JISEA Joint Institute for Strategic Energy Analysis

# Clean Energy Technologies for Economic Development at Global and Community Scales

**Center of Coevolutionary Research for Sustainable Communities**

**Kyushu University, Fukuoka, Japan**

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Director, Joint Institute for Strategic Energy Analysis

U.S. National Renewable Energy Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY · COLORADOSCHOOLOFMINES · Colorado State University · Massachusetts Institute of Technology · STANFORD UNIVERSITY · University of Colorado Boulder

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NATIONAL RENEWABLE ENERGY LABORATORY

**Mission**: NREL advances the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies and provides the knowledge to integrate and optimize energy systems.

**Example Technology Areas:**


- 1800 employees, plus 400 postdoctoral researchers, interns, visiting professionals
- 327-acre campus in Golden, Colorado & 305-acre National Wind Technology Center 13 miles north
- 61 R&D 100 awards. More than 1000 scientific and technical materials published annually

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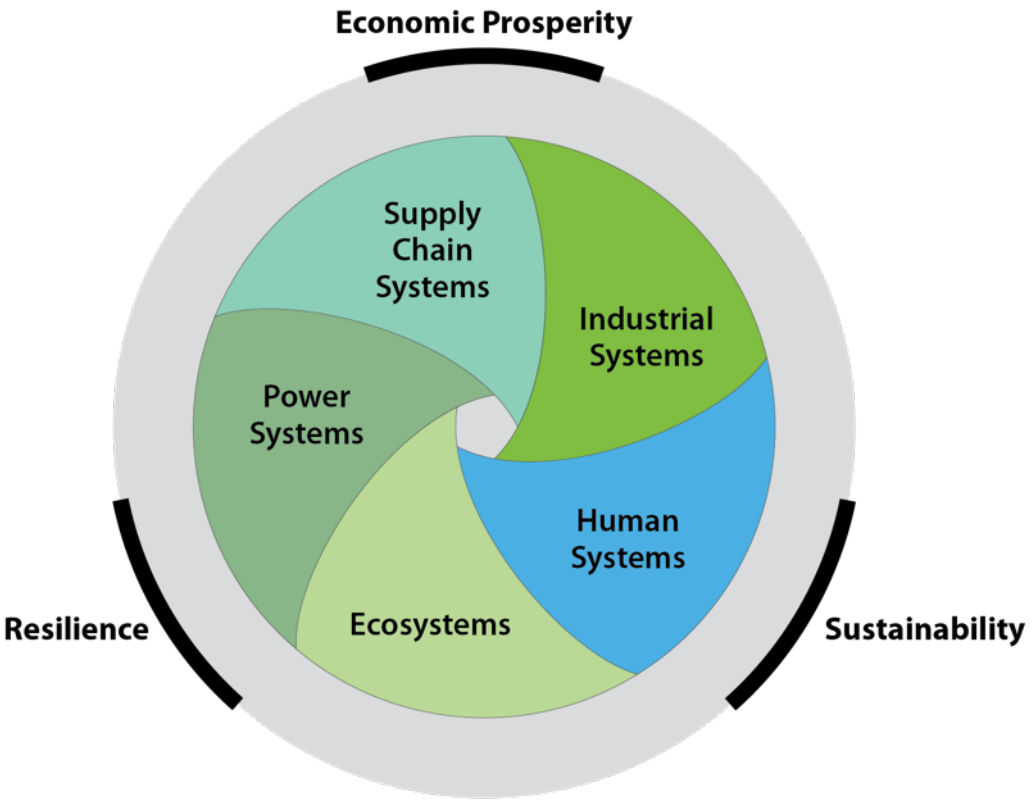
# JISEA

## Joint Institute for Strategic Energy Analysis

*Connecting technologies, economic sectors, and continents to catalyze the transition to the 21st century energy economy.*

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# Outline

- Energy Markets and Trends
- Clean Energy Technologies
  - Solar Photovoltaics
  - Lithium Ion Batteries
- Manufacturing and Economic Development

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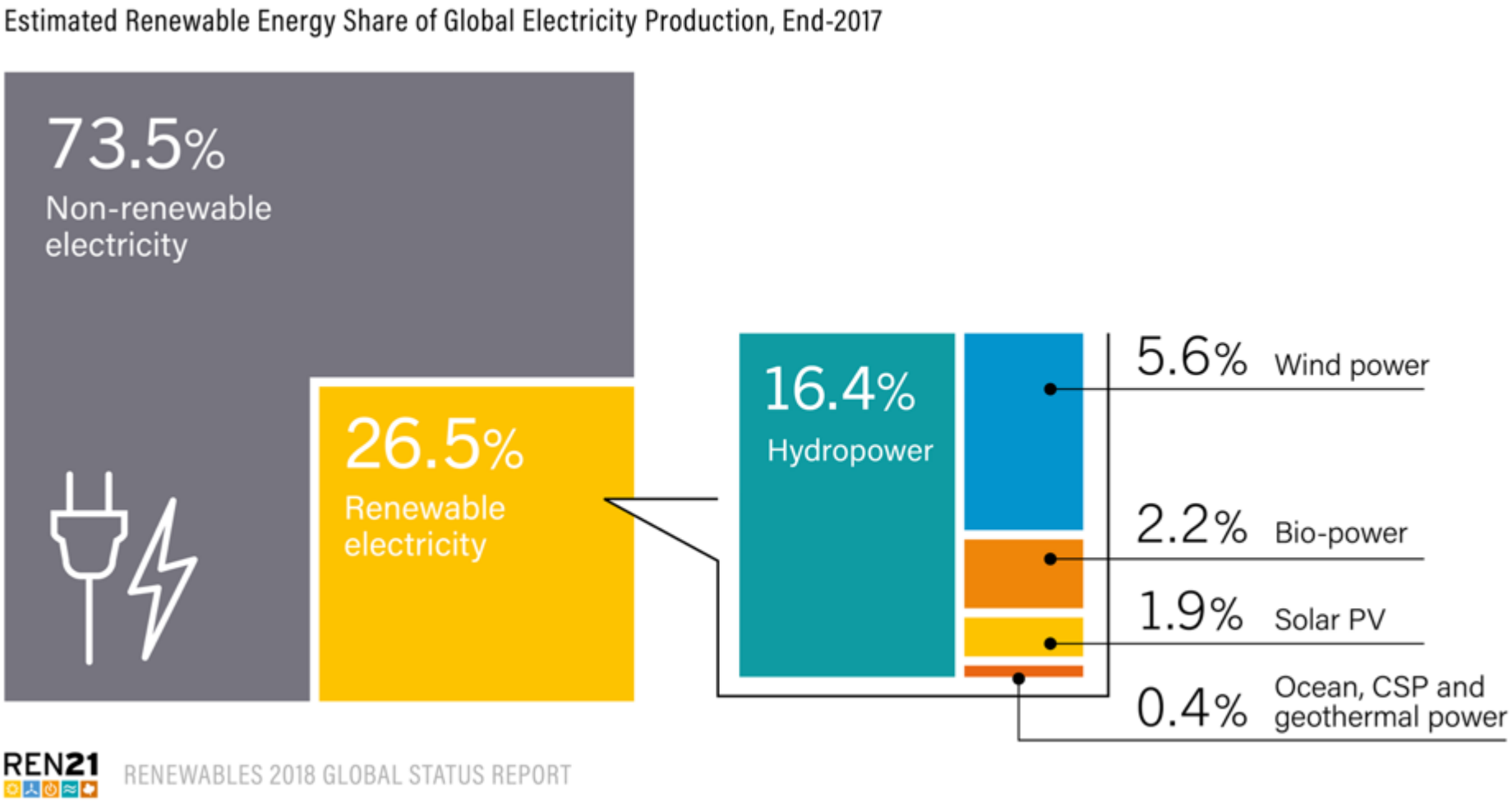
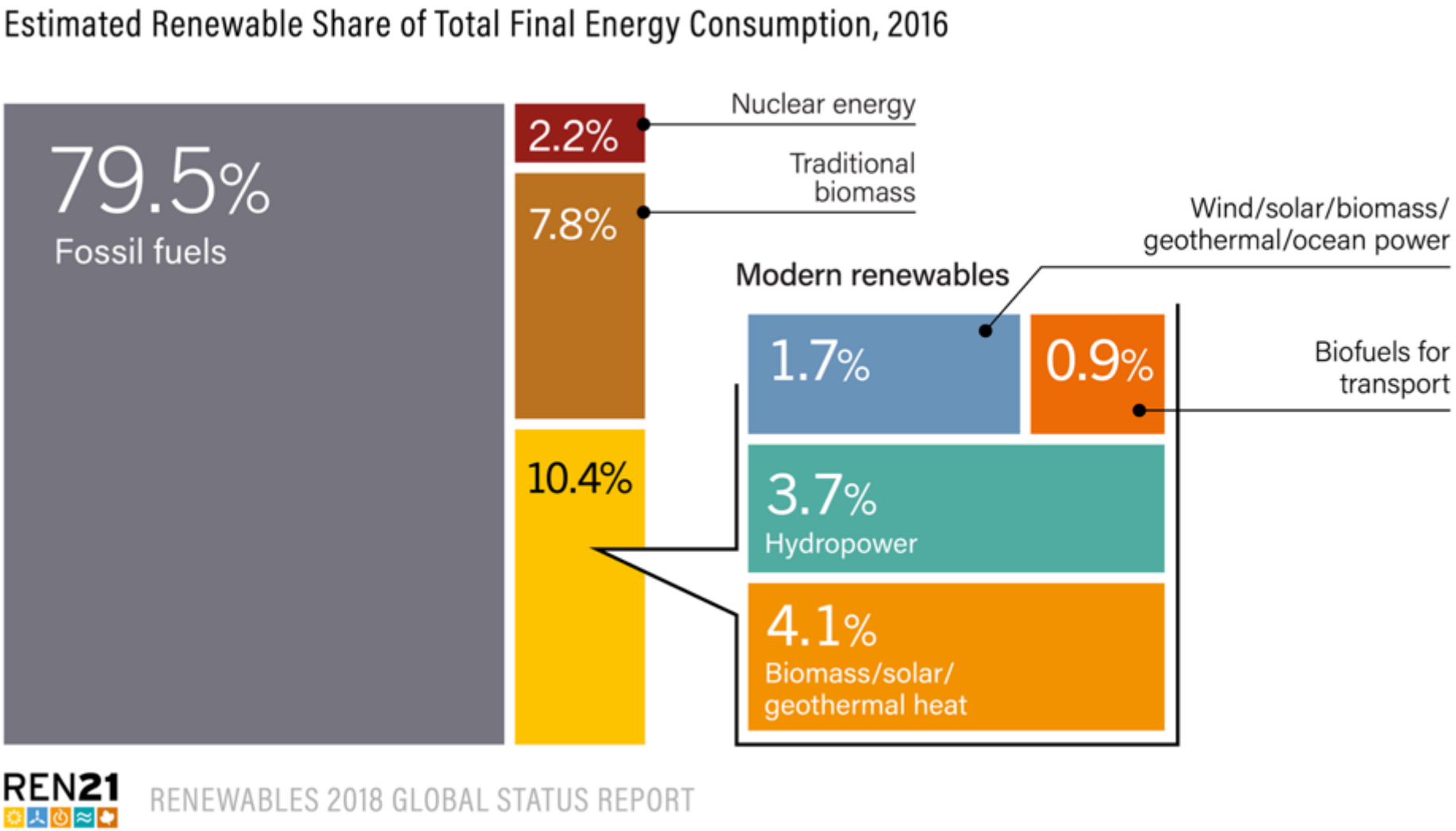
# Global share of renewable energy



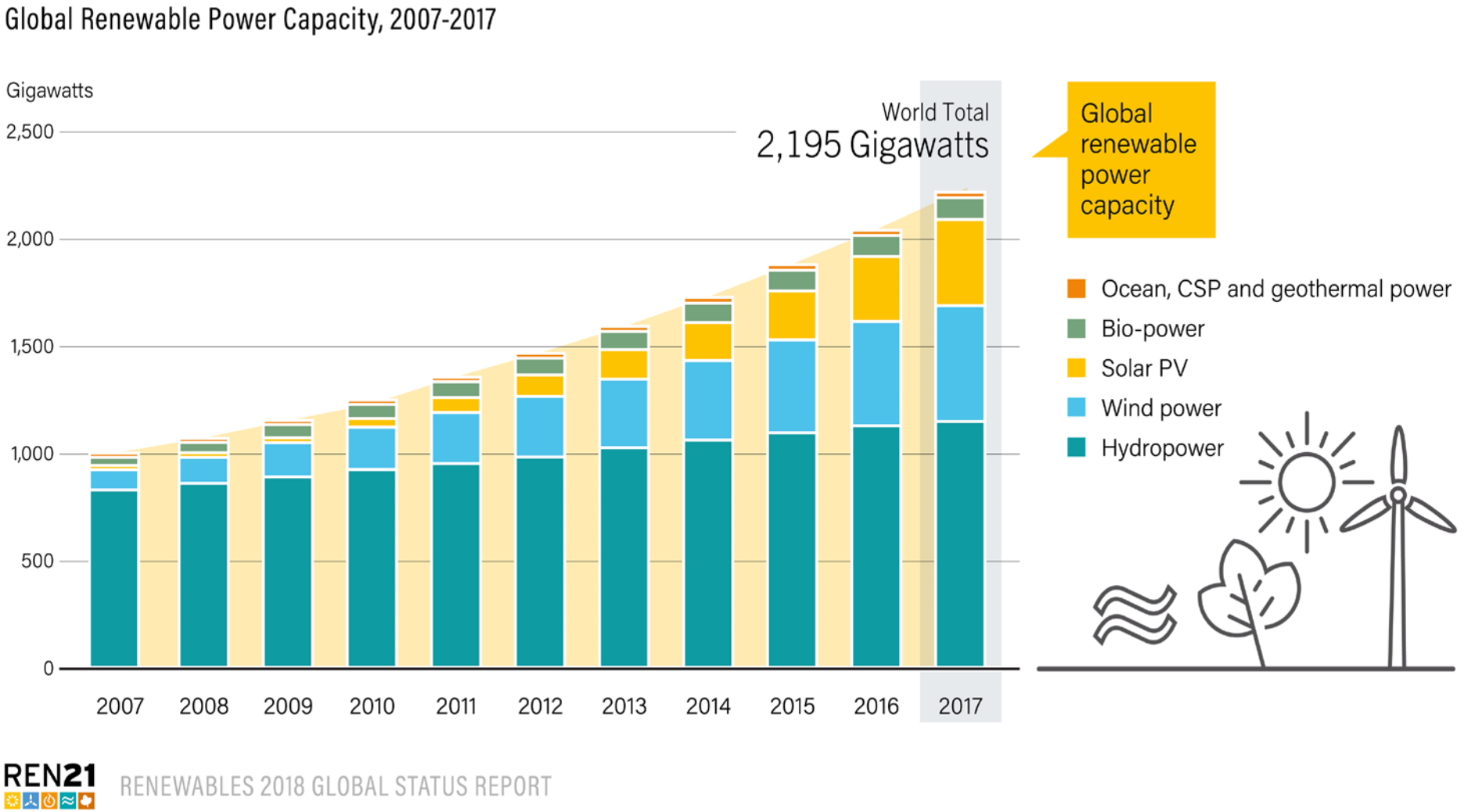

Source: REN21 Renewables 2018 Global Status Report, http://www.ren21.net/gsr-2018/

# Global share of renewable energy



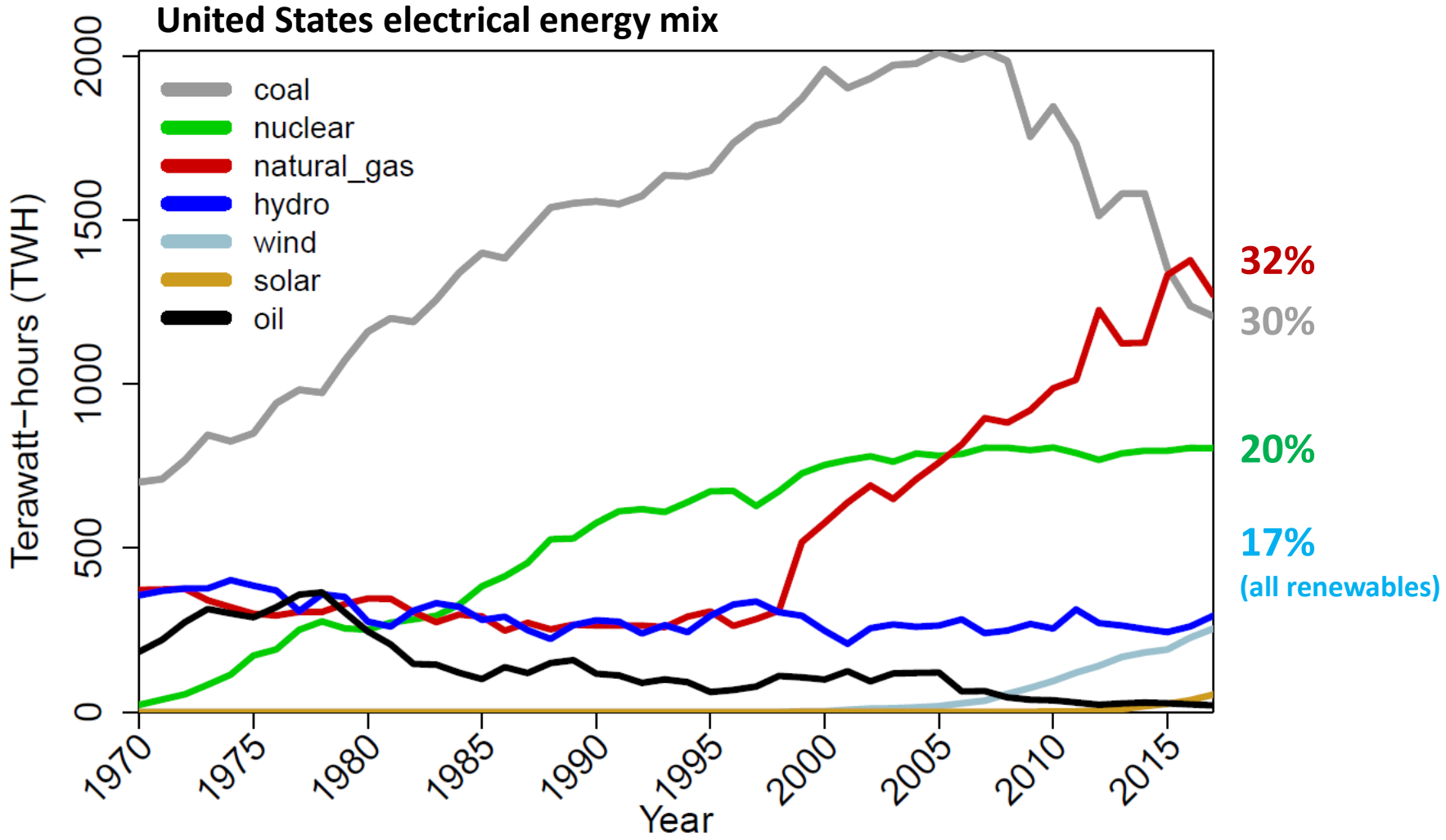

Source: REN21 Renewables 2018 Global Status Report, http://www.ren21.net/gsr-2018/

# Global growth of renewable energy




Source: REN21 Renewables 2018 Global Status Report, http://www.ren21.net/gsr-2018/

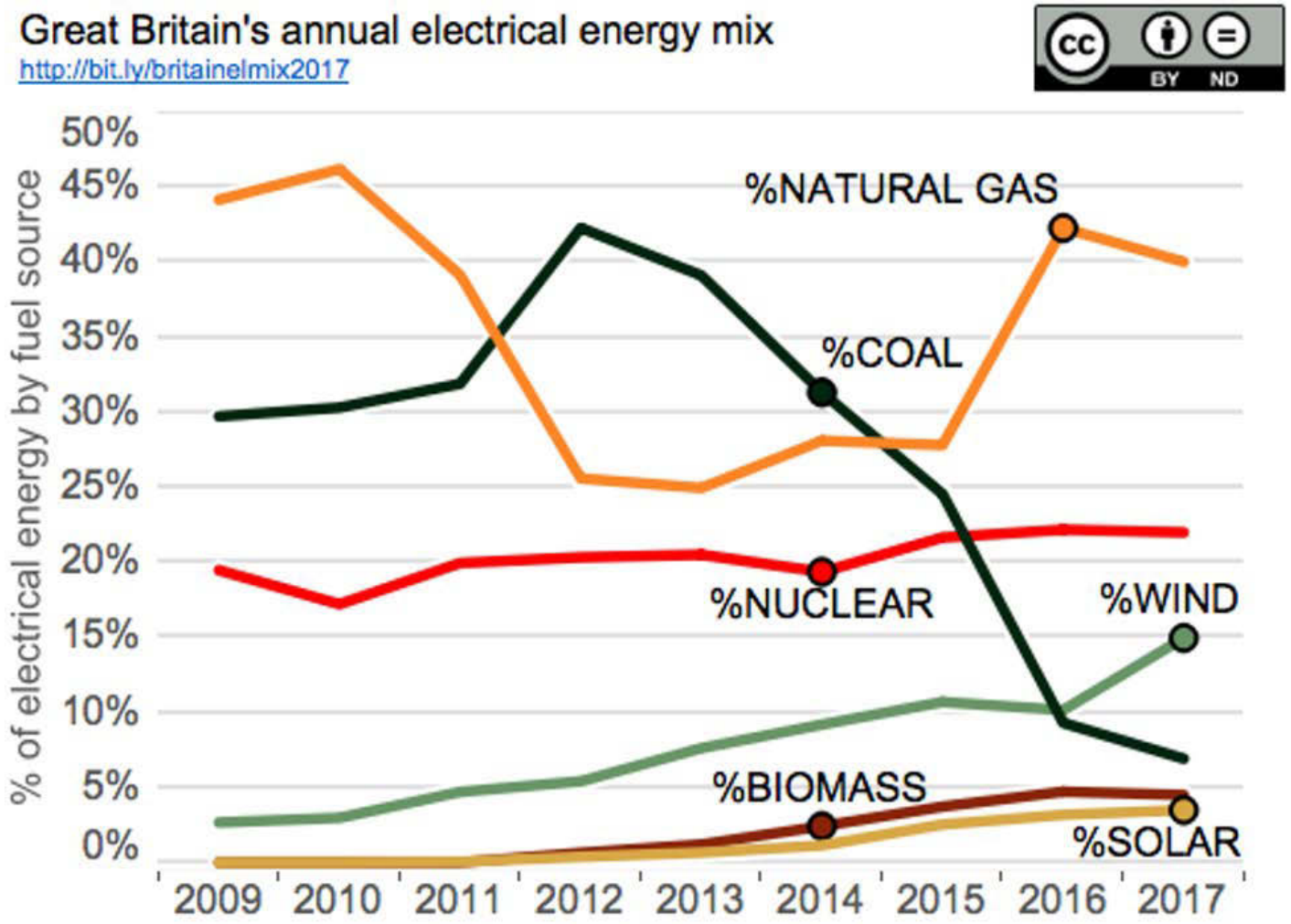
# Electricity Trending to Gas and Renewables




Power sector is undergoing profound transformation, shifting from coal to natural gas and renewable power generation.

Source: EIA Electric Power Monthly and Form EIA-923.

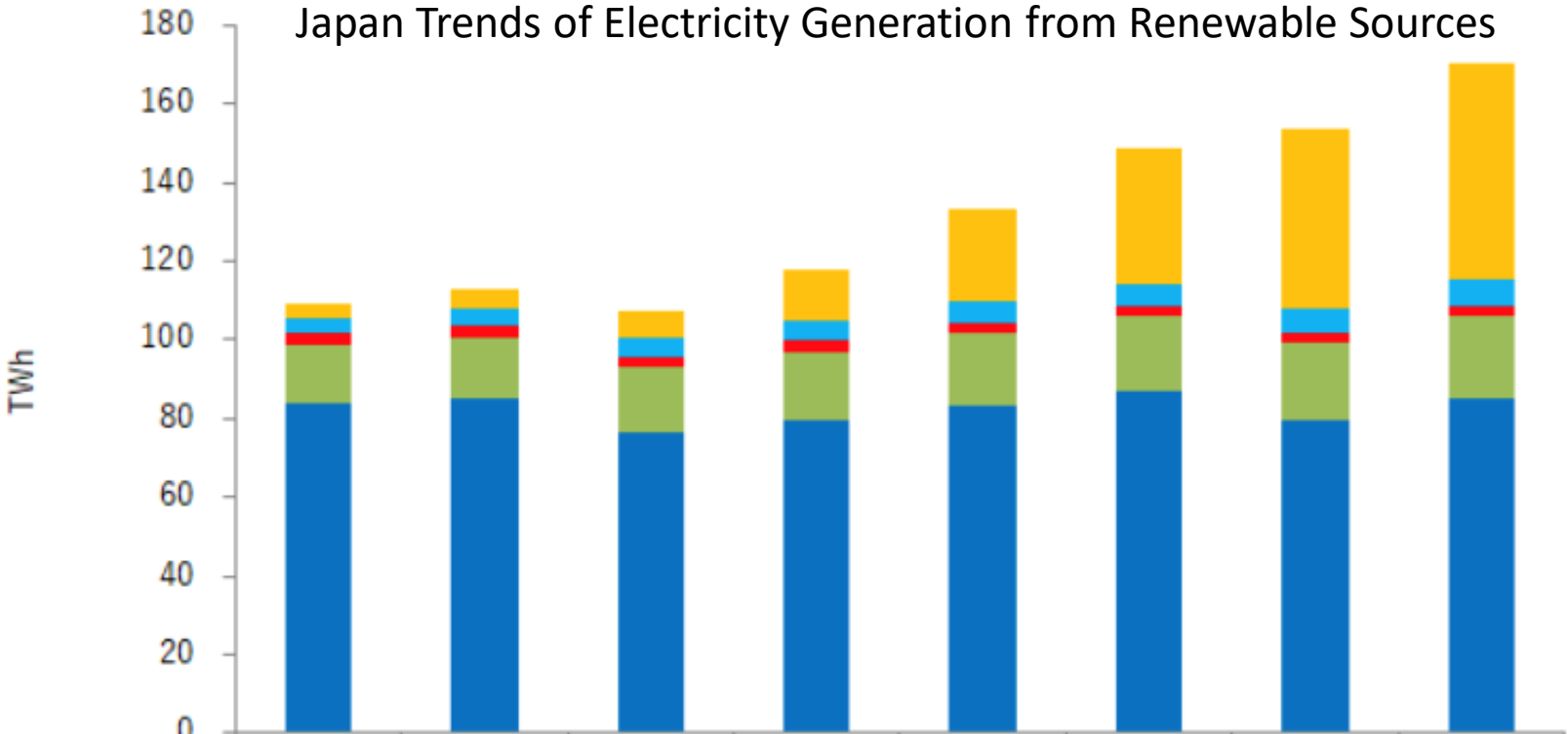
# Electricity Trending to Gas and Renewables




Power sector is undergoing profound transformation, shifting from coal to natural gas and renewable power generation.

Source: Wilson, G. and I. Staffell, Winds of change: Britain now generates twice as much electricity from wind as coal, The Conversation, 5 Jan 2018, https://theconversation.com/winds-of-change-britain-now-generates-twice-as-much-electricity-from-wind-as-coal-89598.

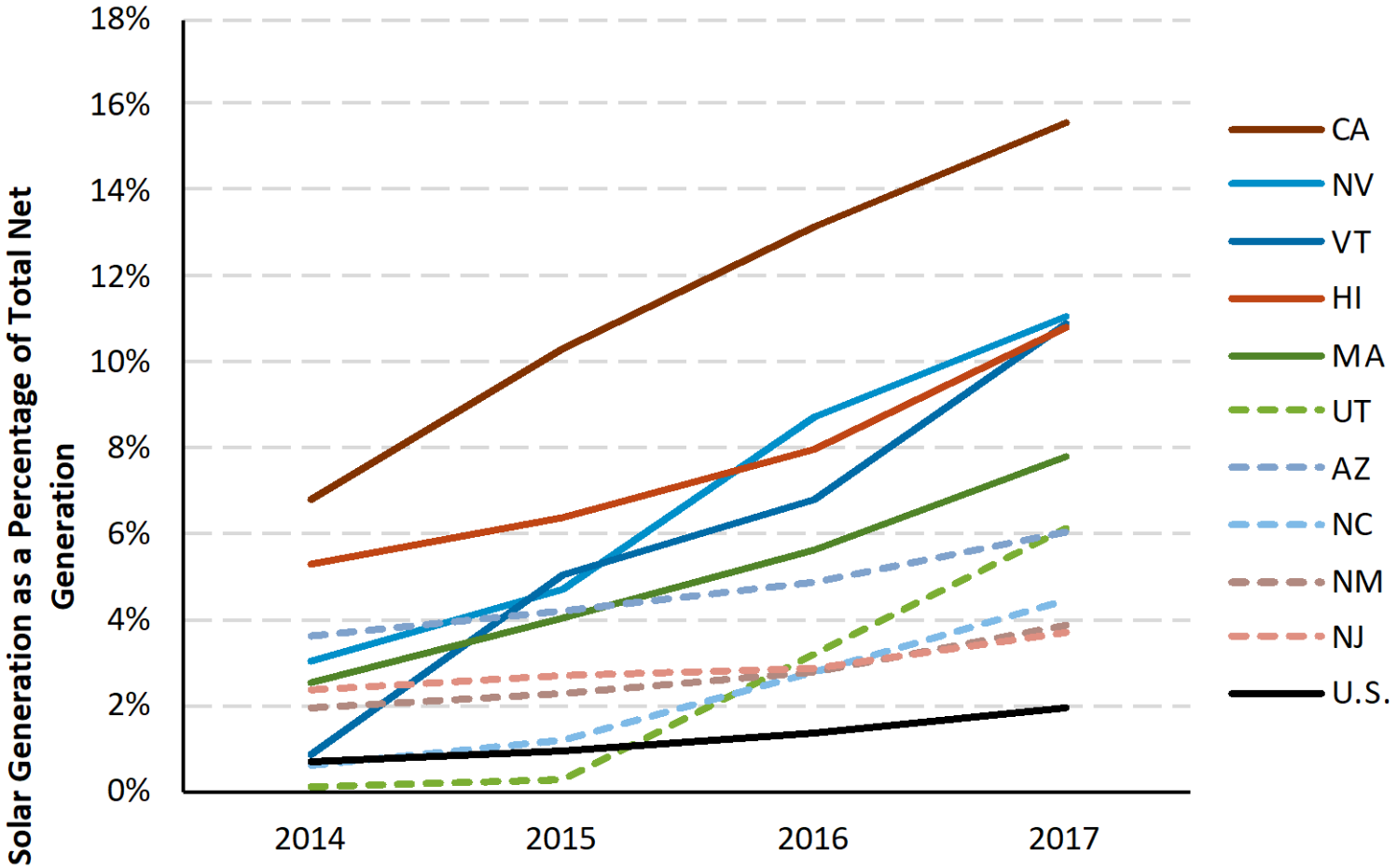
# Electricity Trending to Gas and Renewables




| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| Solar | 4 | 5 | 7 | 13 | 23 | 35 | 46 | 55 |
| Wind | 4 | 5 | 5 | 5 | 5 | 6 | 6 | 6 |
| Geothermal | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 |
| Bioenergy | 15 | 16 | 17 | 18 | 18 | 19 | 20 | 22 |
| Hydropower | 84 | 85 | 77 | 79 | 84 | 87 | 79 | 85 |

Source: U.E. Energy Information Agency, https://www.eia.gov/todayinenergy/detail.php?id=37633 .
Renewable Energy Institute, https://www.renewable-ei.org/en/statistics/electricity/

# Solar Generation as a Percentage of Total Generation, 2014-2017, by State



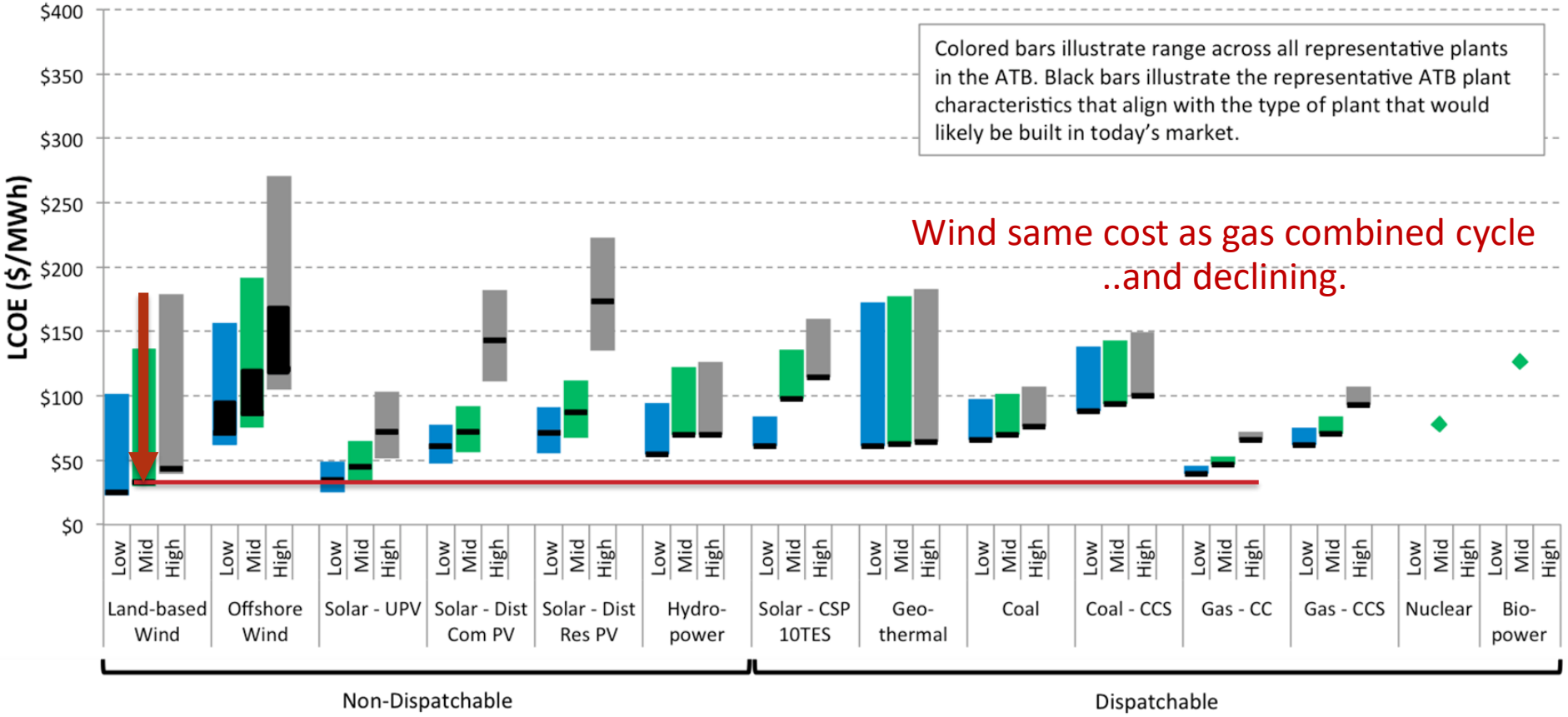

**Note:** EIA monthly data for 2017 are not final. Additionally, smaller utilities report information to EIA on a yearly basis, and therefore, a certain amount of solar data has not yet been reported. "Net Generation" includes DPV generation. Net generation does not take into account imports and exports to and from each state and therefore the percentage of solar consumed in each state may vary from its percentage of net generation.

**Sources:** EIA, "Electric Power Monthly," forms EIA-023, EIA-826, and EIA-861 (February 2018).

Source: NREL, Q4 2017/Q1 2018 Solar Industry Update, May 2018.

# Cost of Renewable & Traditional Electricity Equalizing

**Levelized Cost of Electricity ranges by technology.** Values are in 2015$.

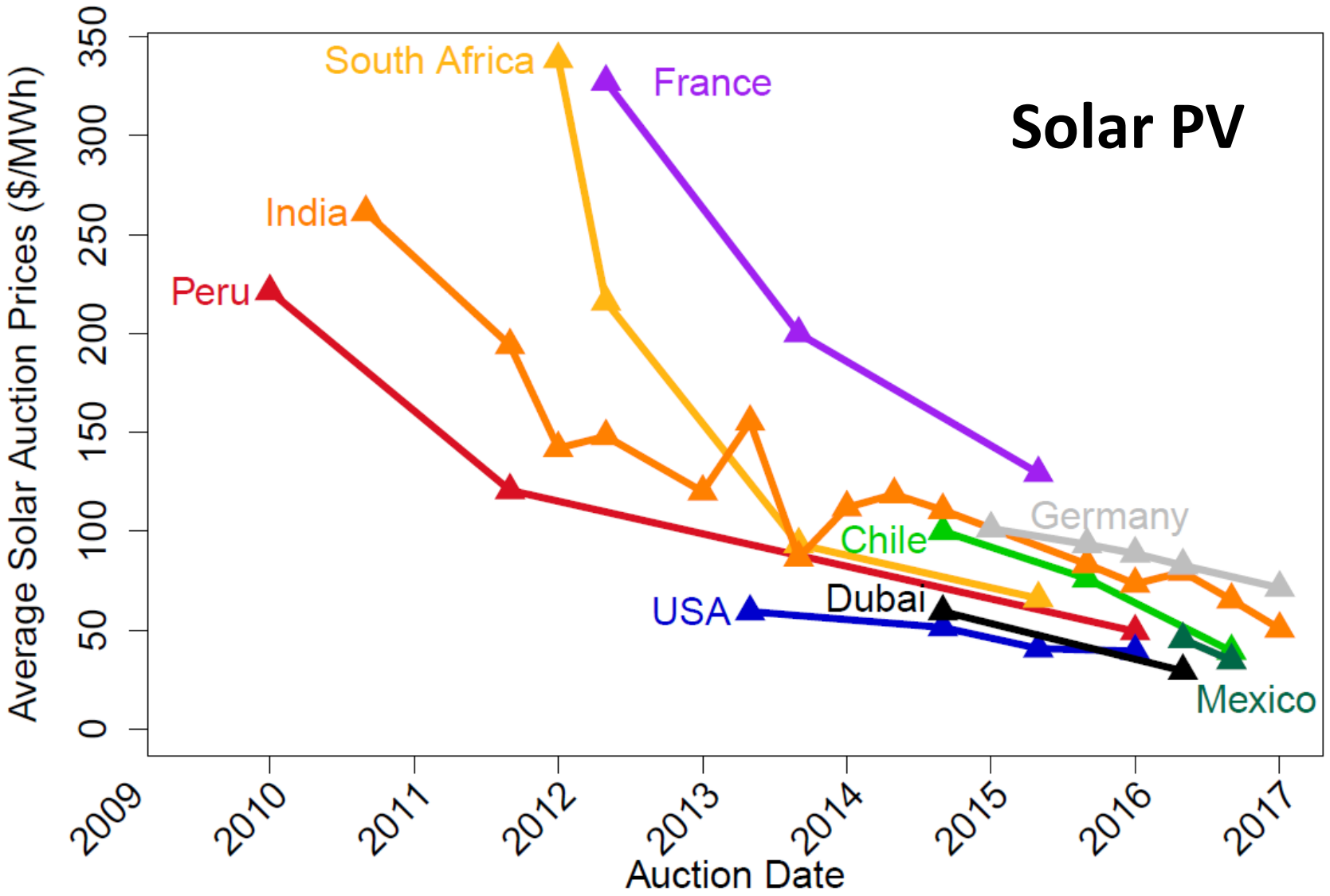



**2017 ATB LCOE range by technology for 2030 based on current market conditions**

Source: National Renewable Energy Laboratory Annual Technology Baseline (2017), http://atb.nrel.gov

Variability due to: Technology; Location; Time (Present v. Future)

# Cost of Renewable Electricity at Auctions Driving Decrease




Source: IRENA Renewable Energy Auctions: Analysing 2016 (2017)

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# Renewable energy is diverse

WIND

Onshore

Offshore

SOLAR PV

Residential: 1-10 kW scale

Commercial: 1-20 MW


Utility: 50-1000 MW

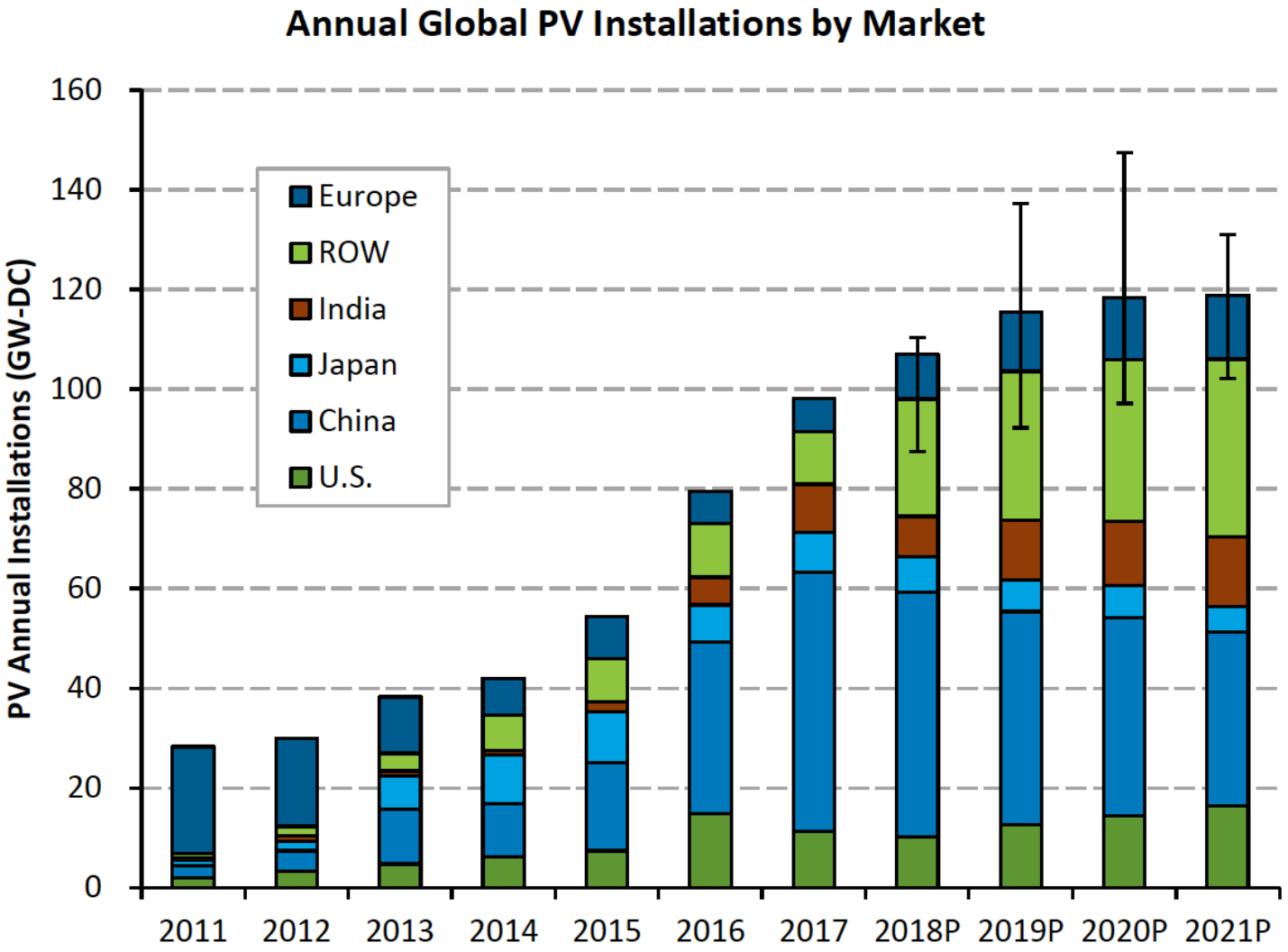
GEOTHERMAL

CONCENTRATING SOLAR

BIOMASS

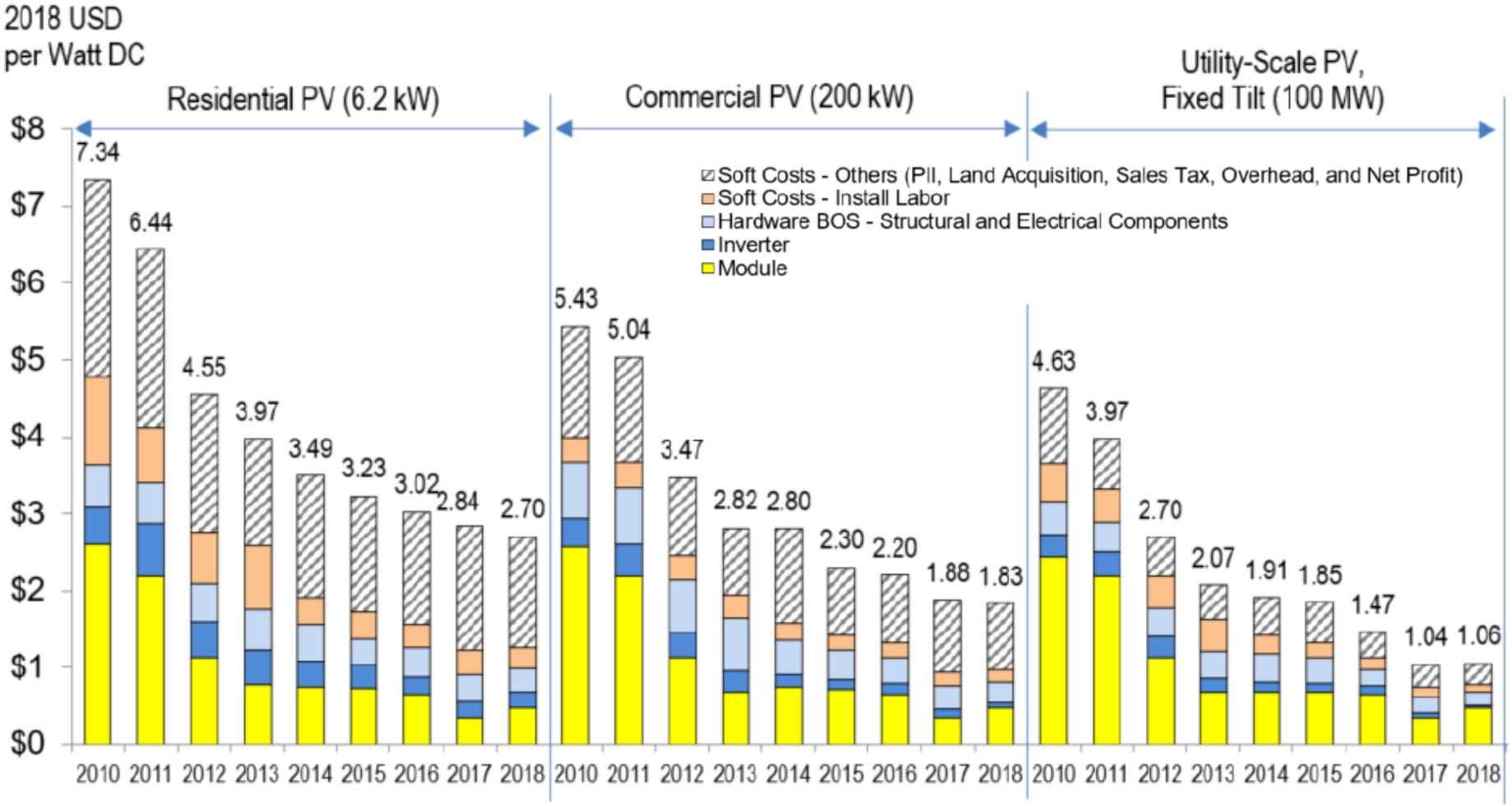
Images from https://images.nrel.gov/

# Global PV market expected to grow




Source: NREL, Q4 2017/Q1 2018 Solar Industry Update, May 2018.

# PV System Installation Prices

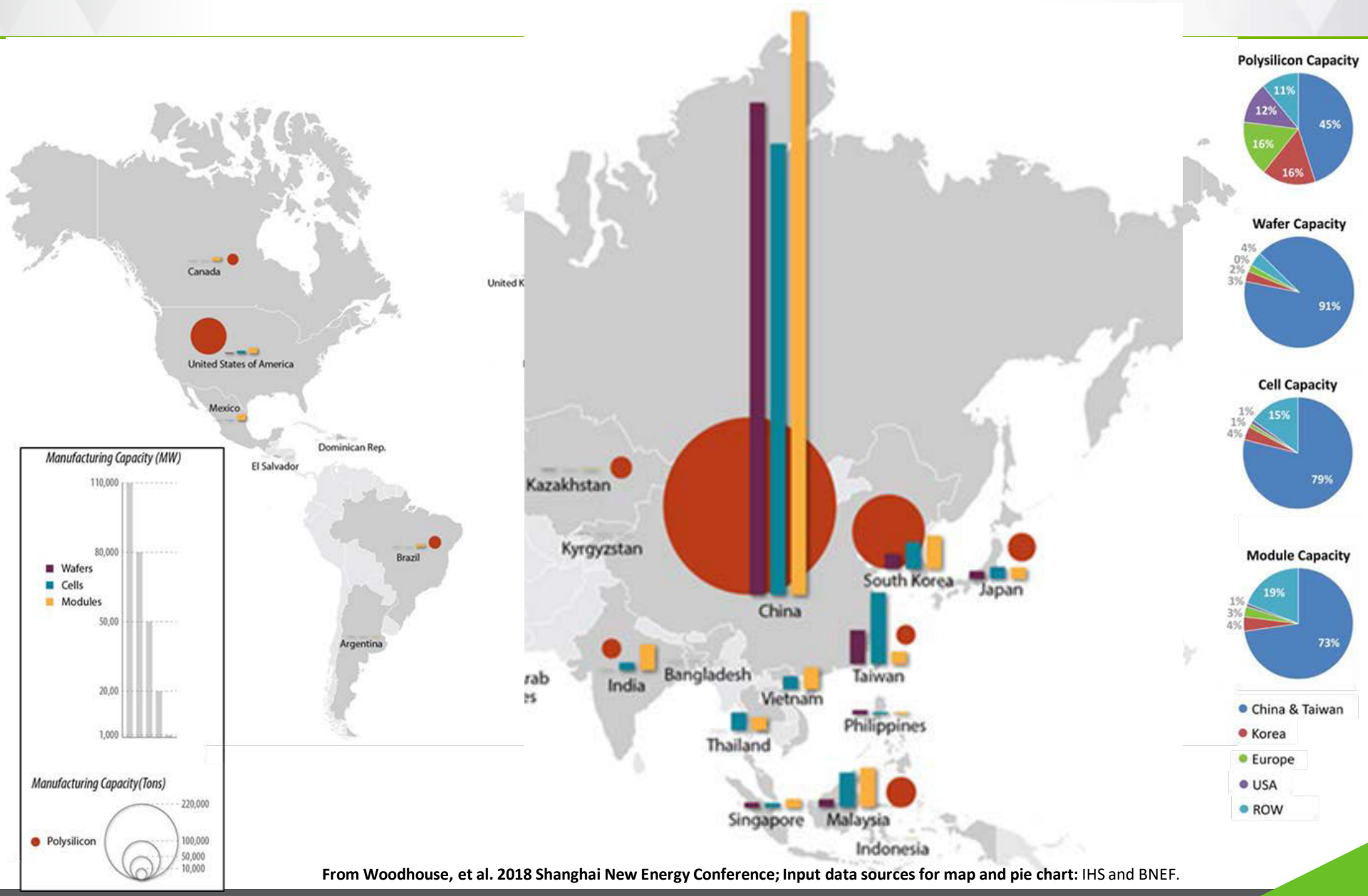



Source: NREL. The U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018, https://www.nrel.gov/docs/fy19osti/72399.pdf

# Supply chain of PV panels


Source: Benchmarks of Global Clean Energy Manufacturing, CEMAC, 2017, https://www.manufacturingcleanenergy.org/benchmark/.

# 2017 Global PV Manufacturing: Top 373 Companies




**From Woodhouse, et al. 2018 Shanghai New Energy Conference; Input data sources for map and pie chart:** IHS and BNEF.

# Balance of trade varies across supply chain (2016 data)

Economies that are net importers of end products may be major exporters of upstream processed materials and subcomponents of those same technologies.


Source: Benchmarks of Global Clean Energy Manufacturing, CEMAC, 2018, http://www.manufacturingcleanenergy.org/blog-20180326.html.

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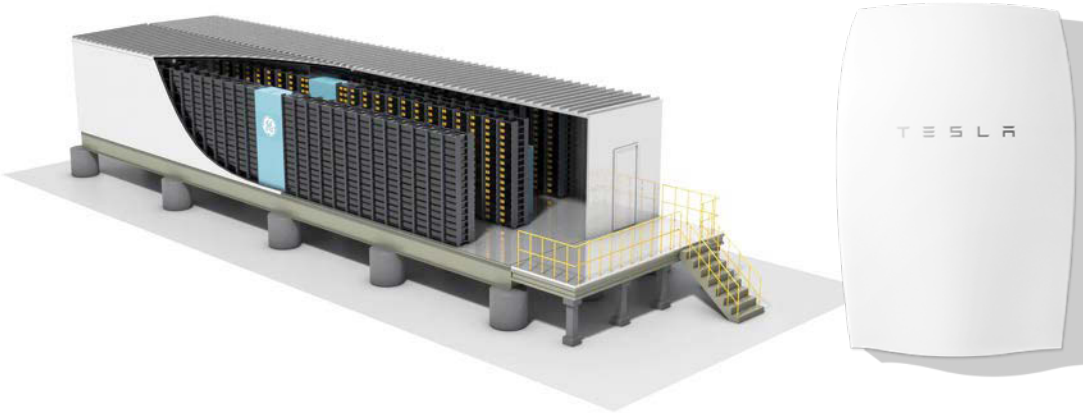
# Lithium ion battery markets

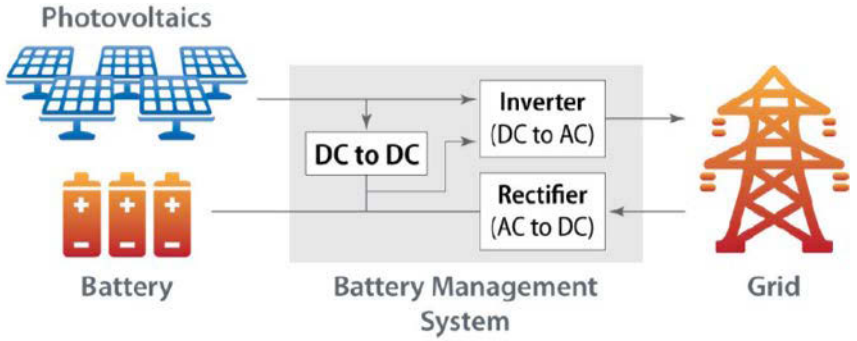
## Consumer Products

## Stationary

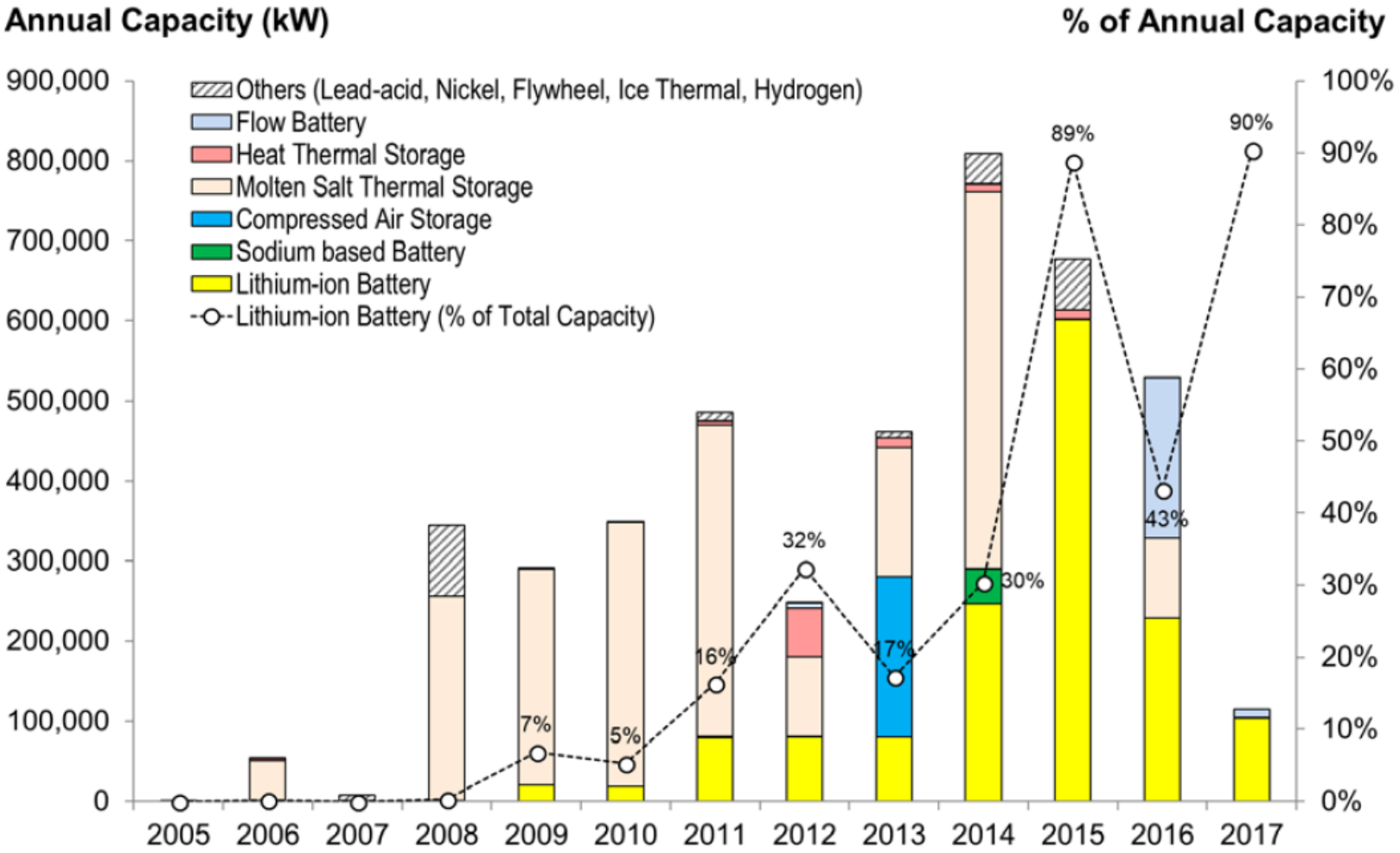



## Transportation

## Hybrid Stationary

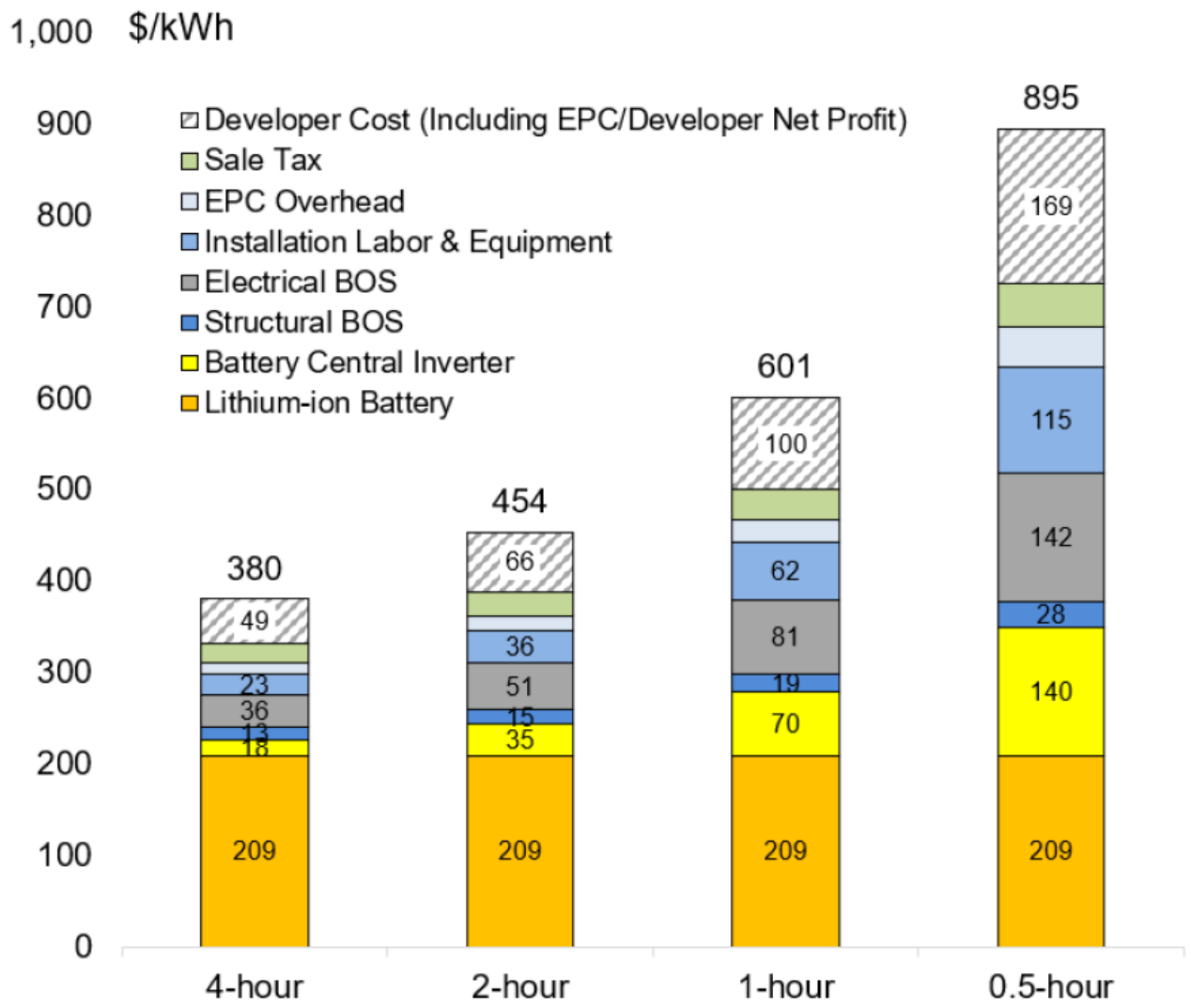


# Capacities of energy storage systems built worldwide



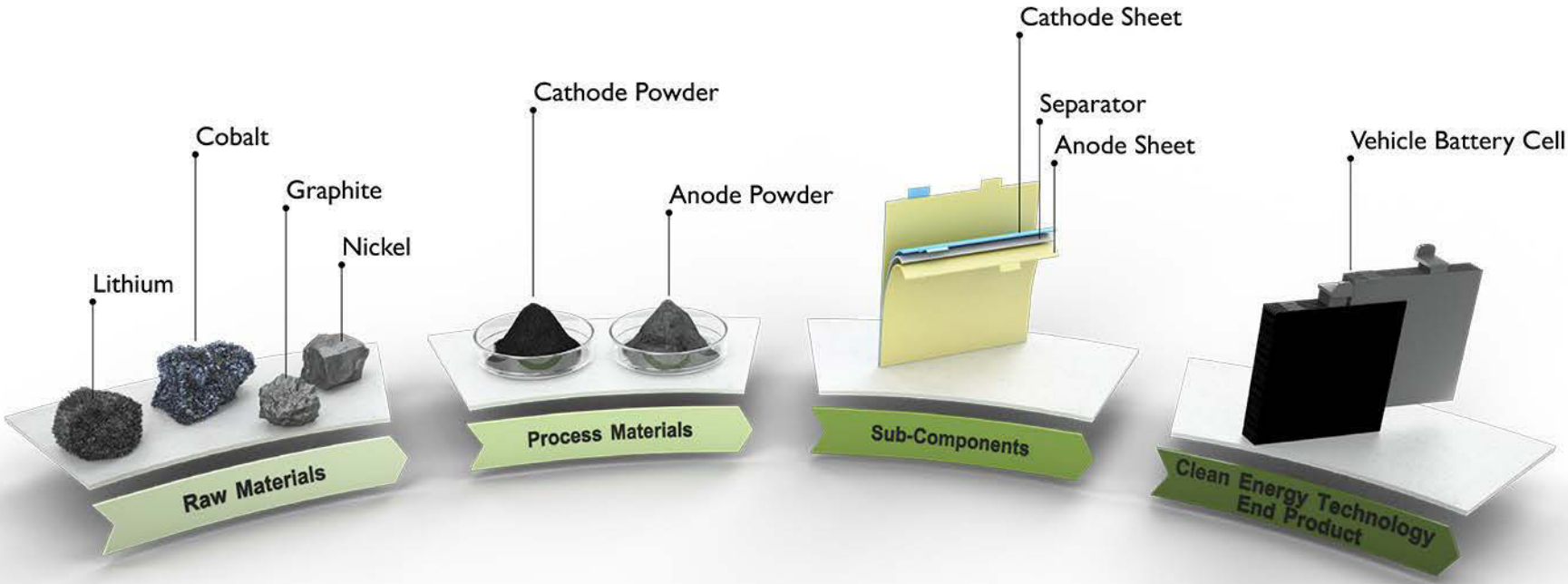

Source: NREL. 2018 U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark. https://www.nrel.gov/docs/fy19osti/71714.pdf.

# U.S. utility-scale lithium-ion standalone storage costs



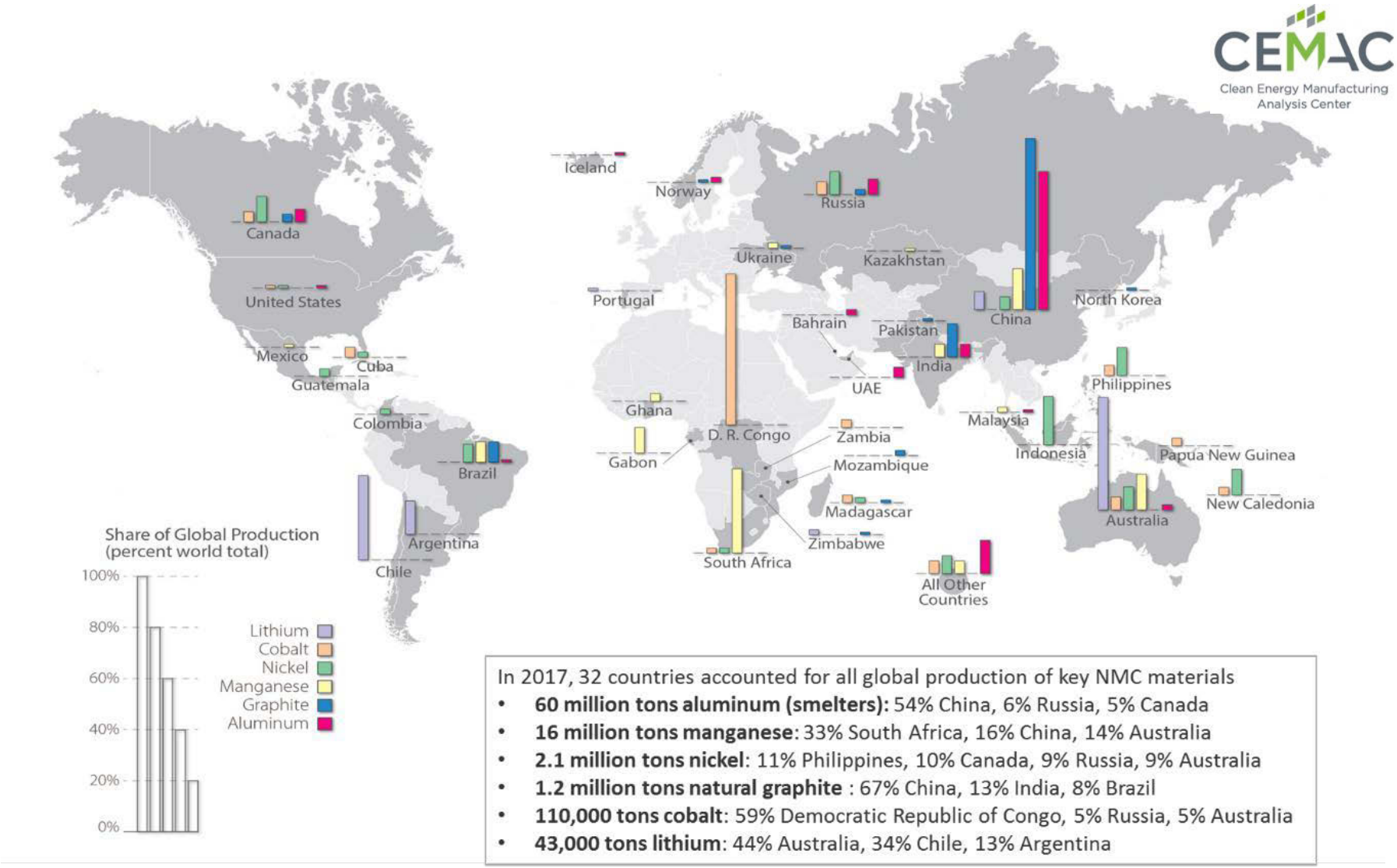

Source: NREL. 2018 U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark. https://www.nrel.gov/docs/fy19osti/71714.pdf.

# Supply chain of lithium ion batteries




Source: Benchmarks of Global Clean Energy Manufacturing, CEMAC, 2017, https://www.manufacturingcleanenergy.org/benchmark/.

# Distribution of critical materials for lithium ion battery manufacturing and possible risks

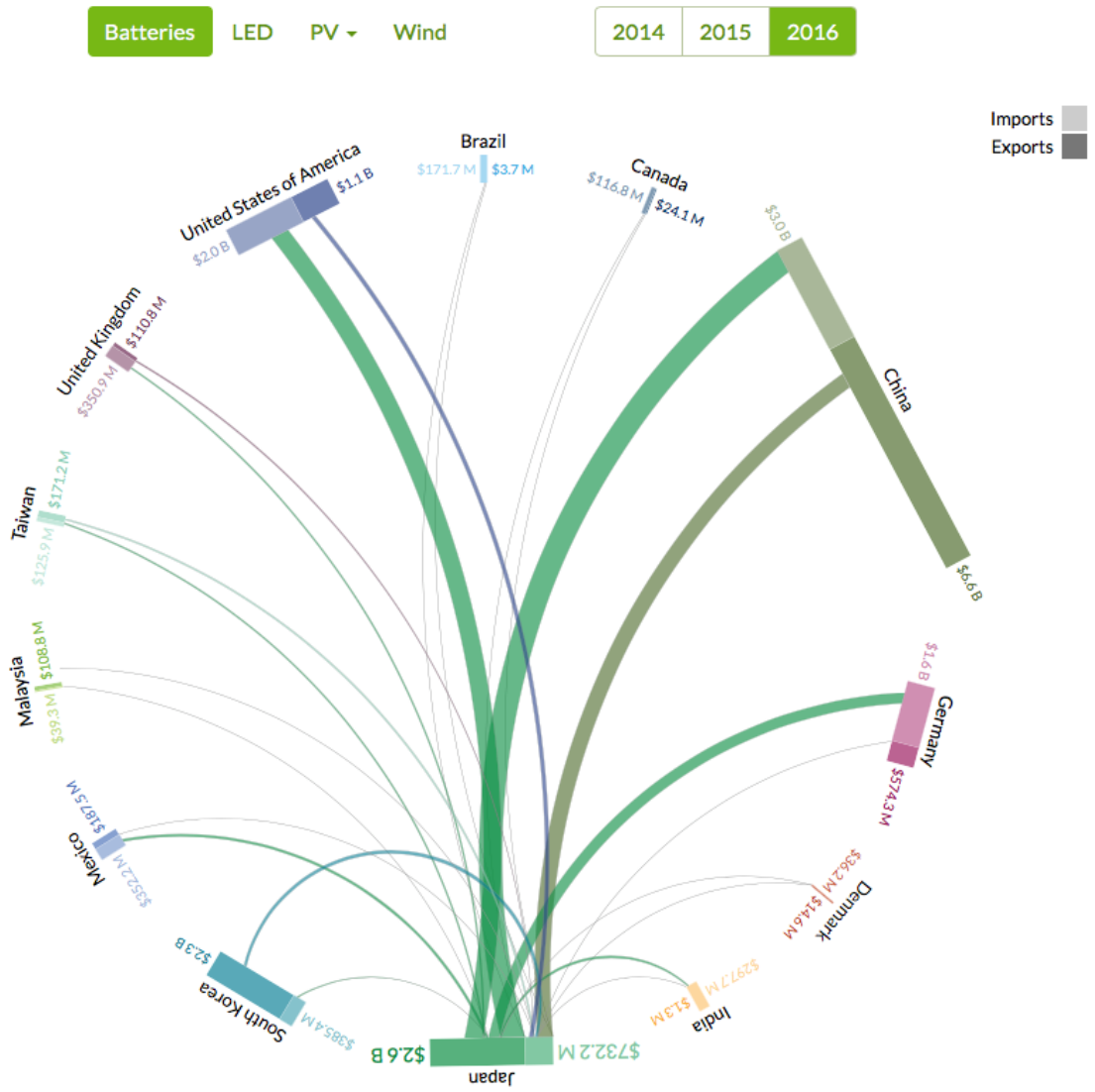



In 2017, 32 countries accounted for all global production of key NMC materials

- **60 million tons aluminum (smelters):** 54% China, 6% Russia, 5% Canada
- **16 million tons manganese**: 33% South Africa, 16% China, 14% Australia
- **2.1 million tons nickel**: 11% Philippines, 10% Canada, 9% Russia, 9% Australia
- **1.2 million tons natural graphite** : 67% China, 13% India, 8% Brazil
- **110,000 tons cobalt**: 59% Democratic Republic of Congo, 5% Russia, 5% Australia
- **43,000 tons lithium**: 44% Australia, 34% Chile, 13% Argentina

Source: Clean Energy Manufacturing Analysis Center Blog, 2018, https://www.manufacturingcleanenergy.org/blog-20180815.html.

# Trade in Li-ion battery cells for vehicles (2016 data)




Source: CEMAC, Benchmarks of Global Clean Energy Manufacturing, Forthcoming. Available at https://www.manufacturingcleanenergy.org/benchmark/battery.php.

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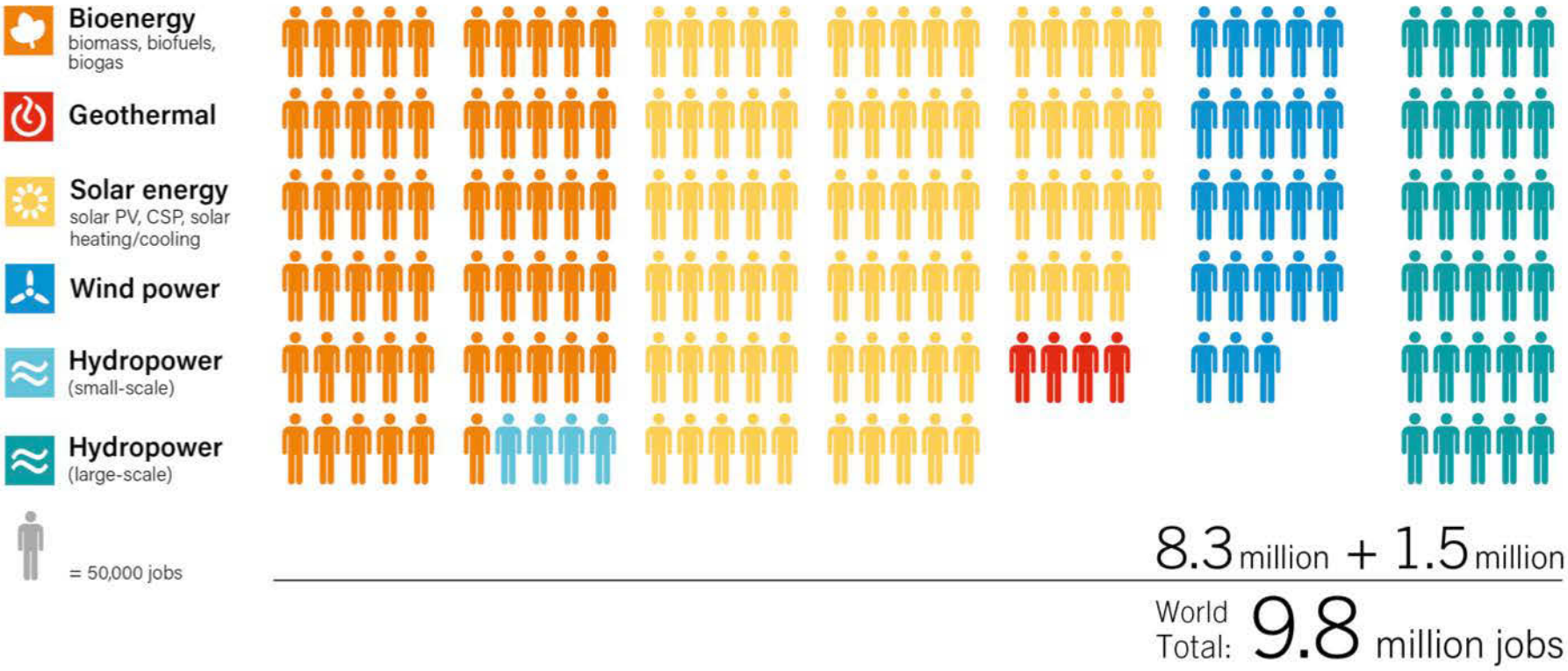
# Clean energy is important to communities

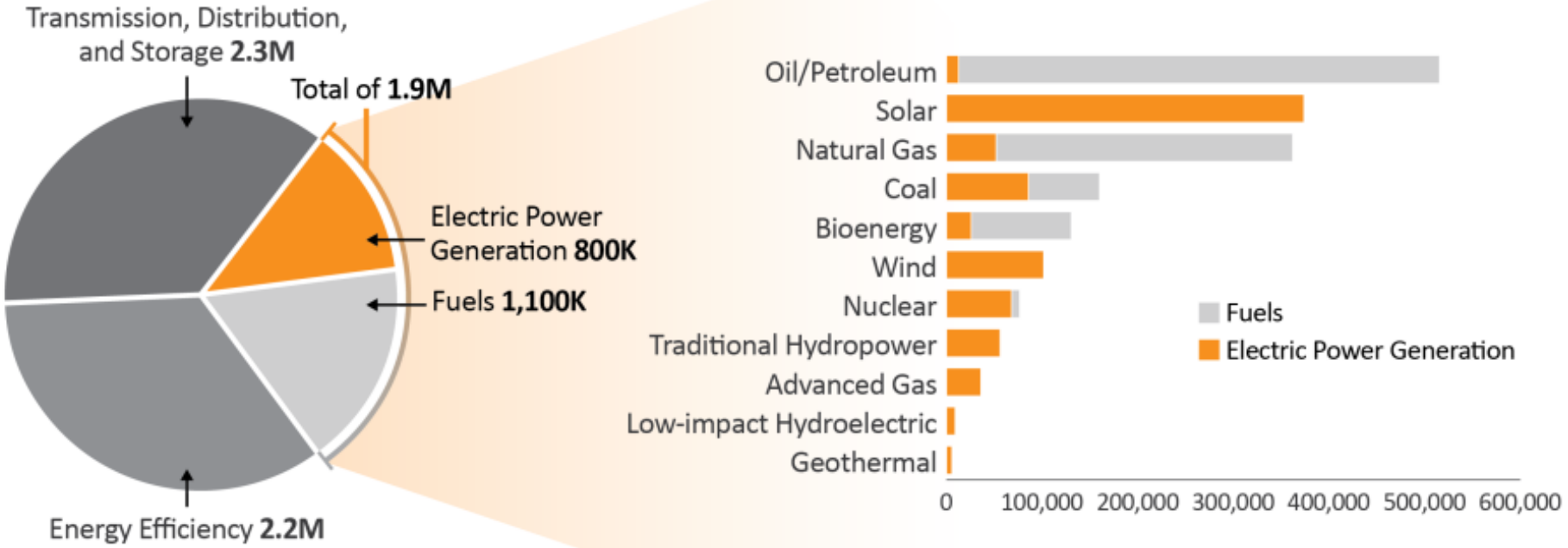
# The renewable energy transition creates new jobs




Source: Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2017 Global Status Report

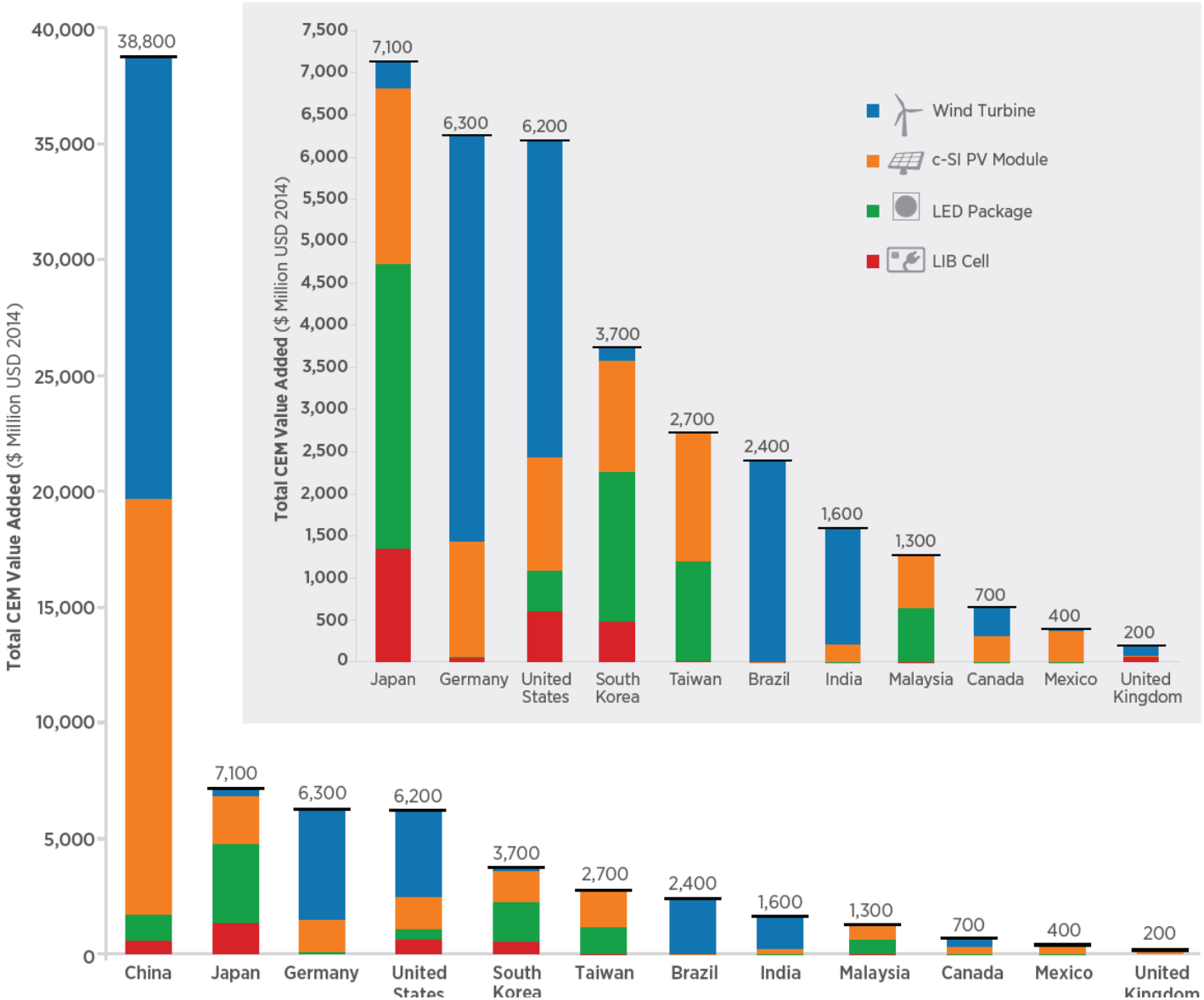
# Solar Employs 43% of U.S. Electric Power Workforce; Second in total employment to petroleum

6.4 million Americans employed in energy sectors




Source: *U.S. Energy and Employment Report*. U.S. Department of Energy, January 2017

# Manufacturing of clean energy technologies creates economic value, especially for Japan (2014 data)



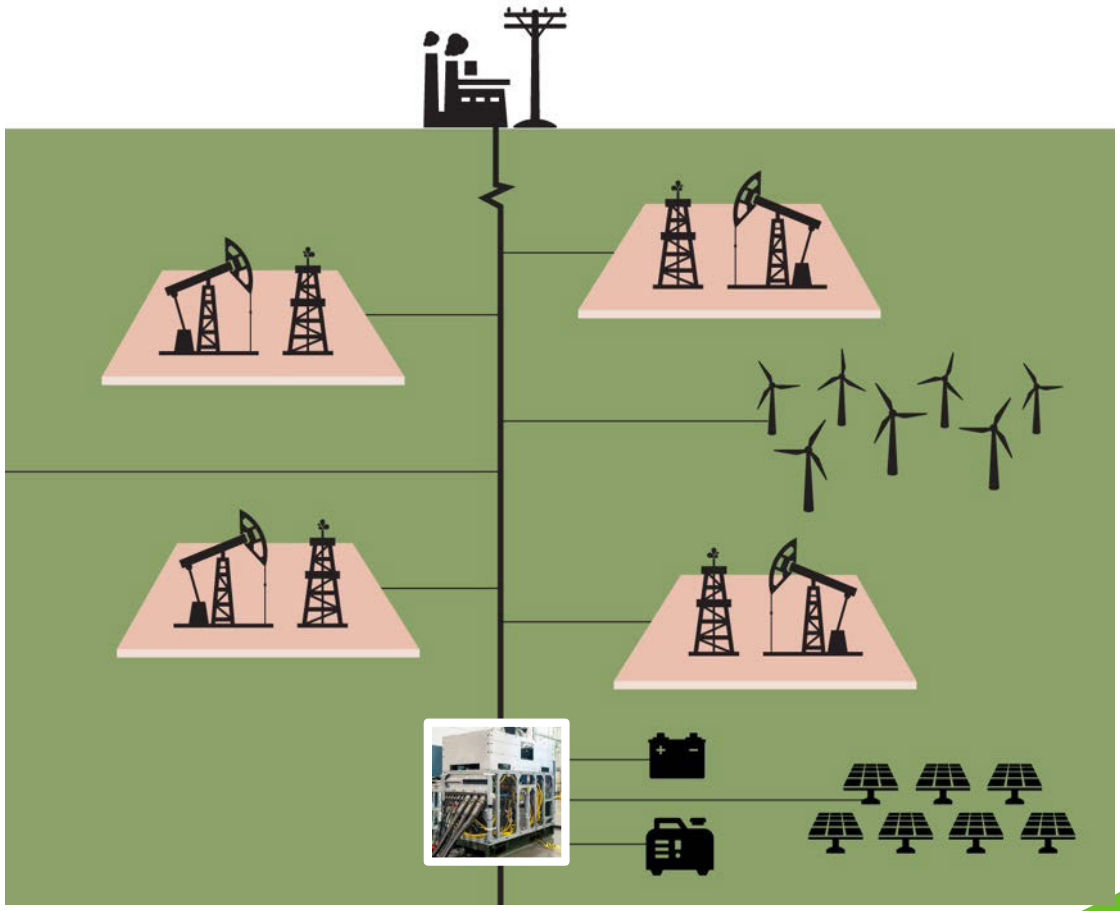

Manufacturing value added for c-Si PV modules, wind turbine components, LED packages, and LDV Li-ion battery cells is highest for China, Japan, Germany and the United States and lowest for the United Kingdom, Mexico, and Canada.

Source: Benchmarks of Global Clean Energy Manufacturing, CEMAC, 2017, https://www.manufacturingcleanenergy.org/benchmark/.

# Industry must change to join clean energy transition

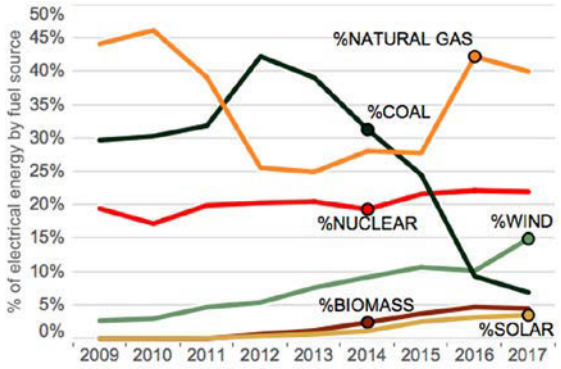
- Electrification of all equipment at wellpad connected via microgrid
- Power could consist of:
  - Field/Flare Gas fired generator
  - Solar PV/wind systems
  - Fuel cells
  - Energy Storage
    - Hydrogen
    - Batteries
  - Grid power (or offgrid)
- Benefits:
  - Resiliency during outages
  - Optimize for least cost
  - Reduce emissions
- Leverage work on
  - Remote bases & communities
  - Islands

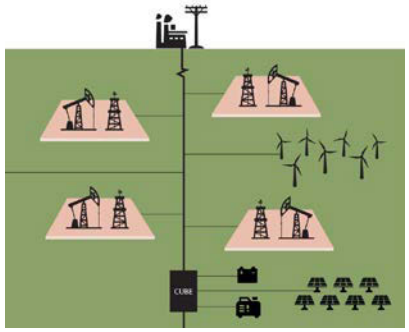
**Example: Clean power electrification of oil and gas operations**



# Energy-Water-Food Nexus important to communities

# Conclusion and Discussion



- Global trend toward cleaner and lower cost energy with potential for growth in manufacturing, extraction, deployment
- Manufacturing and deployment of clean technologies can have a positive effect on community economies
- Increasing intersection of renewable energy with other sectors of community economies:
  - Agriculture
  - Manufacturing & Industry
  - Transportation

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# Questions and Discussion

# Thank you!

# Disclaimer

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