United States.

Cumulative Wind Electricity Capacity (2013) – Top 10 Countries



Sources: LBNL, REN21

Cumulative Installed Offshore Wind Capacity by Country (MW)



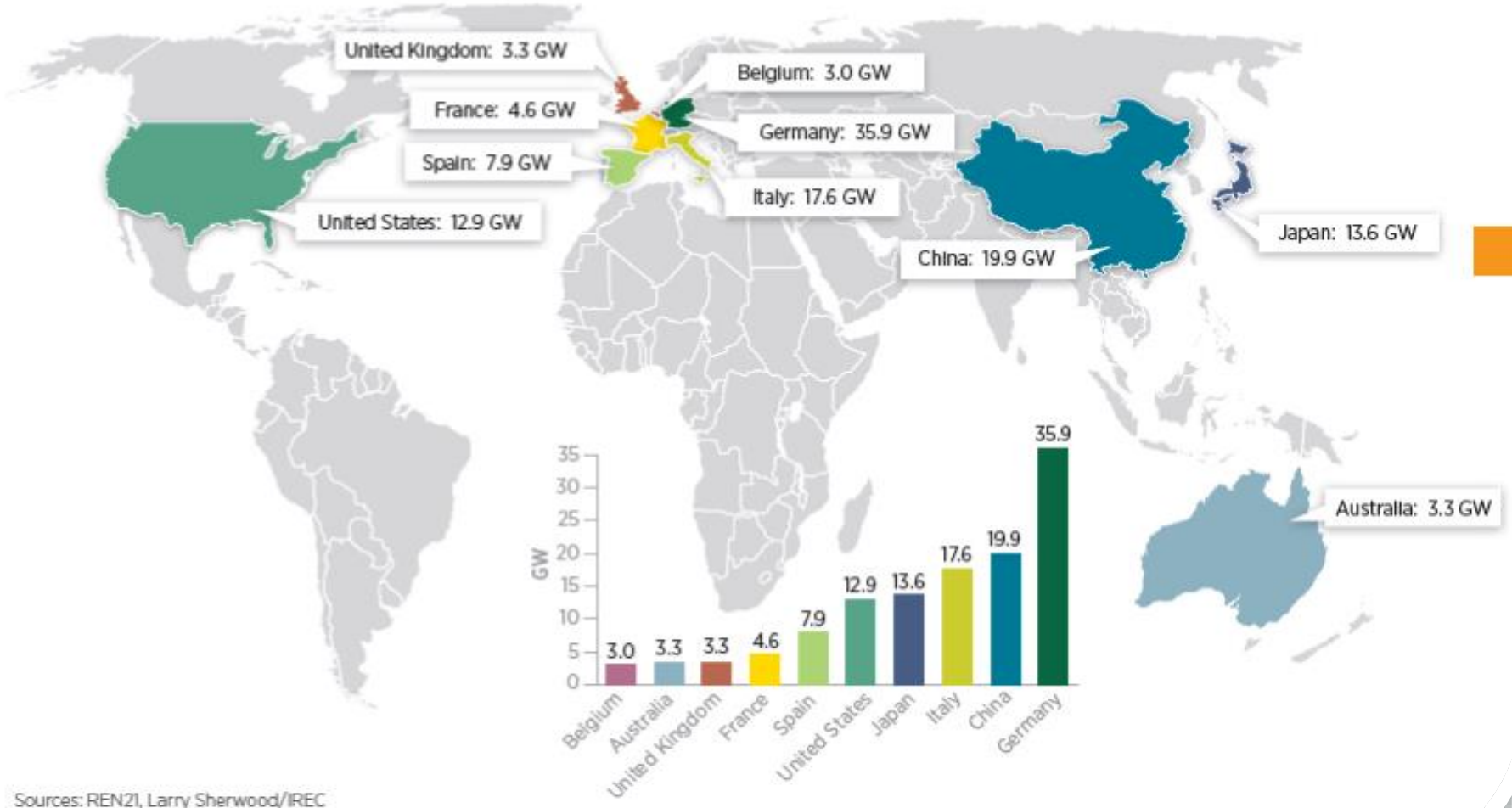
Sources: Global Wind Energy Council (GWEC), LBNL


Solar

Solar Electricity

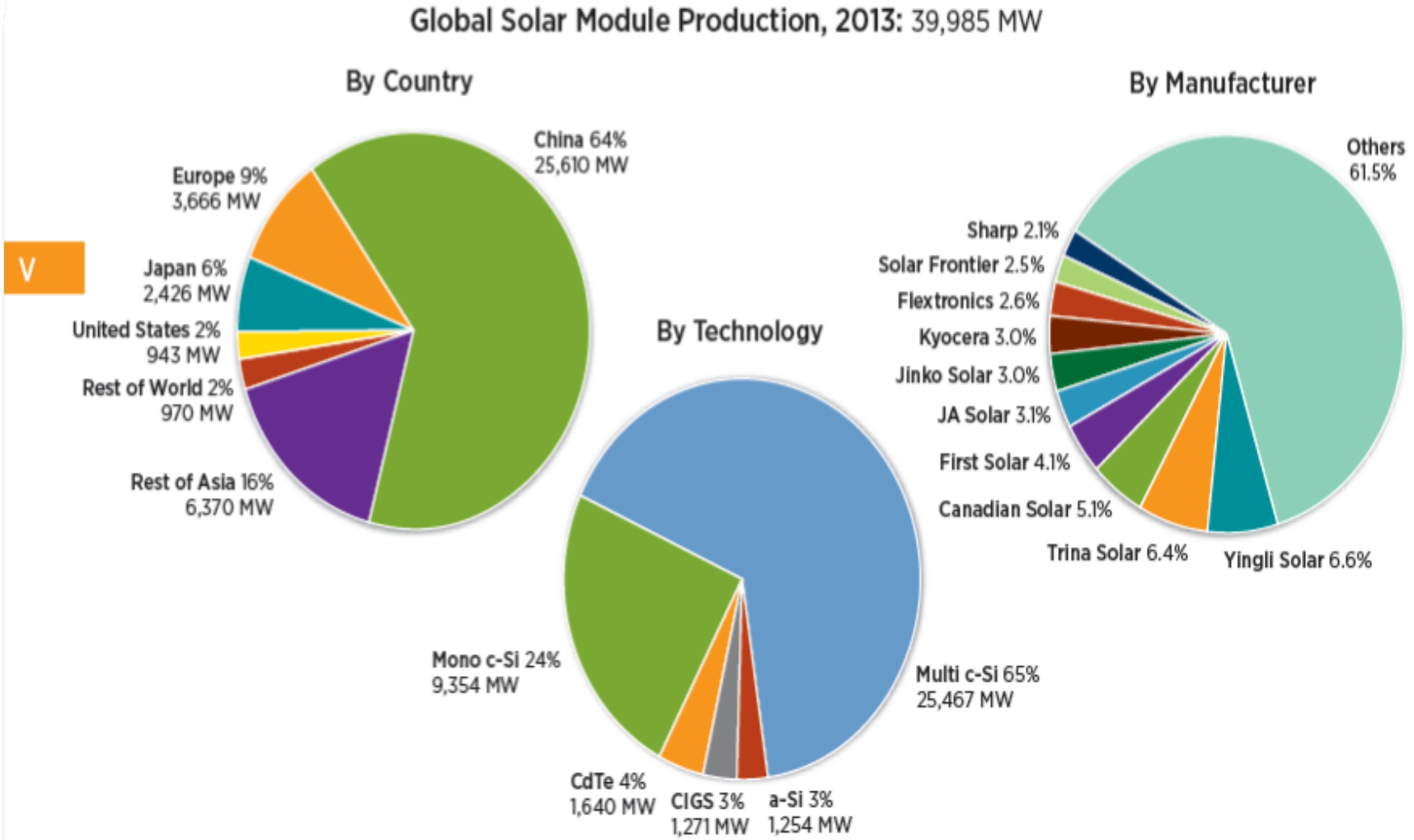
- Solar electricity generating capacity grew by a factor of 35 between 2000 and 2013 and currently accounts for 0.5% of annual U.S. electricity generation.
- PV cumulative capacity increased 65% in 2013 .
- Countries with extensive solar policies—such as Germany and Spain—lead the world in solar PV and CSP deployment, respectively. Similarly, U.S. states with extensive solar incentives led the United States in both cumulative and annual installations in 2013 (California, Arizona, New Jersey, North Carolina, and Massachusetts).
- 410 MW of new CSP capacity came online in the United States in 2013, an increase in cumulative capacity of 81%. Approximately 400-500 MW of CSP capacity is currently under construction and expected to come online in 2014 and 2015, while another 3,600 MW is under development.

Solar Electricity Installed Capacity (2013) – Select Countries



Sources: REN21, Larry Sherwood/IREC
Includes CSP and grid-connected PV

Worldwide Photovoltaic Manufacturing (2013)



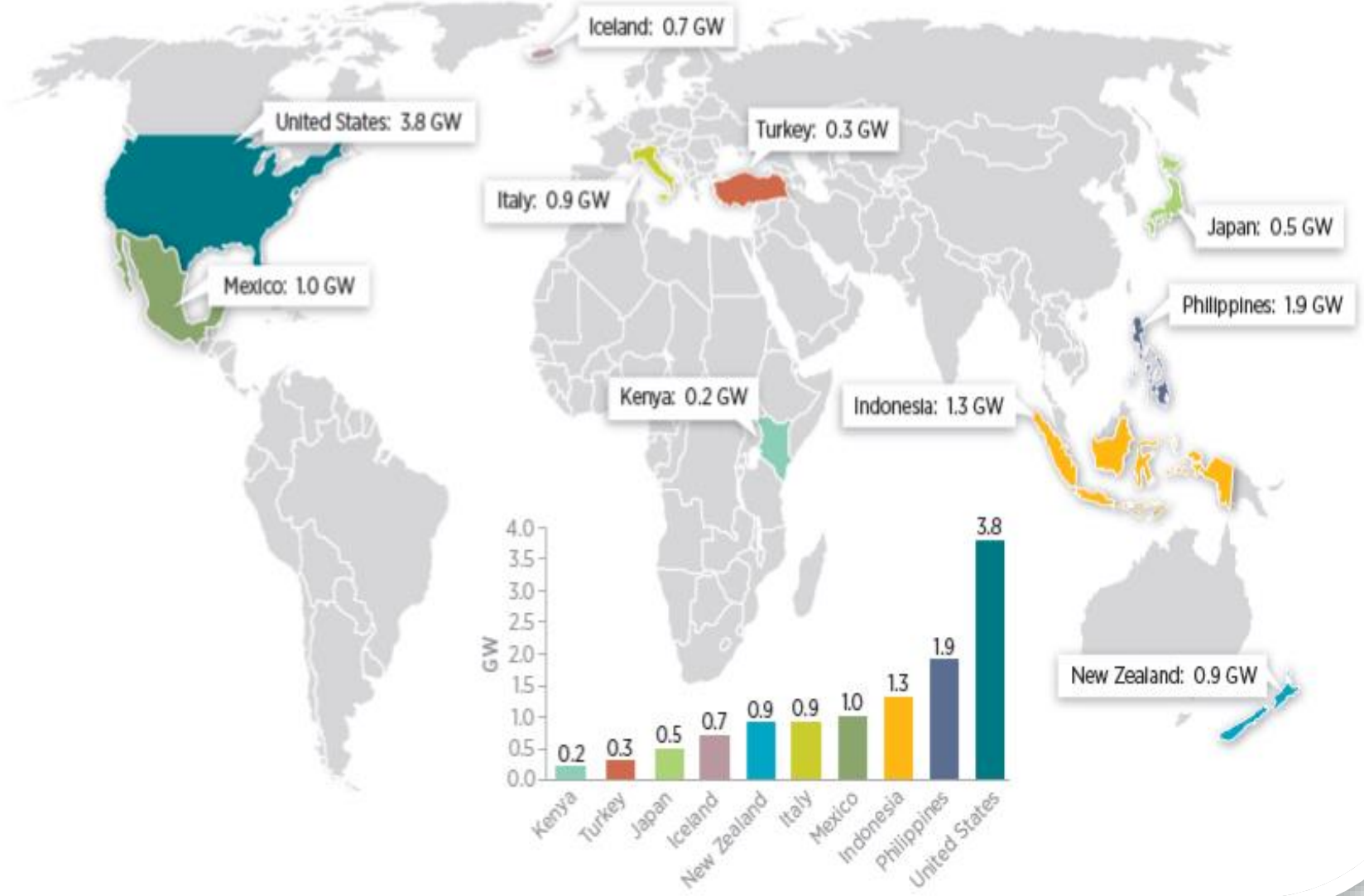
Source: GTM PV News, May 2014


Geothermal

Geothermal Electricity

- The United States leads the world in installed geothermal electricity capacity and generation, with most of that capacity installed in California, followed by Nevada.
- U.S. geothermal electricity capacity has remained relatively stable, increasing at a 2.4% compound annual growth rate (CAGR) since 2000.
- As a base load source of energy, geothermal is distinct from variable renewables, such as wind and solar, because it can provide consistent electricity throughout the day and year.
- Five Enhanced Geothermal System (EGS) technology multi-year demonstration projects were active in 2013.

Cumulative Geothermal Electricity Capacity (2013) – Top 10 Countries

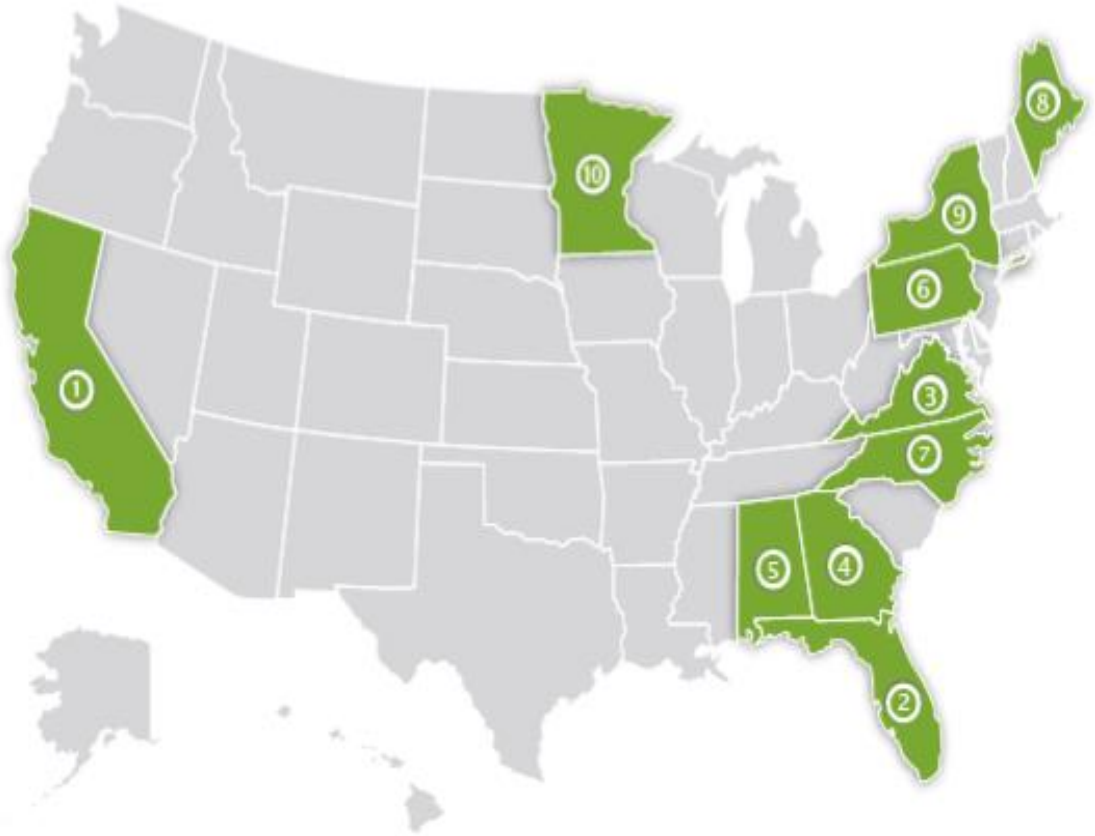



Biopower

Biopower Electricity

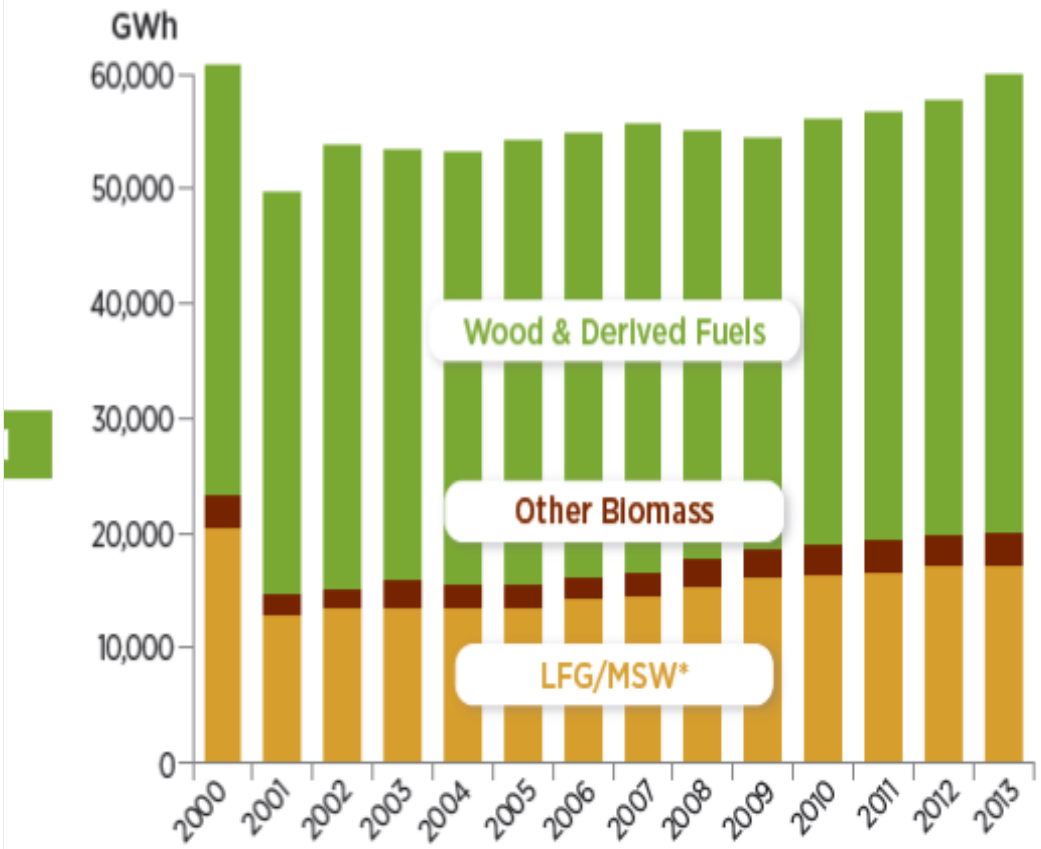
- In 2013, biopower electricity generation accounted for 11% of all renewable energy generated in the United States.
- • Biopower electricity comes primarily from wood and agricultural residues that are burned as a fuel for cogeneration in the industrial sector (such as in the pulp and paper industry).
- • U.S. installed biopower electricity capacity has grown recently, with a compound annual growth rate (CAGR) of 3.8% from 2007 to 2013.

States Leading Biopower Electricity Development (2013)



Total Installed Capacity (MW)*	
1 California	1,452
2 Florida	1,324
3 Virginia	808
4 Georgia	807
5 Alabama	720
6 Pennsylvania	665
7 North Carolina	616
8 Maine	609
9 New York	526
10 Minnesota	491

U.S. Biopower Electricity Generation Sources (GWh)



	LFG/ MSW*	Other Biomass	Wood and Derived Fuel	Total
2000	20,305	2,826	37,595	60,726
2001	12,714	1,834	35,200	49,748
2002	13,398	1,646	38,665	53,709
2003	13,383	2,428	37,529	53,340
2004	13,281	2,216	37,576	53,073
2005	13,470	2,009	38,681	54,160
2006	14,106	2,004	38,649	54,759
2007	14,462	2,063	39,014	55,539
2008	15,253	2,481	37,300	55,034
2009	15,982	2,461	36,050	54,493
2010	16,304	2,613	37,172	56,089
2011	16,398	2,824	37,449	56,671
2012	17,125	2,701	37,798	57,624
2013	17,142	2,816	39,936	59,894

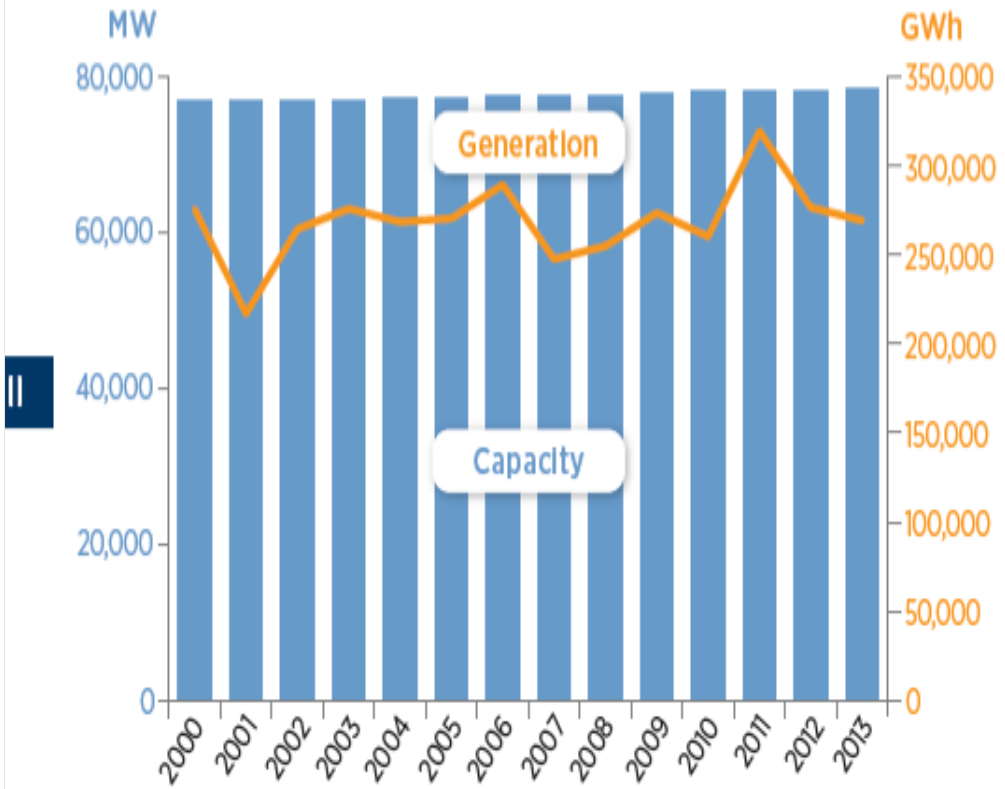
Source: EIA


Hydropower

Hydropower Electricity

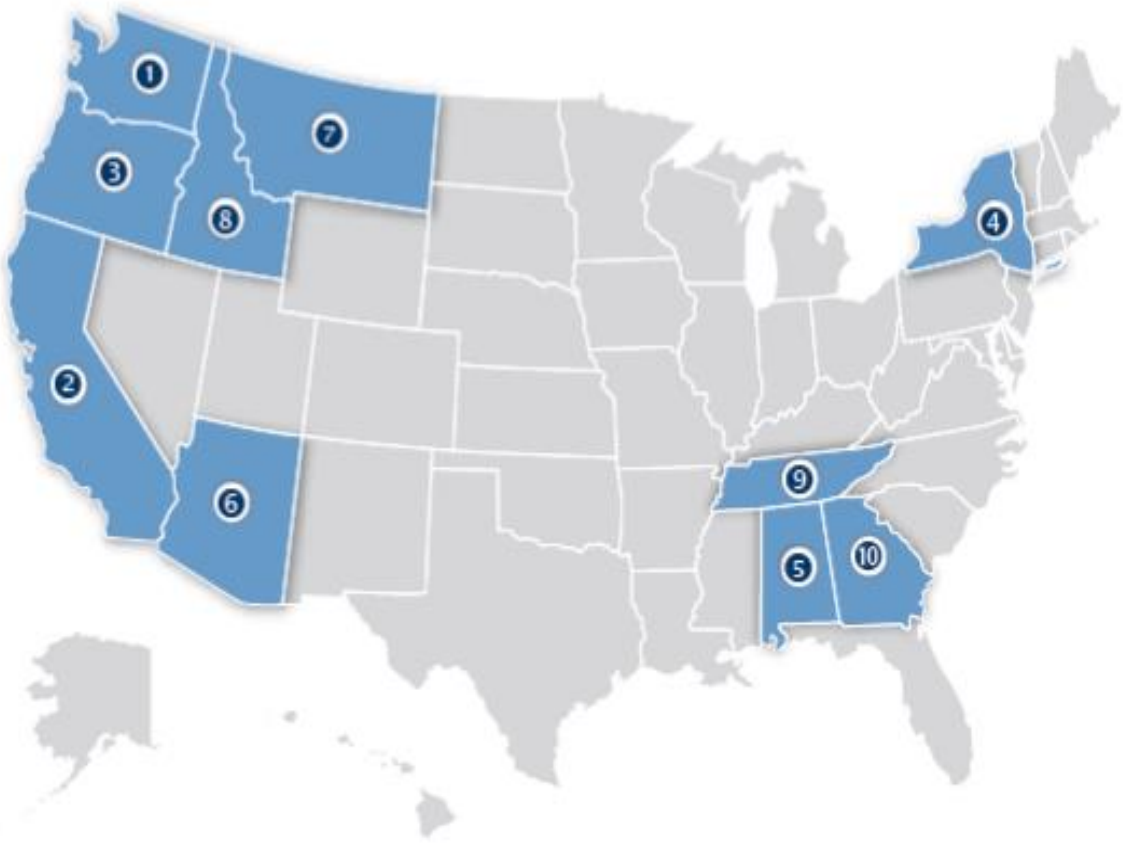
- Hydropower capacity has remained essentially constant since 2000, with less than a 2% total increase.
- Hydropower remains the largest source of renewable electricity generation, primarily large-scale hydropower, which accounted for 6.6% of U.S. electricity generation in 2013.
- Additional hydropower capacity was installed in the United States in 2013.
- However, generation from existing hydropower facilities has been declining since 2011.

U.S. Hydropower* Electricity Capacity and Generation



	U.S. Hydropower Generation (GWh)	U.S. Hydropower Capacity and % Increase from Previous Year	
		Total (MW)	% Increase
2000	275,573	76,946	0.0%
2001	216,961	76,911	0.0%
2002	264,329	77,047	0.2%
2003	275,806	77,020	0.0%
2004	268,417	77,130	0.1%
2005	270,321	77,354	0.3%
2006	289,246	77,419	0.1%
2007	247,510	77,432	0.0%
2008	254,831	77,640	0.3%
2009	273,445	77,910	0.3%
2010	260,203	78,204	0.4%
2011	319,355	78,194	0.0%
2012	276,535	78,241	0.1%
2013	269,137	78,457	0.3%

States Leading Hydropower Electricity Development (2013)



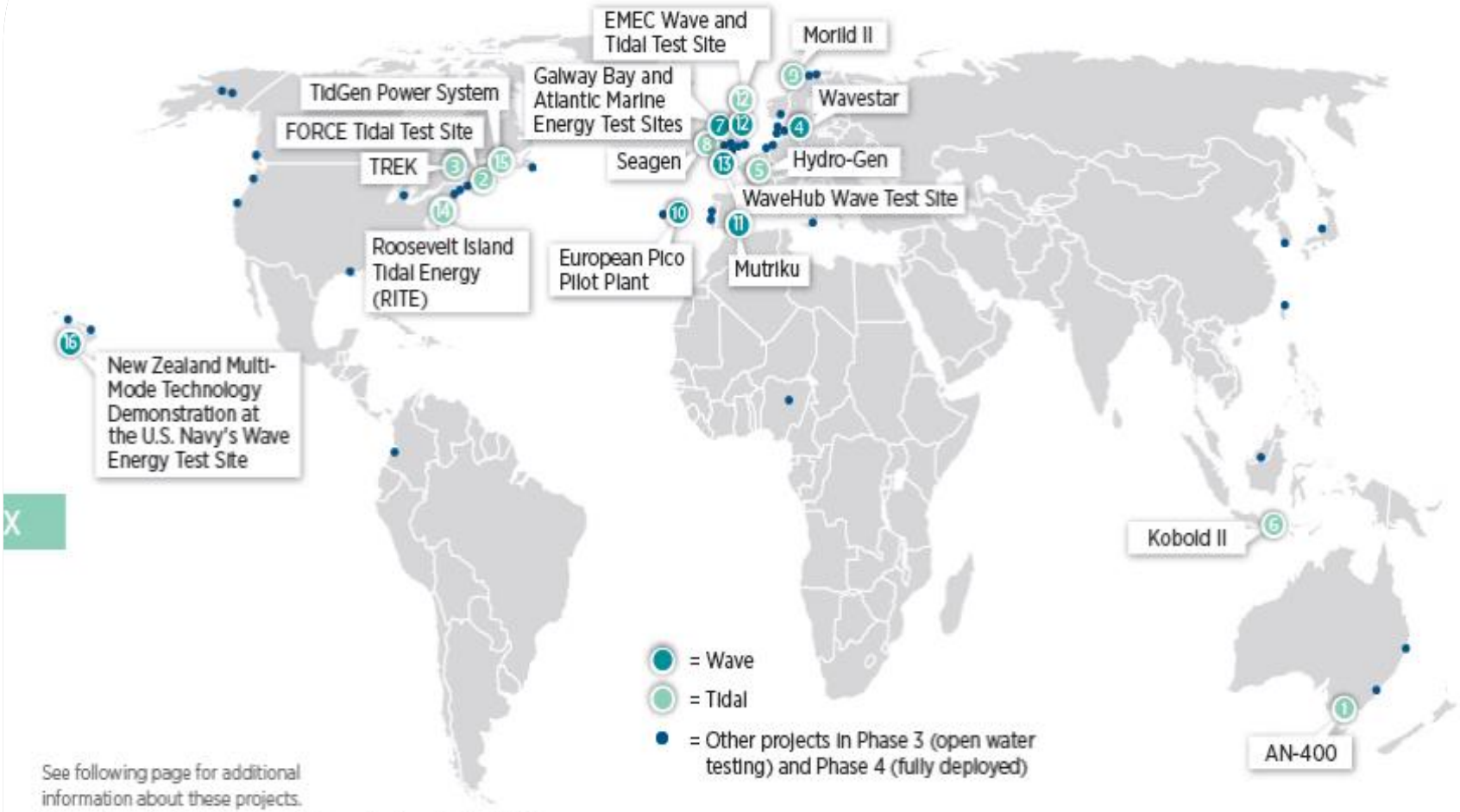
	Capacity (MW)
1 Washington	20,957
2 California	10,040
3 Oregon	8,243
4 New York	4,659
5 Alabama	3,280
6 Arizona	2,718
7 Montana	2,639
8 Idaho	2,541
9 Tennessee	2,499
10 Georgia	1,927


Advanced Water Power

Advanced Water Power Electricity

- U.S. interest in advanced water power—such as tidal, river, ocean current, and ocean wave energy—continues to steadily grow with many prototype projects in testing stages and permits for production facilities being filed with the Federal Energy Regulatory Commission (FERC).
- There were no new tidal power project licenses issued by FERC in 2013. However, in September 2013, Ocean Renewable Power Company's Tidal Energy Project became the first tidal power project to deliver power to an electric utility grid in the United States.
- • Advanced water power development activity is concentrated in the North America and Europe.

Worldwide Advanced Water Power – Select Commercial and Pilot Plants



See following page for additional information about these projects.

Information about additional projects can be found in the EERE Marine and Hydrokinetic Technology Database, accessible at: http://en.openei.org/wiki/Marine_and_Hydrokinetic_Technology_Database.

Sources: EERE, Ocean Energy Systems

Hydrogen and Fuel Cells

H2 and Fuel cells Electricity

- The cumulative installed global fuel cell capacity for stationary power increased by a factor of 3 between 2008 and 2013, reaching approximately 150–160 MW in 2013.
- In 2013, global electrical generation capacity from stationary fuel cells increased by nearly 25% from the previous year.
- In 2013, global fuel cell shipments increased approximately 25% from the previous year.
- In 2013, revenues from fuel cell systems shipped increased by more than 30% over the previous year.
- In the United States, nearly 9 million metric tons of hydrogen are produced today, mostly serving the petroleum refining and chemicals industries; there are more than 1,500 miles of hydrogen pipelines.

H2 and Fuel cells Electricity

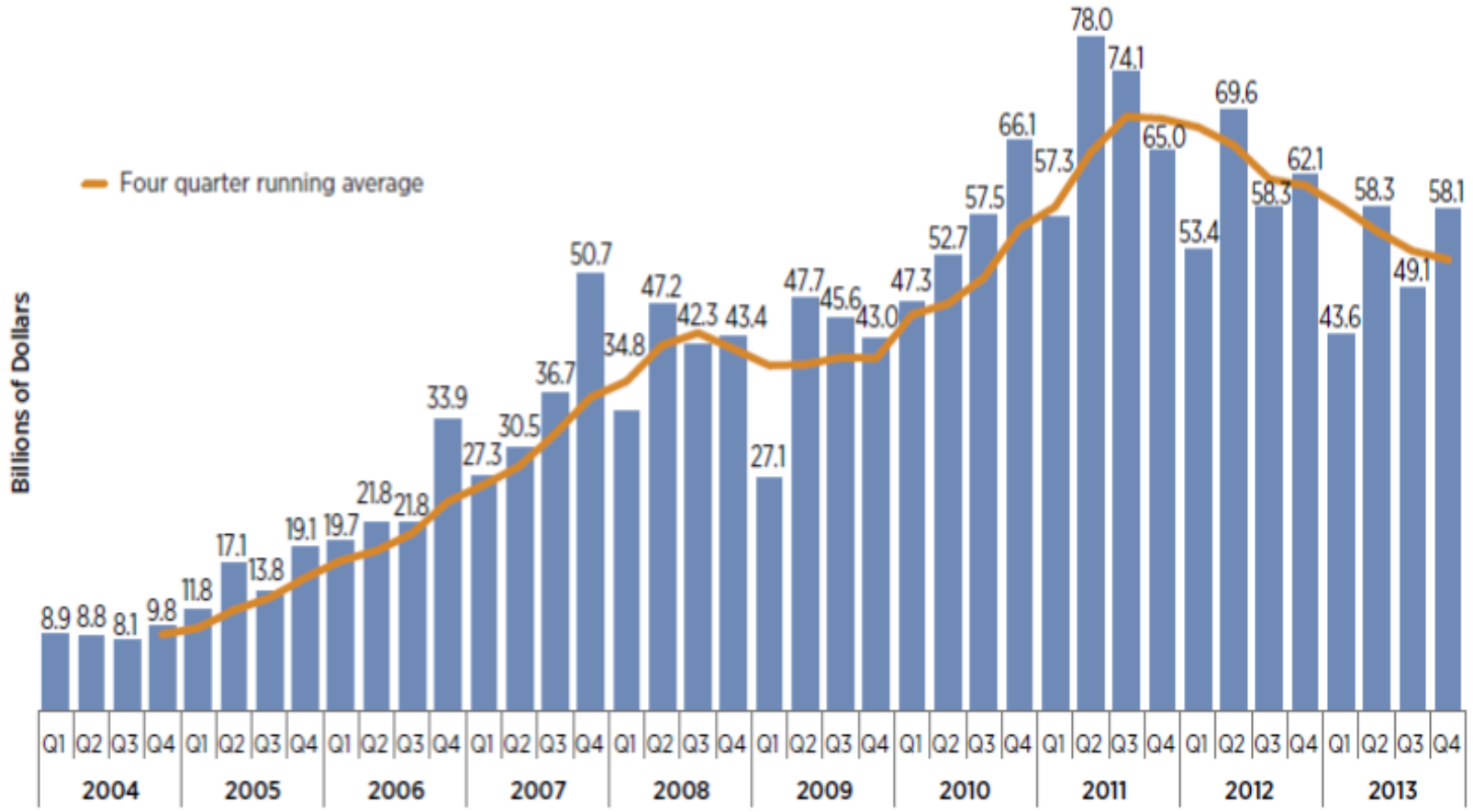
- The world's largest fuel cell power plant was opened in Hwasung City, South Korea in 2013. The 59 MW facility will provide baseload power to the electricity grid and high-grade heat for district heating. Another fuel cell power generation plant (19.6 MW) is being planned for construction in Seoul City, South Korea.
- In the United States, a 15-MW fuel cell power park was completed in Bridgeport, Connecticut and is delivering baseload power to the electricity grid.
- Globally, more than 5,000 fuel cell units have been installed or ordered for backup power applications. These units have a successful startup rate greater than 99.7%.
- Globally, more than 8,200 fuel cells have been ordered or installed in forklifts.


Clean Energy Investments

Investments on RES

- Global new investments in renewable energy have grown dramatically in the past decade, but have seen an 11% decrease since 2011, with $254 billion in new investments in 2013.
- New investment in clean energy in the U.S. totaled $36.7 billion in 2013.
- In 2013, solar experienced the highest levels of new investment, followed by wind.
- Global venture capital and private equity new investment in clean energy has increased from $1.4 billion in 2004 to $4.4 billion in 2013.

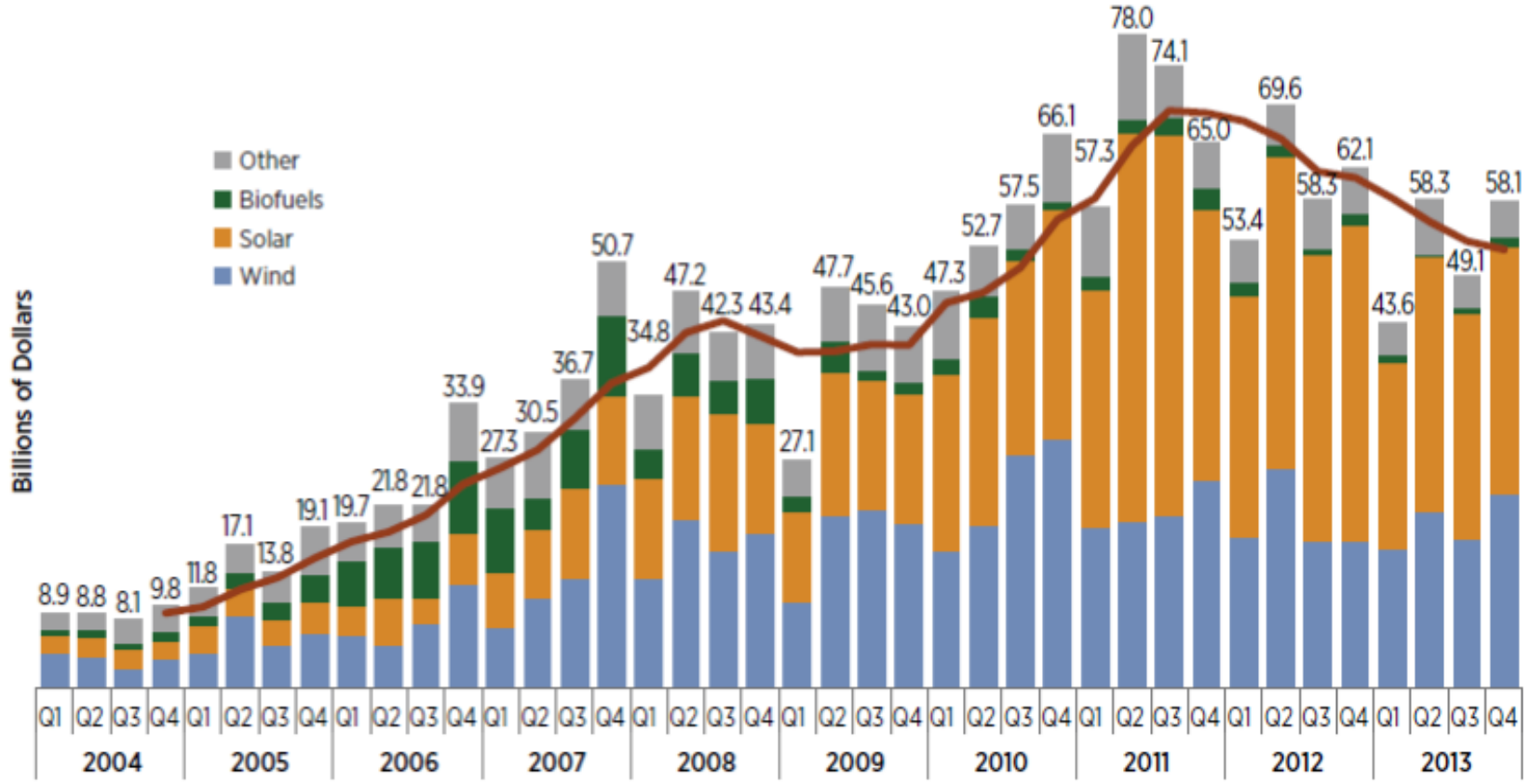
New Investment In Clean Energy – Global



Total values include estimates for undisclosed deals. Excludes corporate and government R&D, and spending for digital energy and energy storage projects (reported in annual statistics only).

Source: Bloomberg New Energy Finance

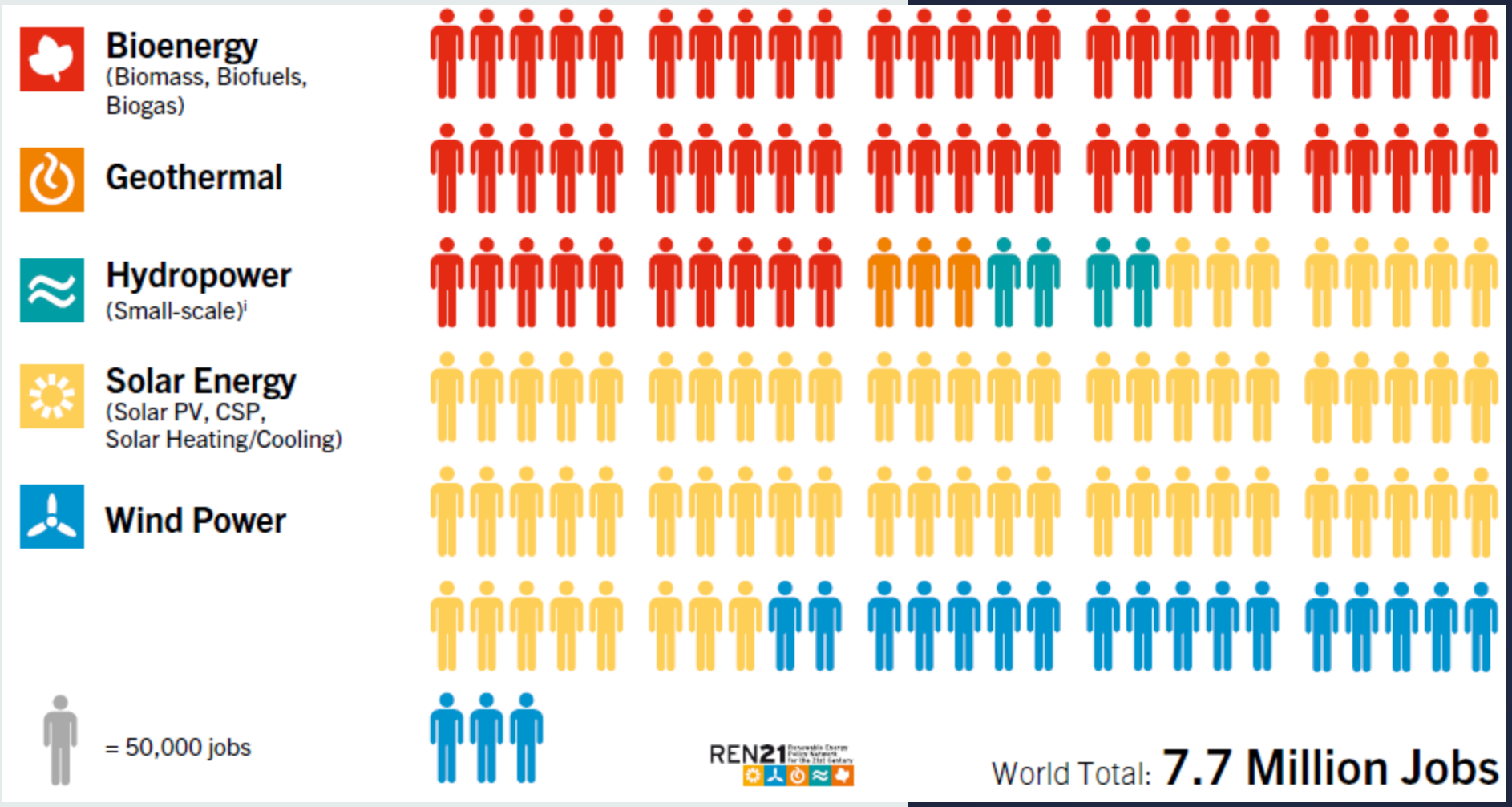
New Investment In Global Clean Energy By Technology – Global



Total values include estimates for undisclosed deals. Excludes corporate and government R&D, and spending for digital energy and energy storage projects (reported in annual statistics only).

Source: Bloomberg New Energy Finance

Jobs in Renewable Energy



- Thanks to Technological advances, policy support and improved understanding of deployment potential.
- We are increasingly powering our electricity and transportation systems with clean, RES.
- A clean energy future is here and expanding.

THANK YOU