ECE 333 – GREEN ELECTRIC ENERGY

Lecture 16: *PV* Status and Issues

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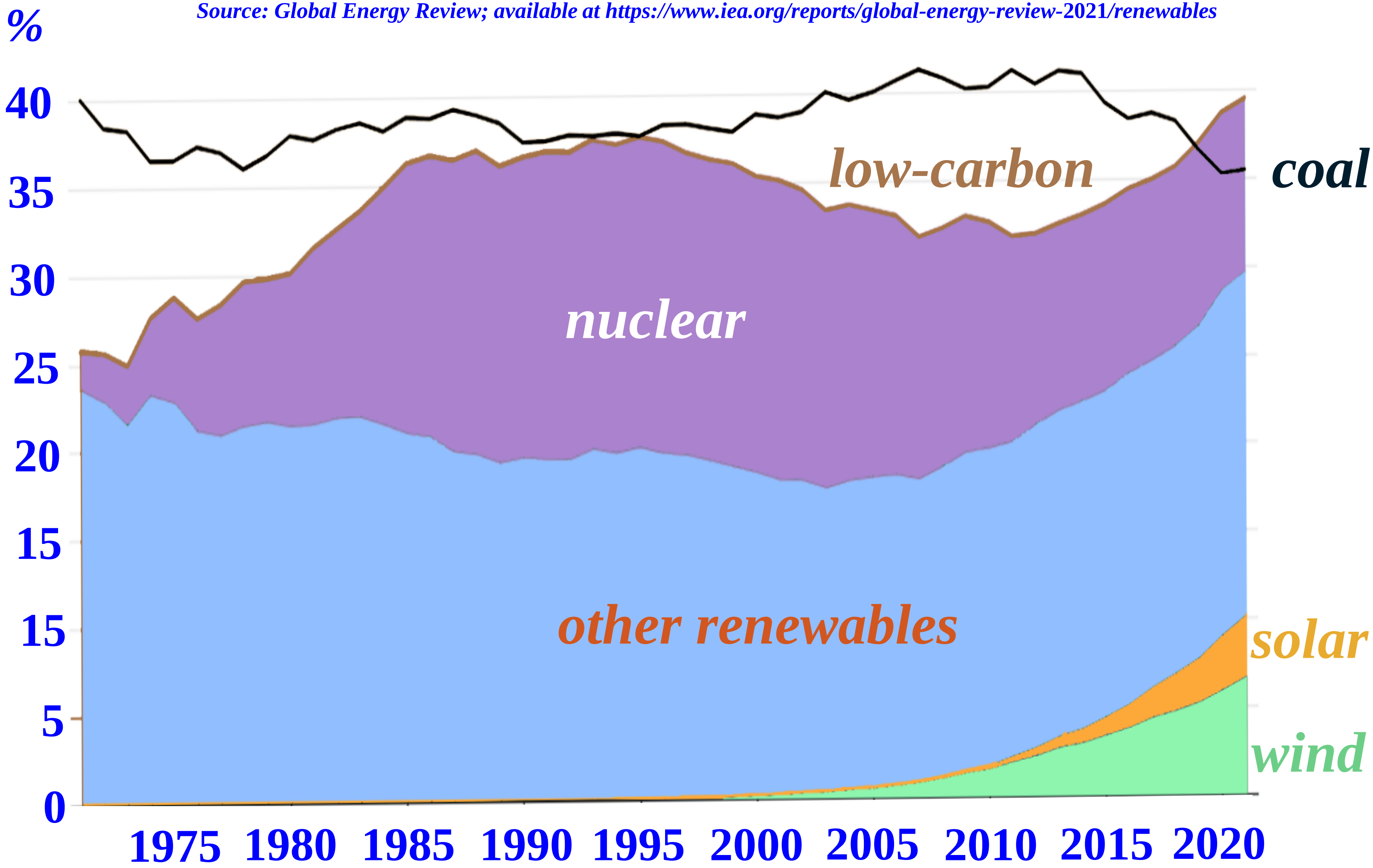
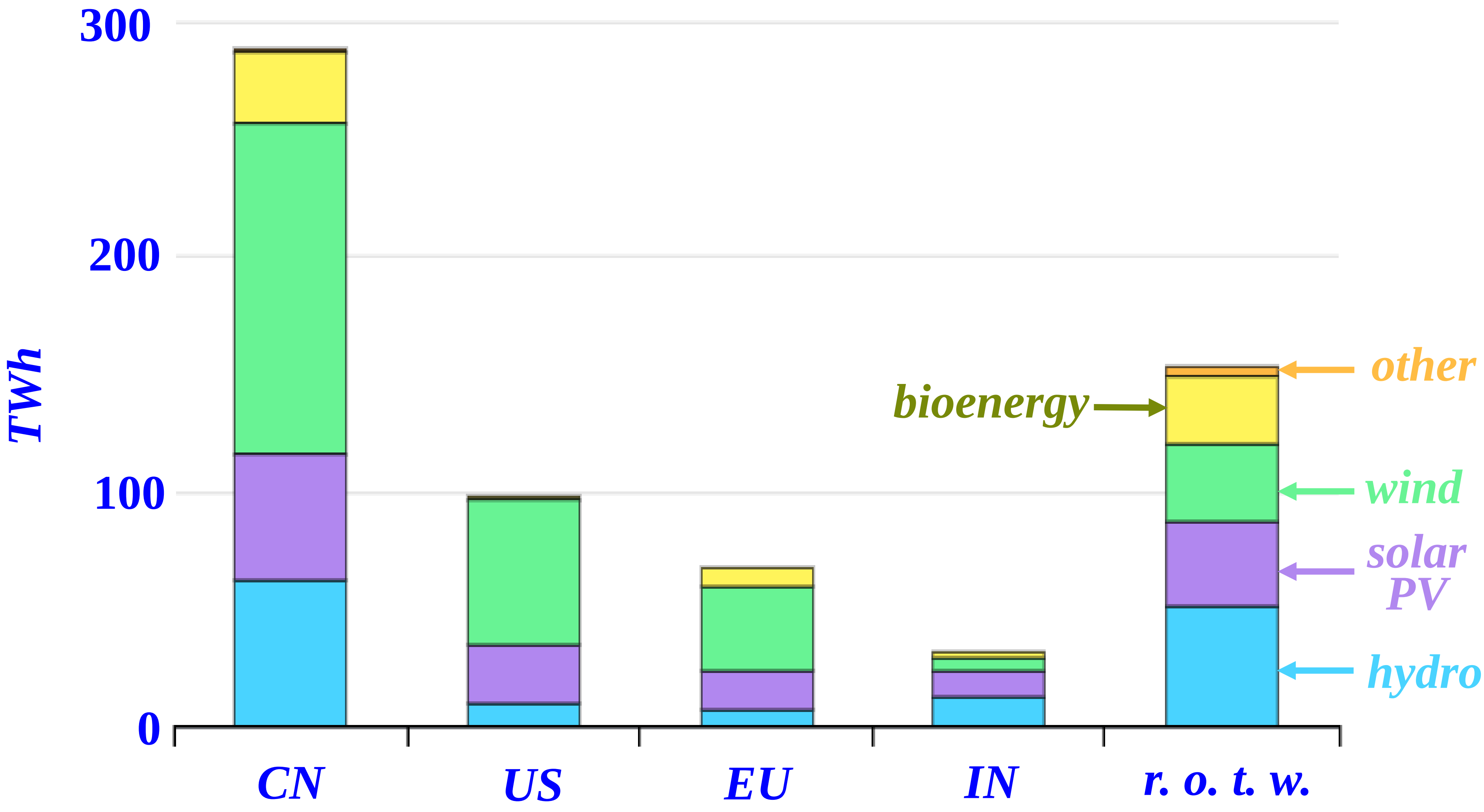
PRIMARY SOURCE SHARES OF WORLD ELECTRICITY GENERATION: 1971–2021

Source: Global Energy Review; available at https://www.iea.org/reports/global-energy-review-2021/renewables



RENEWABLE ELECTRICITY GENERATION BY NATION/REGION: 2020 – 2021

Source: Global Energy Review; available at https://www.iea.org/reports/global-energy-review-2021/renewables

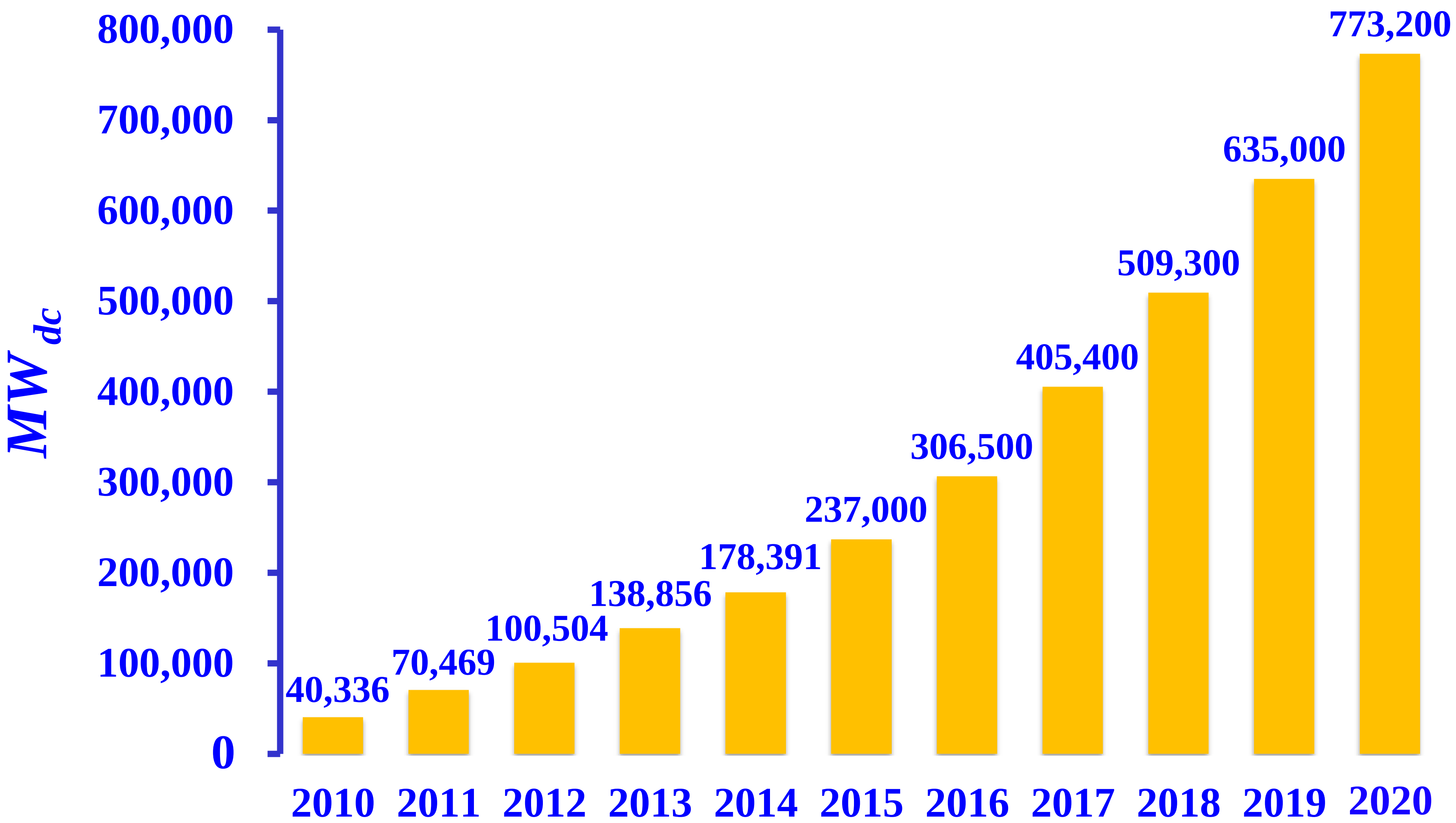


OUTLINE

- *PV* solar system status: global and *US*
- *PV* system costs and prices
- Examples of large solar projects
- Major challenges in *PV* solar resource integration
- Key drivers of the *PV* system growth
- *PV* technology benefits

GLOBAL ANNUAL CUMULATIVE *PV* CAPACITY: 2010 – 2020

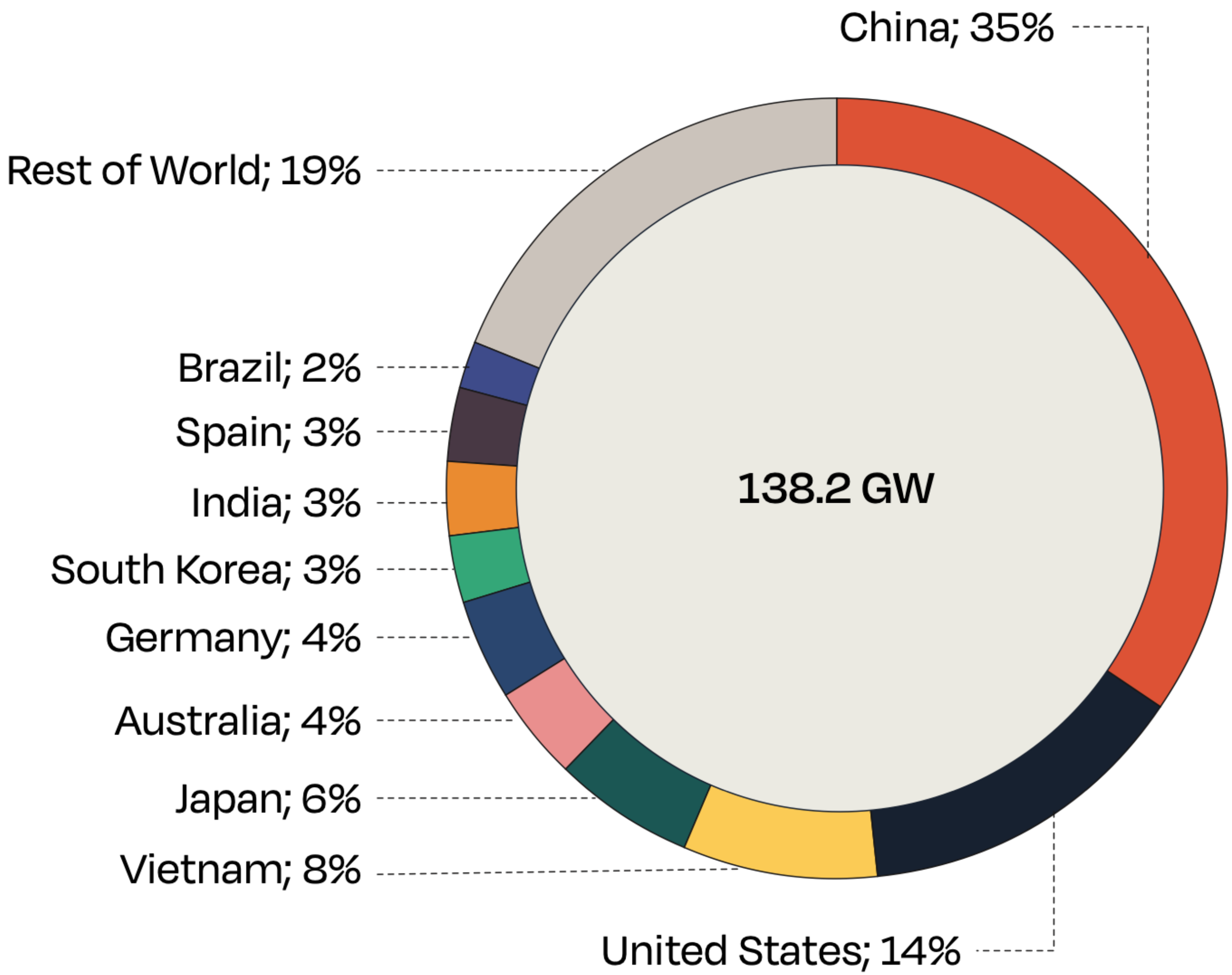
Source*: *SolarPower Europe, Global Market Outlook for Solar Power* 2021-2025; *p.5, all prices in 2019 USD; available at
https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863



2020 WORLD STATUS OF *PV* SOLAR RESOURCES

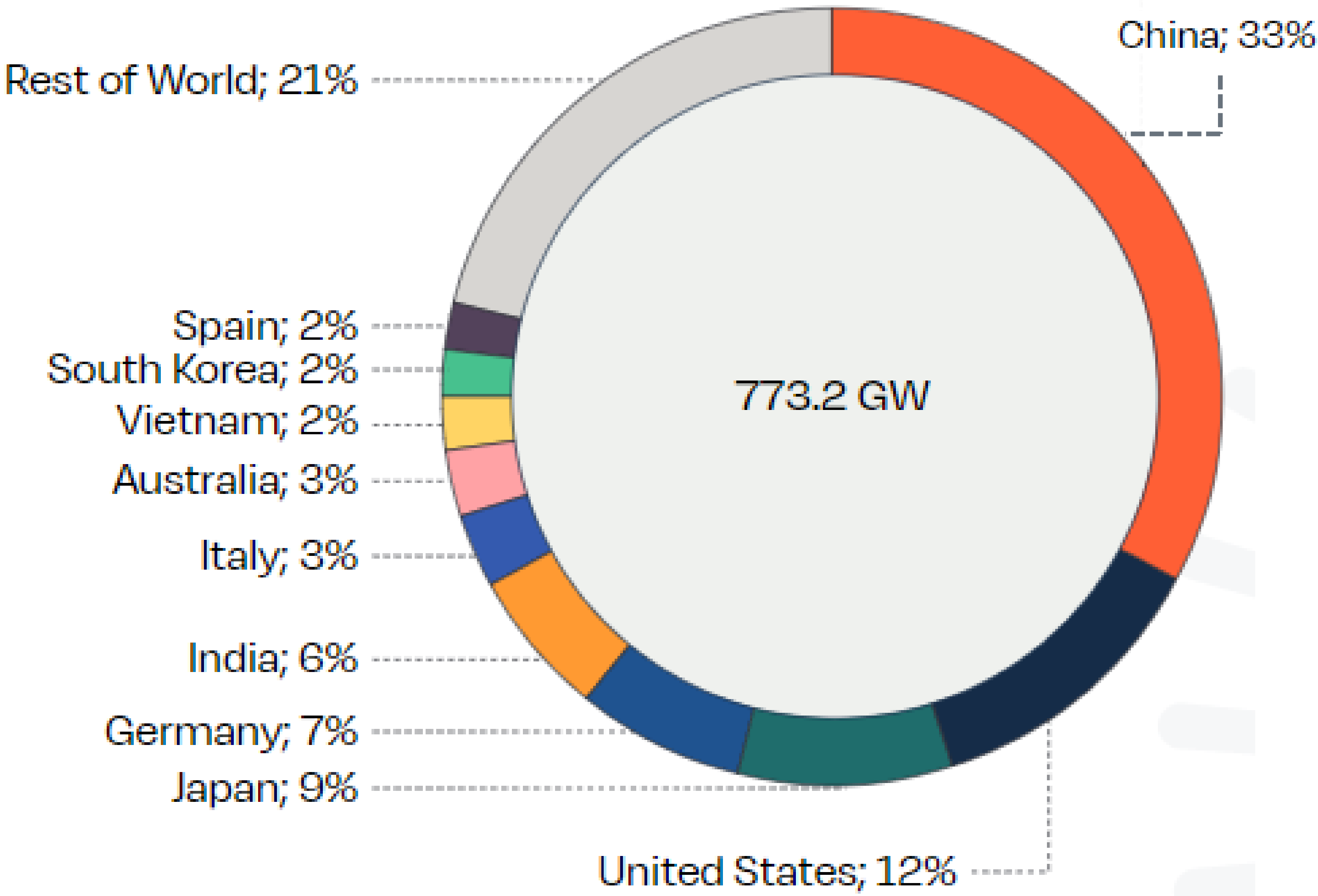
- **More than 138.2 *GW* of new capacity additions have increased the global cumulative *PV* capacity to over 773.2 *GW***
- **The *Asia-Pacific* region with more than 368.3 *GW* is now the world's leading region in terms of total installed capacity, with about a 58 % share of the global *PV* capacity**

2020 INSTALLED *PV* SOLAR TOP 10 COUNTRIES



Source: SolarPower Europe, Global Market Outlook for Solar Power 2021-2025, p.16; available at https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863

2020 TOTAL INSTALLED *PV* SOLAR TOP 10 COUNTRIES



Source: SolarPower Europe, Global Market Outlook for Solar Power 2021-2025, p.21; available at https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863

2019 *PV* SOLAR STATUS

- **The *global* *PV cumulative capacity* reached 773.2 *GW* with the 138.2 *GW* added in 2020 – a 22 % increase over the 2019 installed capacity**
- ***China*, *US* and *Vietnam* were the *top three nations* in *PV* capacity additions in 2020**
- **In 2020, 18 nations installed more than 1 *GW* of *PV* capacity**

2019 WORLD STATUS OF *PV* RESOURCES

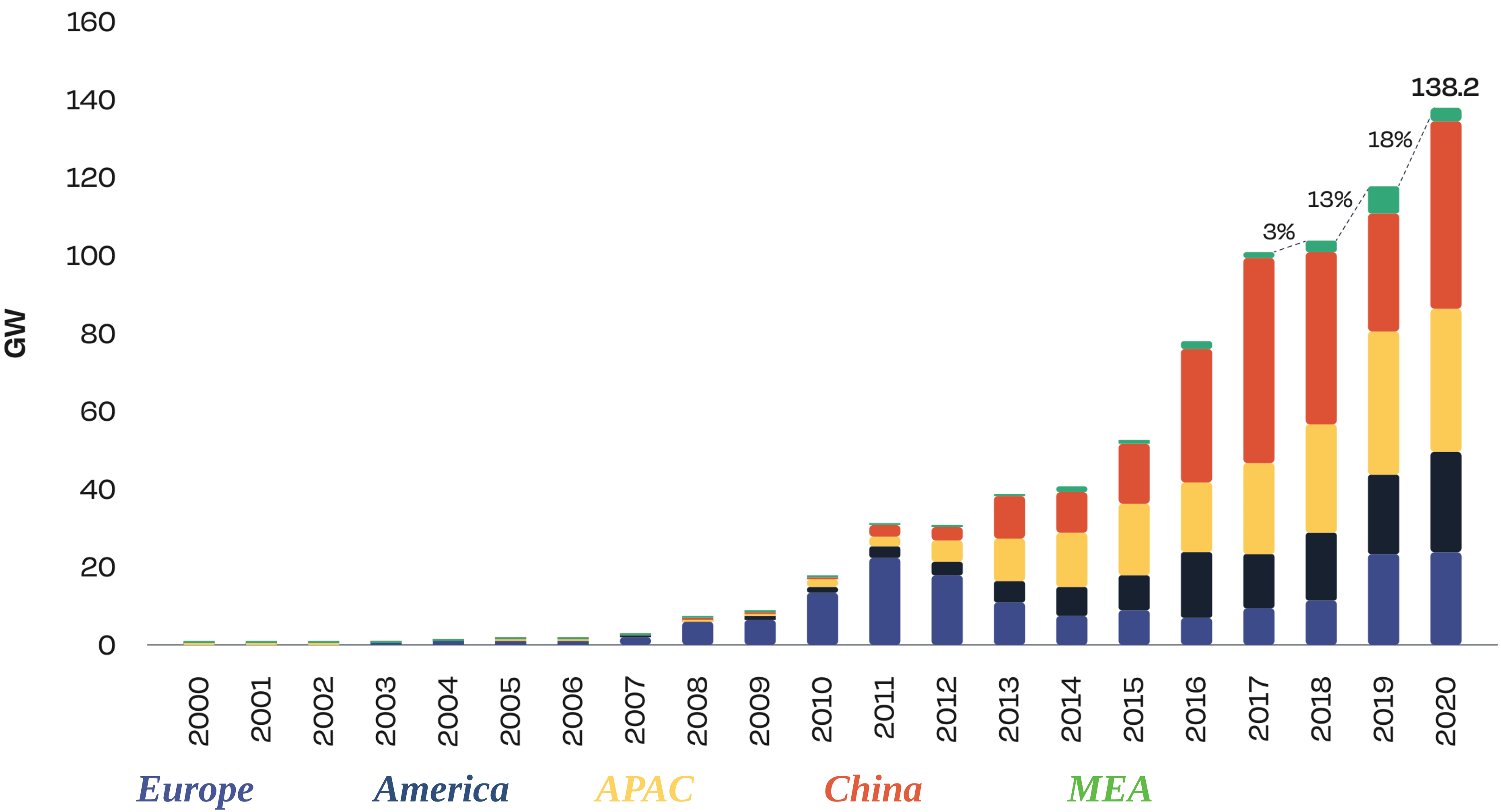
- ***China*** **installed 48.2 *GW* – a 60 % growth from the 30.1 *GW* installed in 2019 – to continue as the largest solar capacity nation in the world**
- **The *US* solar power capacity additions increased from 13.3 *GW* in 2019 to 19.2 *GW* in 2020**
- ***India*, with its 41 *GW* of *PV* capacity, became the 5^{th} largest solar capacity nation in the world**

2020 WORLD STATUS OF *PV* SOLAR RESOURCES

- The *Asian-Pacific* region is the largest solar capacity region in the world with its circa 60 % share of the global *PV* capacity
- *Europe*'s cumulative total of 173.9 *GW* represents a 22.4 % of the global *PV* capacity with the addition of only 23.7 *GW* of *PV* capacity; nevertheless, the *European* region maintains its position as the 2nd largest solar capacity region in the world

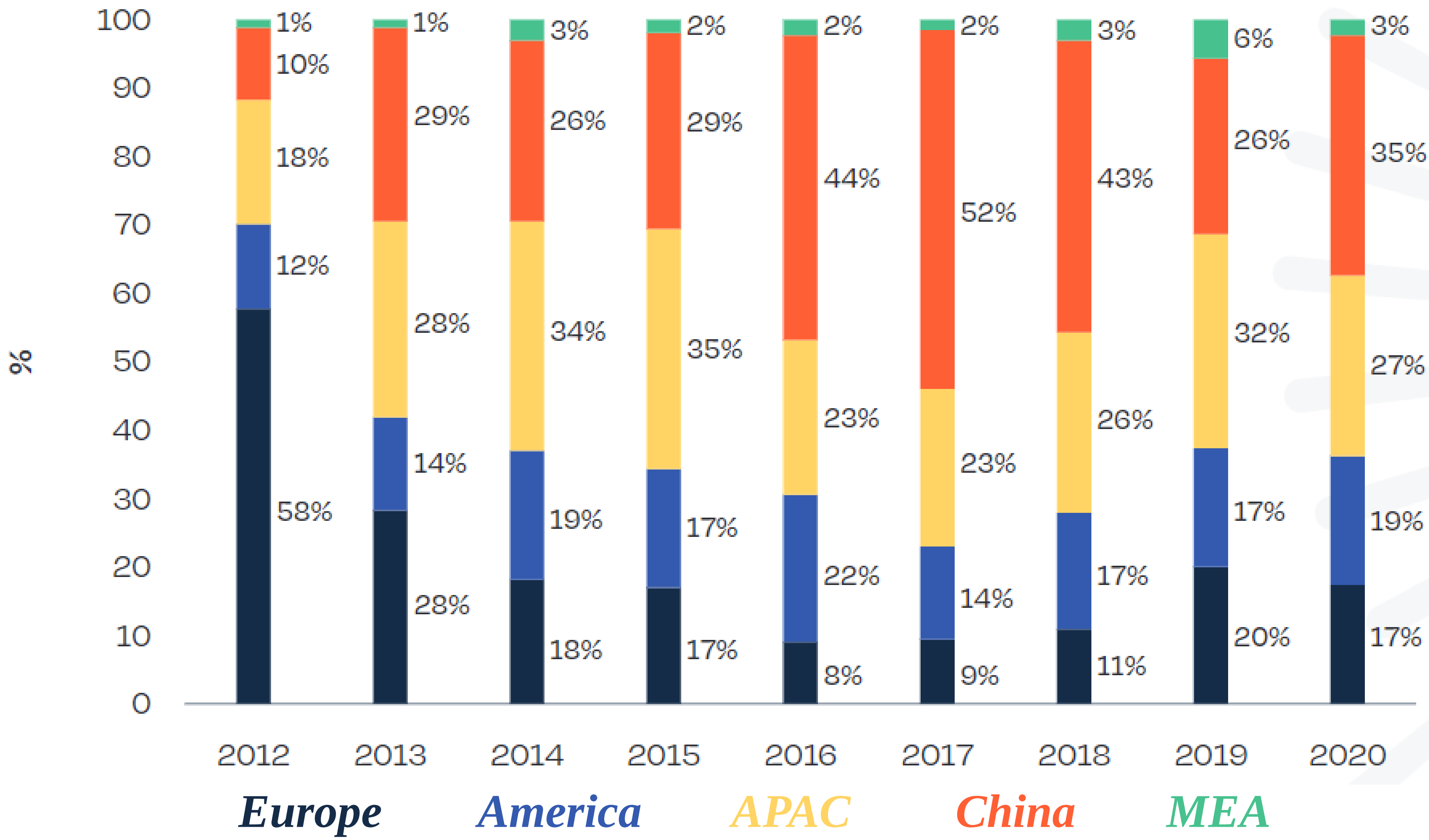
GLOBAL *PV* CAPACITY ADDITIONS BY REGION: 2000 – 2020

Source*: *SolarPower Europe, Global Market Outlook for Solar Power 2021-2025; p.12; available at https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863



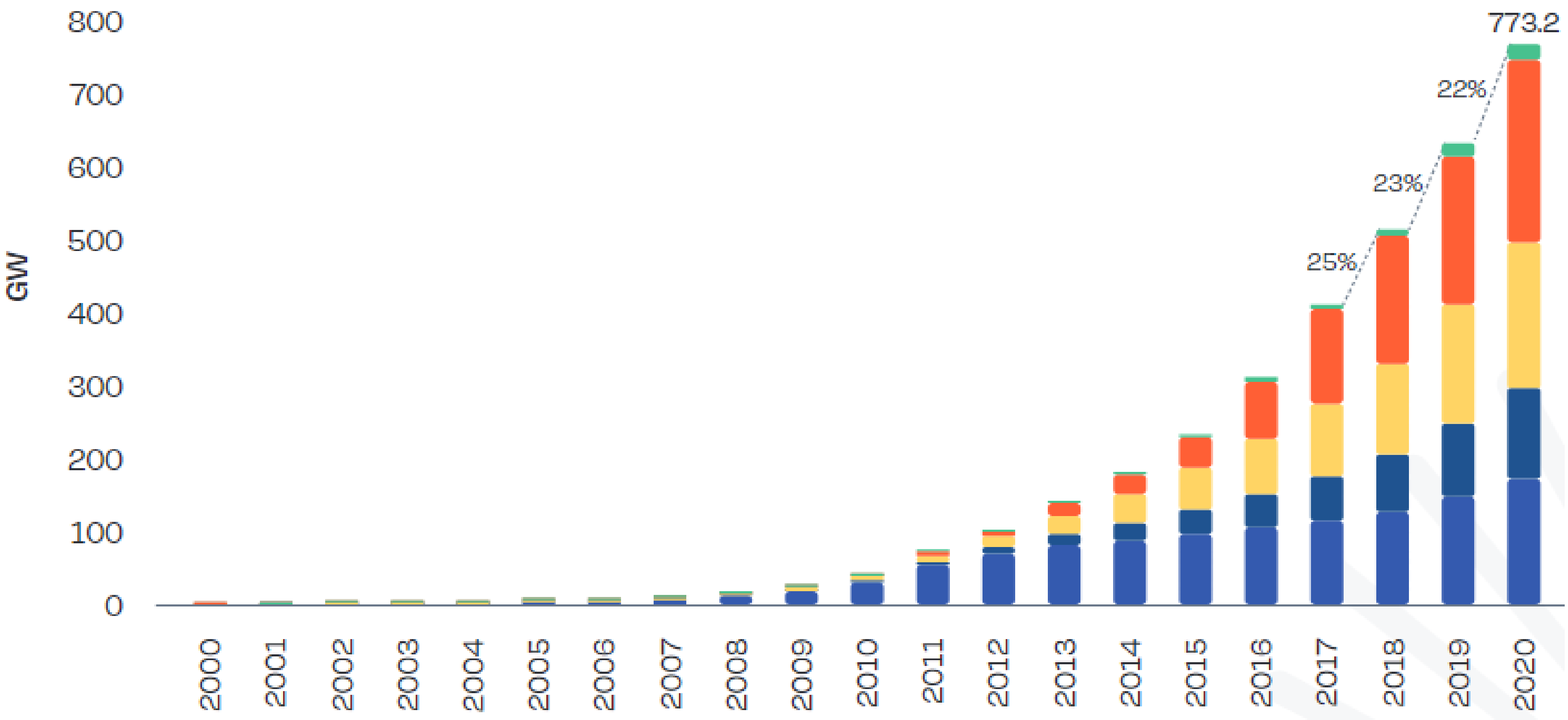
ANNUAL SOLAR *PV* ADDED CAPACITY SHARES BY REGION: 2012 – 2020

Source*: *SolarPower Europe, Global Market Outlook for Solar Power 2021-2025; p.17; available at https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863



GLOBAL CUMULATIVE *PV* SOLAR CAPACITY BY REGION: 2000 – 2020

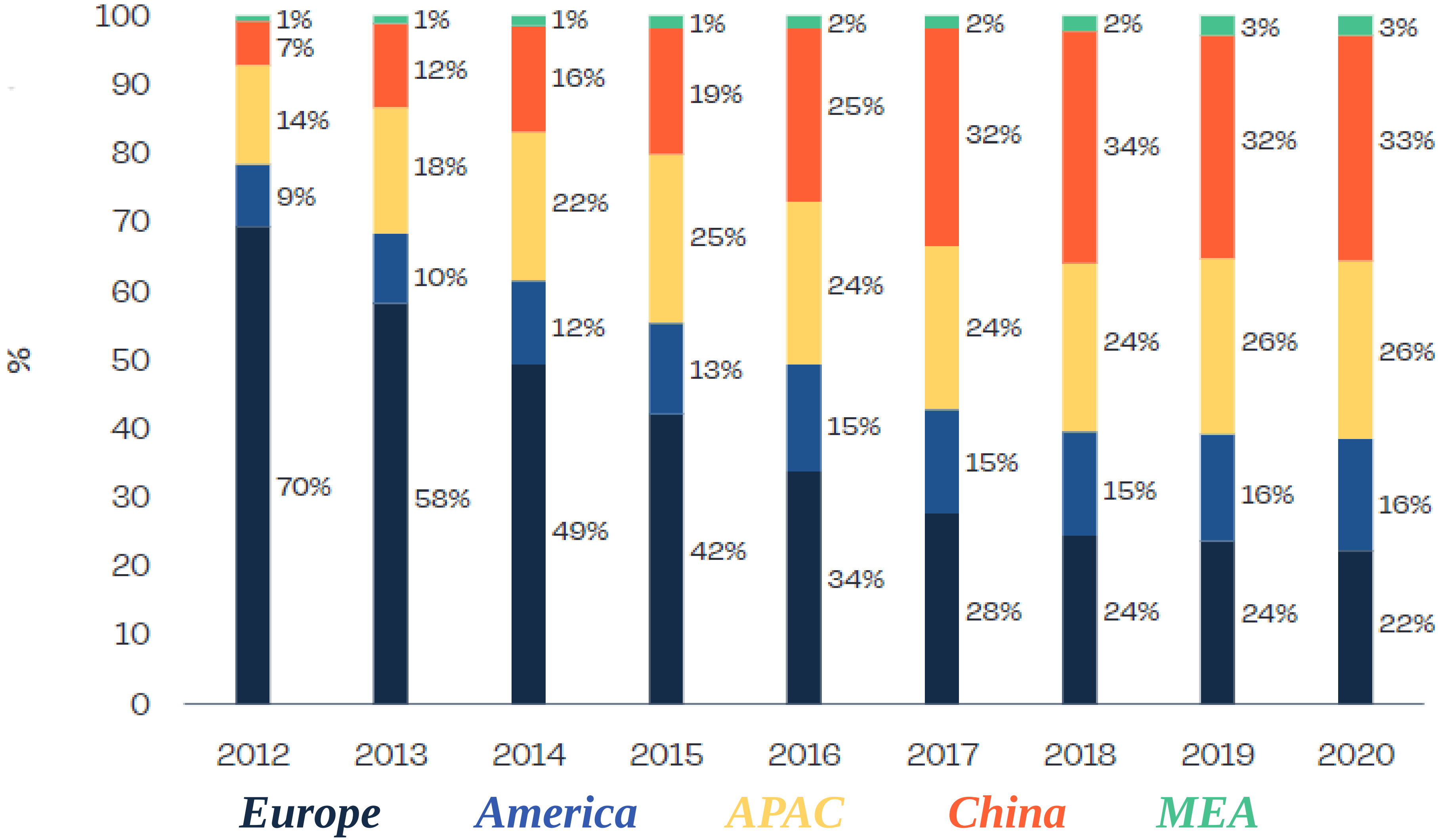
Source*: *SolarPower Europe, Global Market Outlook for Solar Power 2021-2025; p.19; available at https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863



Europe ***America*** ***APAC*** ***China*** ***MEA***

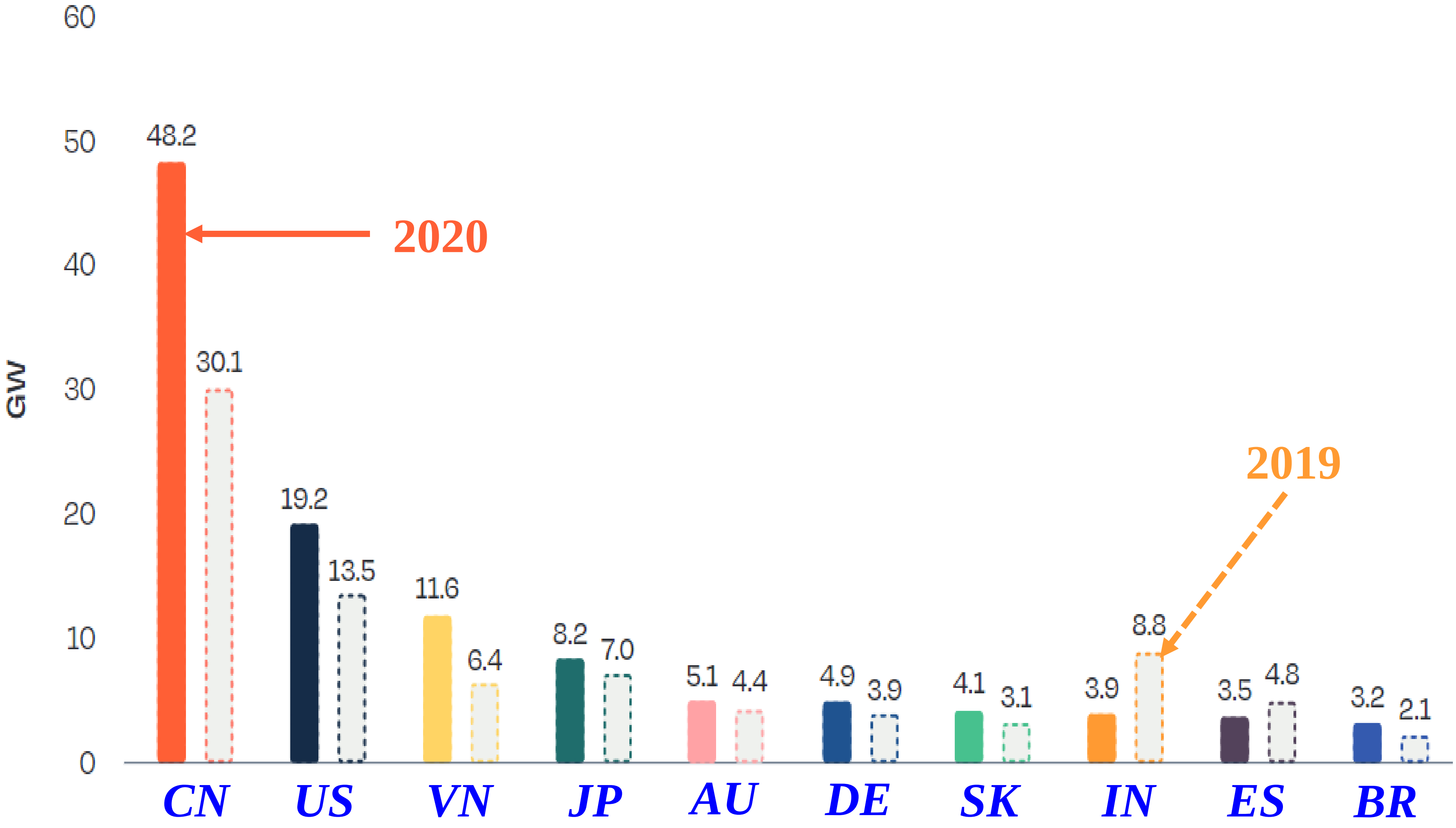
CUMULATIVE SOLAR *PV* INSTALLED CAPACITY SHARES: 2012 – 2020

Source*: *SolarPower Europe, Global Market Outlook for Solar Power 2021-2025; p.20; available at https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863



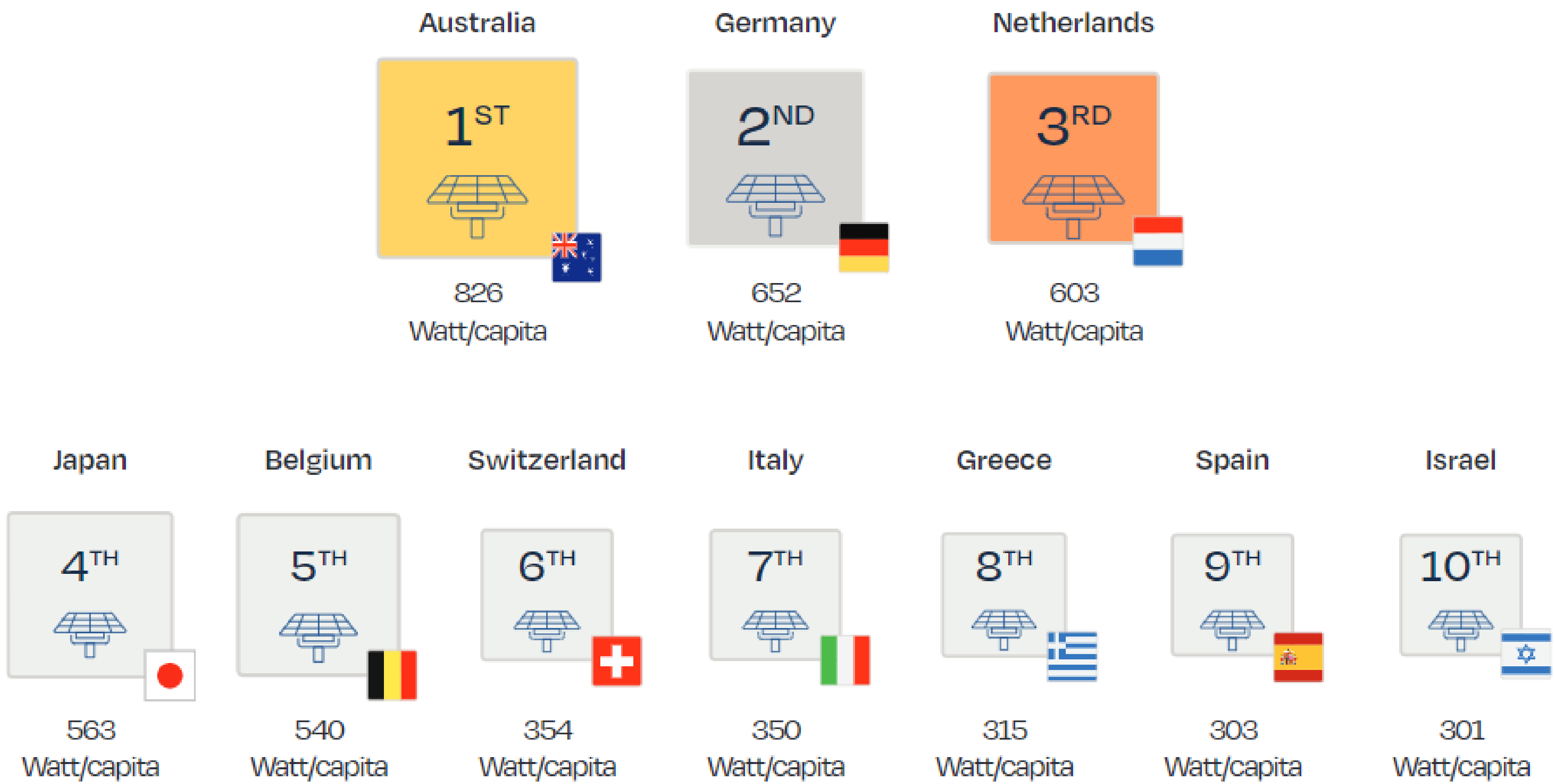
TOP 10 SOLAR *PV* NATIONS IN 2020 AND COMPARISON TO 2019

Source**: *SolarPower Europe, Global Market Outlook for Solar Power 2021-2025; p.13; available at https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863***



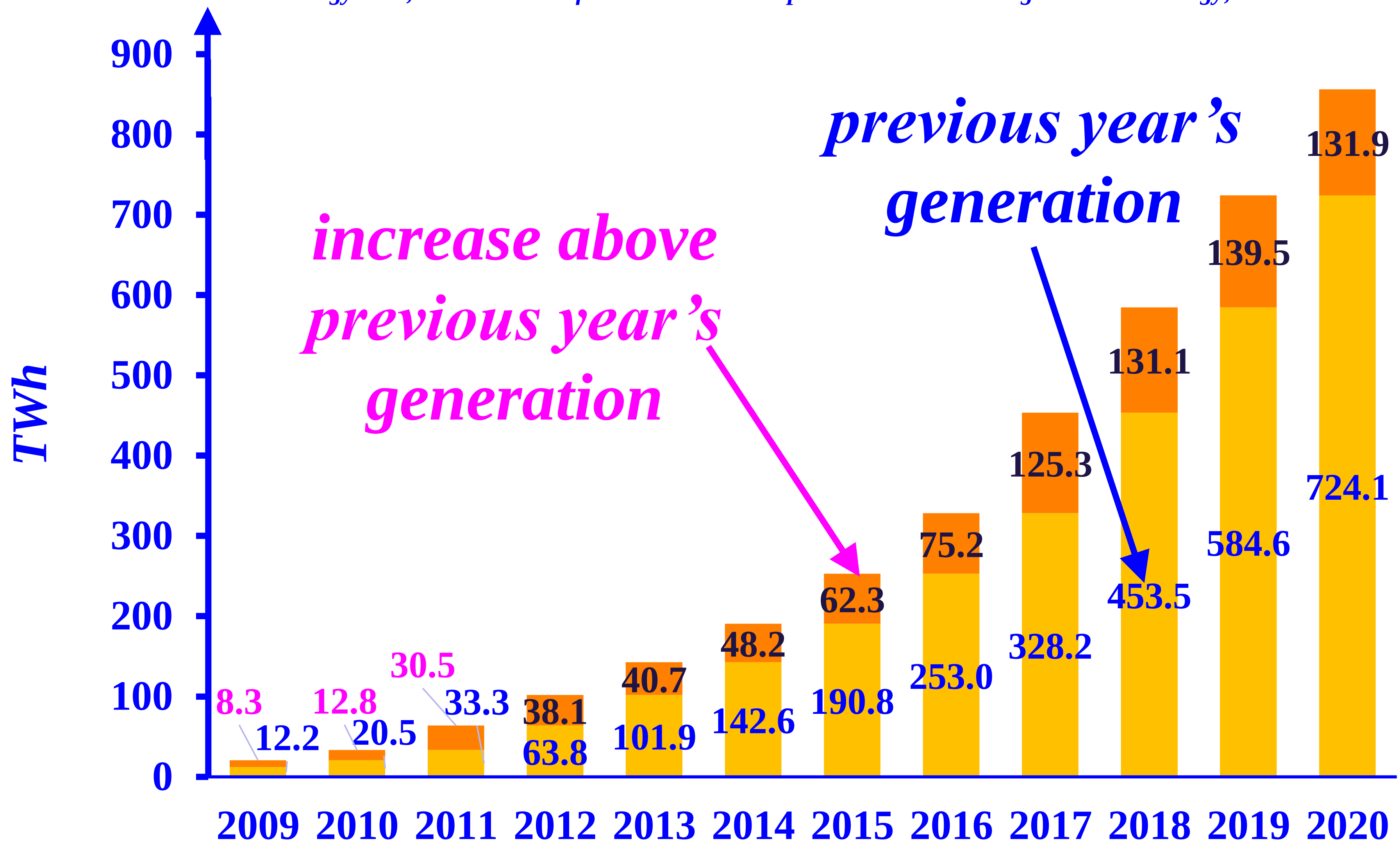
TOP 10 COUNTRIES SOLAR CAPACITY PER CAPITA 2020

Source: SolarPower Europe, Global Market Outlook for Solar Power 2021-2025; p.22; available at https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863



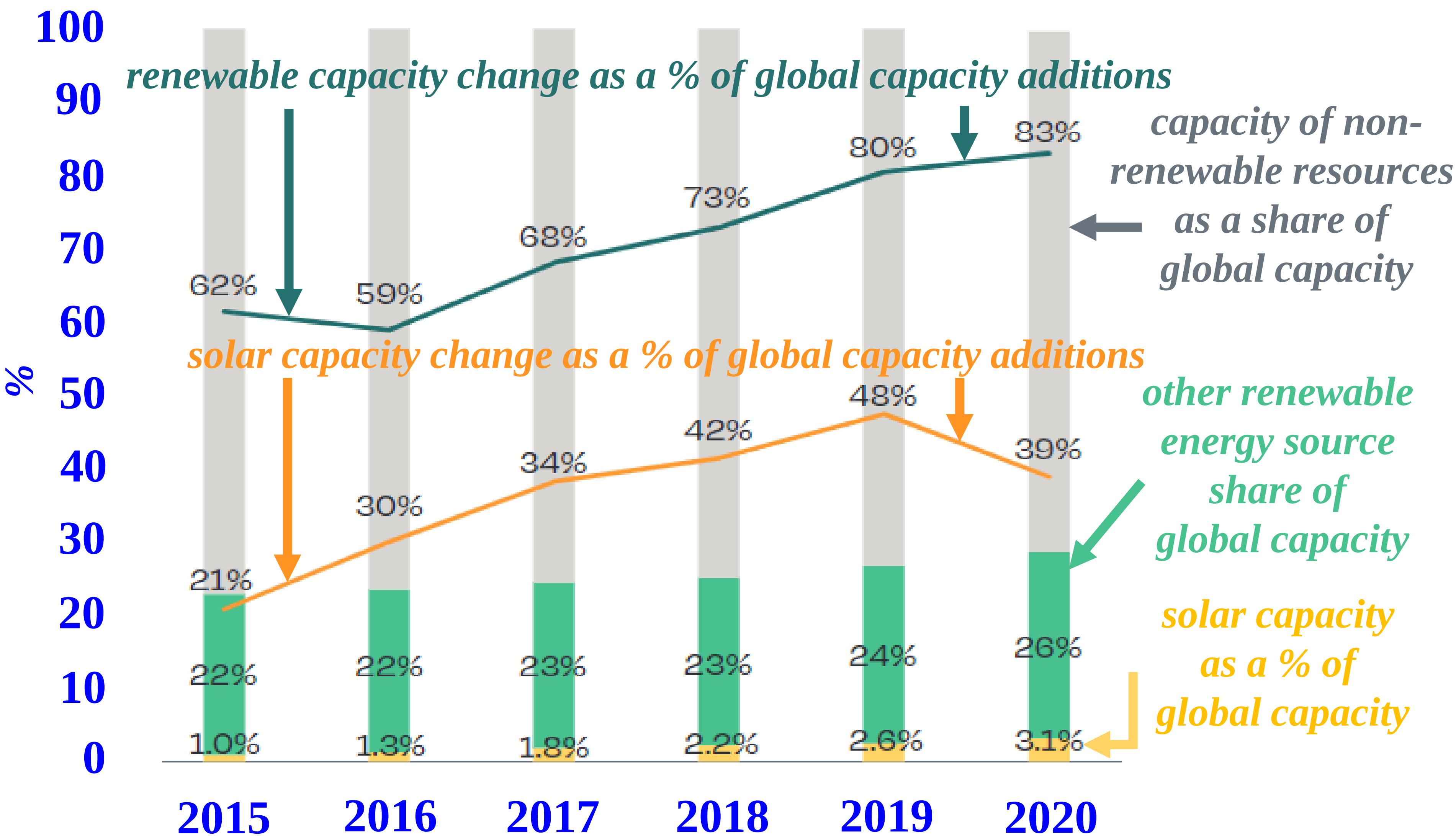
2009 – 2020: GLOBAL *PV* ELECTRICITY GENERATION

Sources: *BP Statistical Review of World Energy 2020, pg. 55; https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html; also 2020 data from the website: https://ourworldindata.org/renewable-energy;*

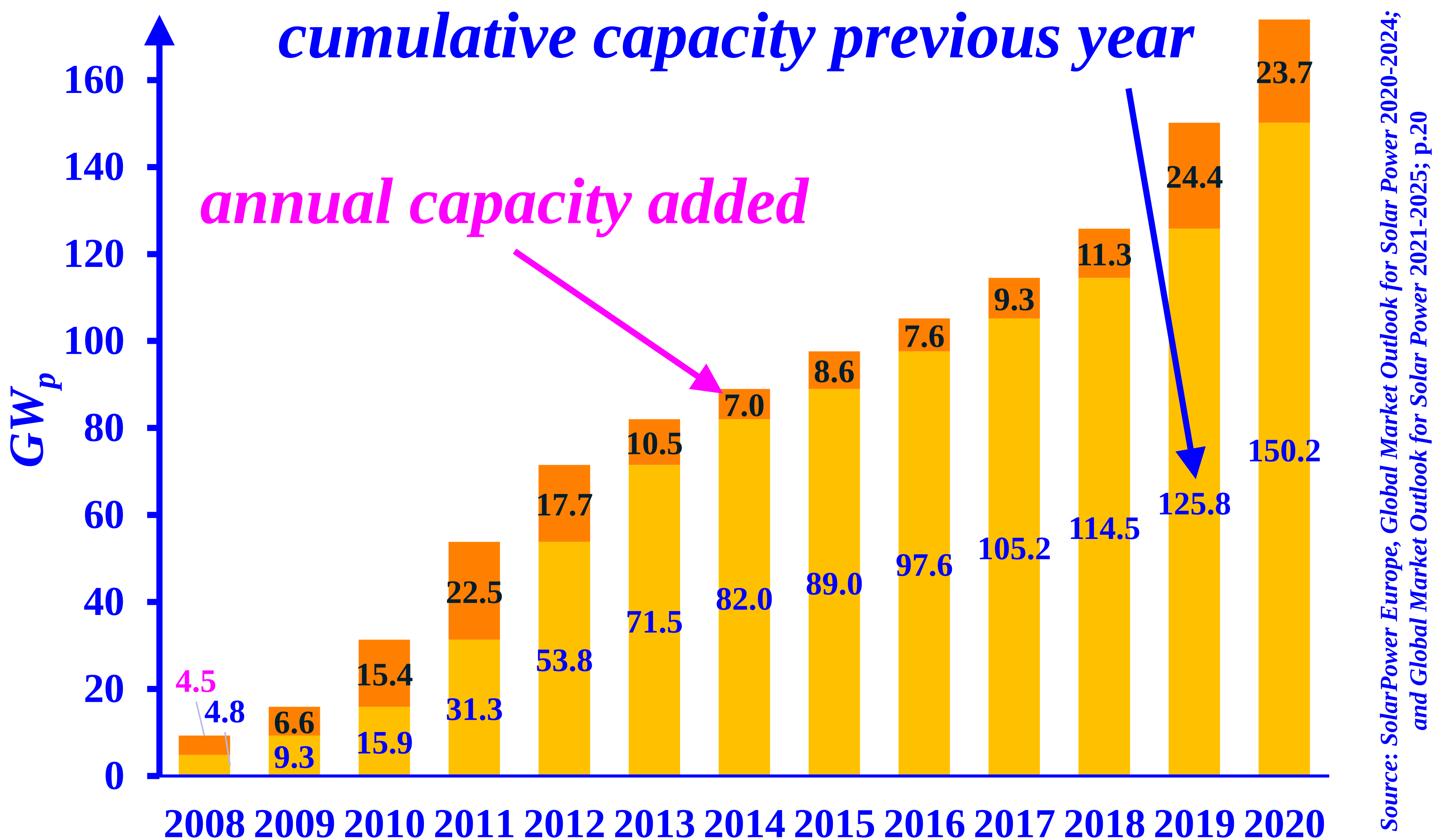


SOLAR AND RENEWABLE SHARE OF GLOBAL CAPACITY: 2015 – 2020

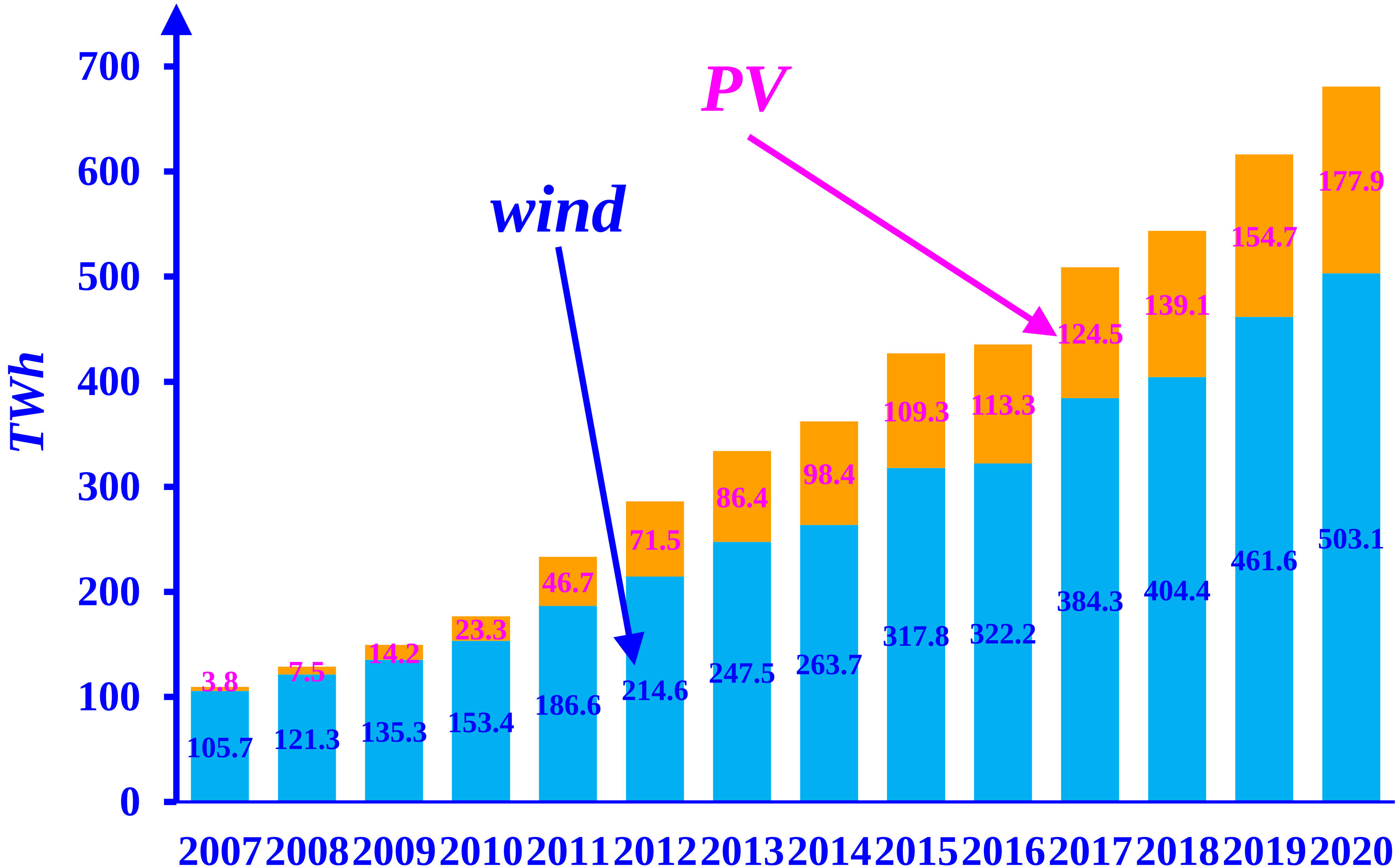
Source: SolarPower Europe, Global Market Outlook for Solar Power 2021-2025; p.8; available at https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863



2008 – 2020 *EUROPEAN PV* ANNUAL CAPACITY ADDITIONS

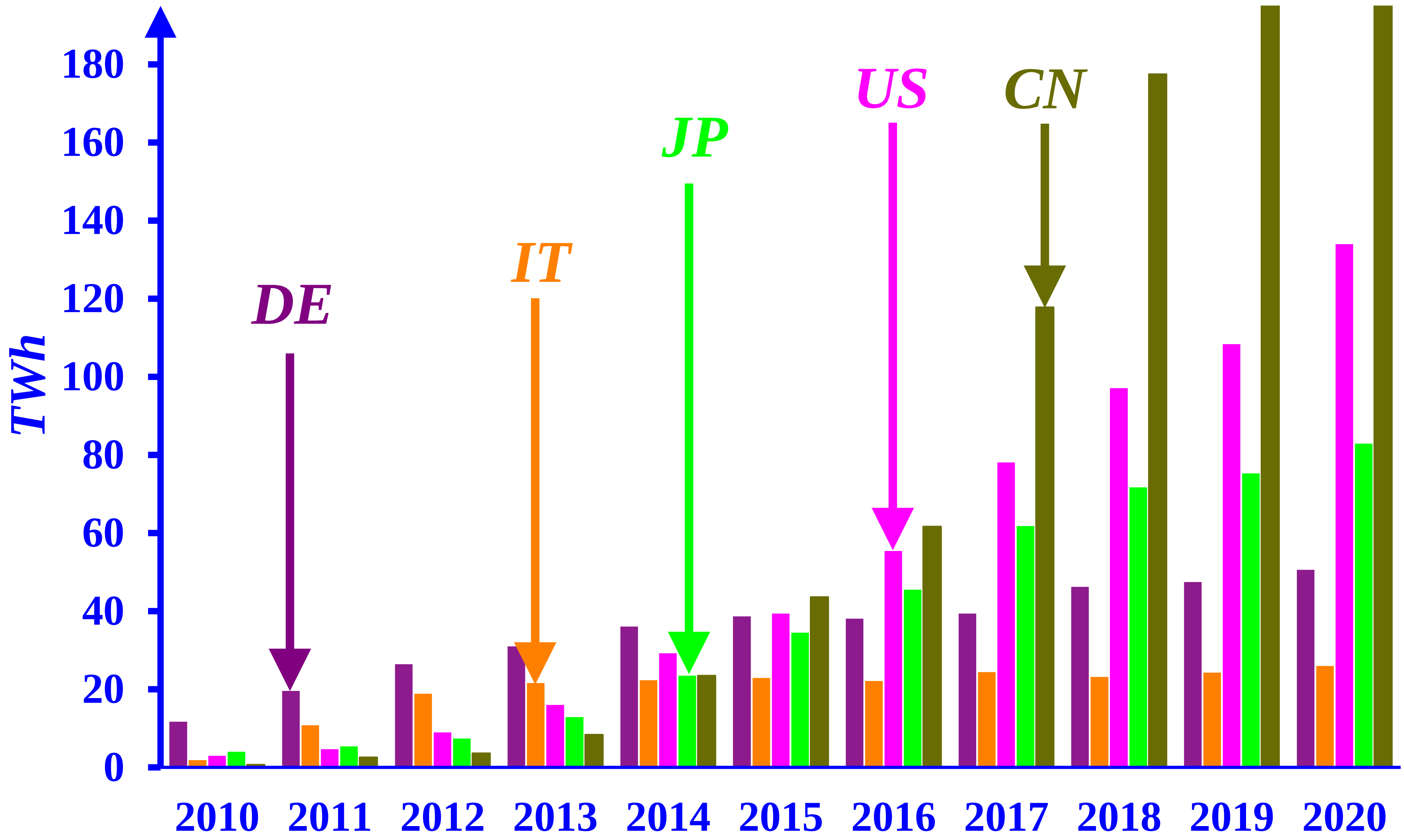


EUROPEAN ANNUAL WIND AND *PV* GENERATED ELECTRICITY: 2007 – 2020



Source: BP Statistical Review of World Energy 2020, pg. 55; https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html; https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf; p.57

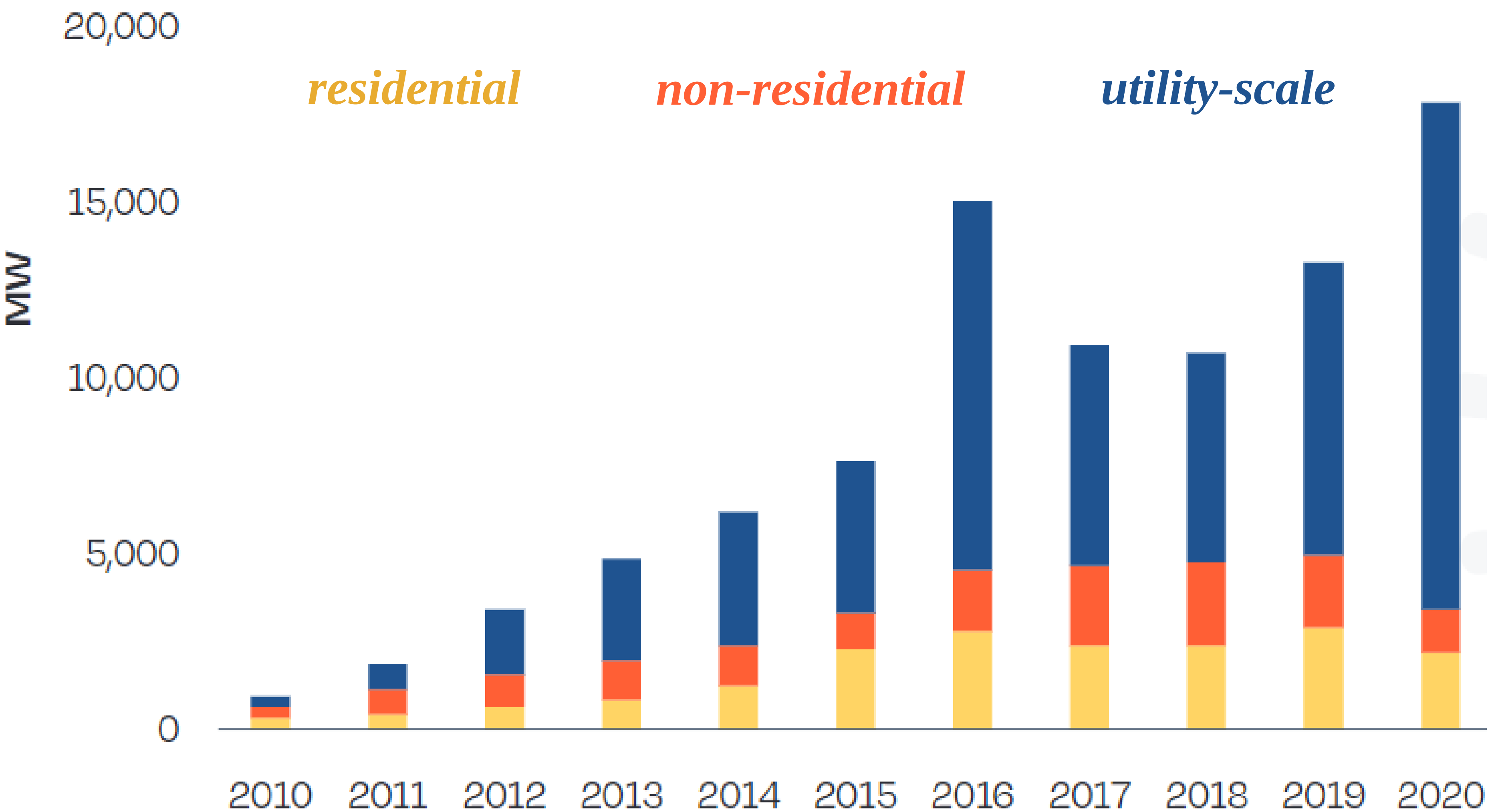
2009 – 2019: *PV* SOLAR ELECTRICITY GENERATION BY LEADING NATIONS



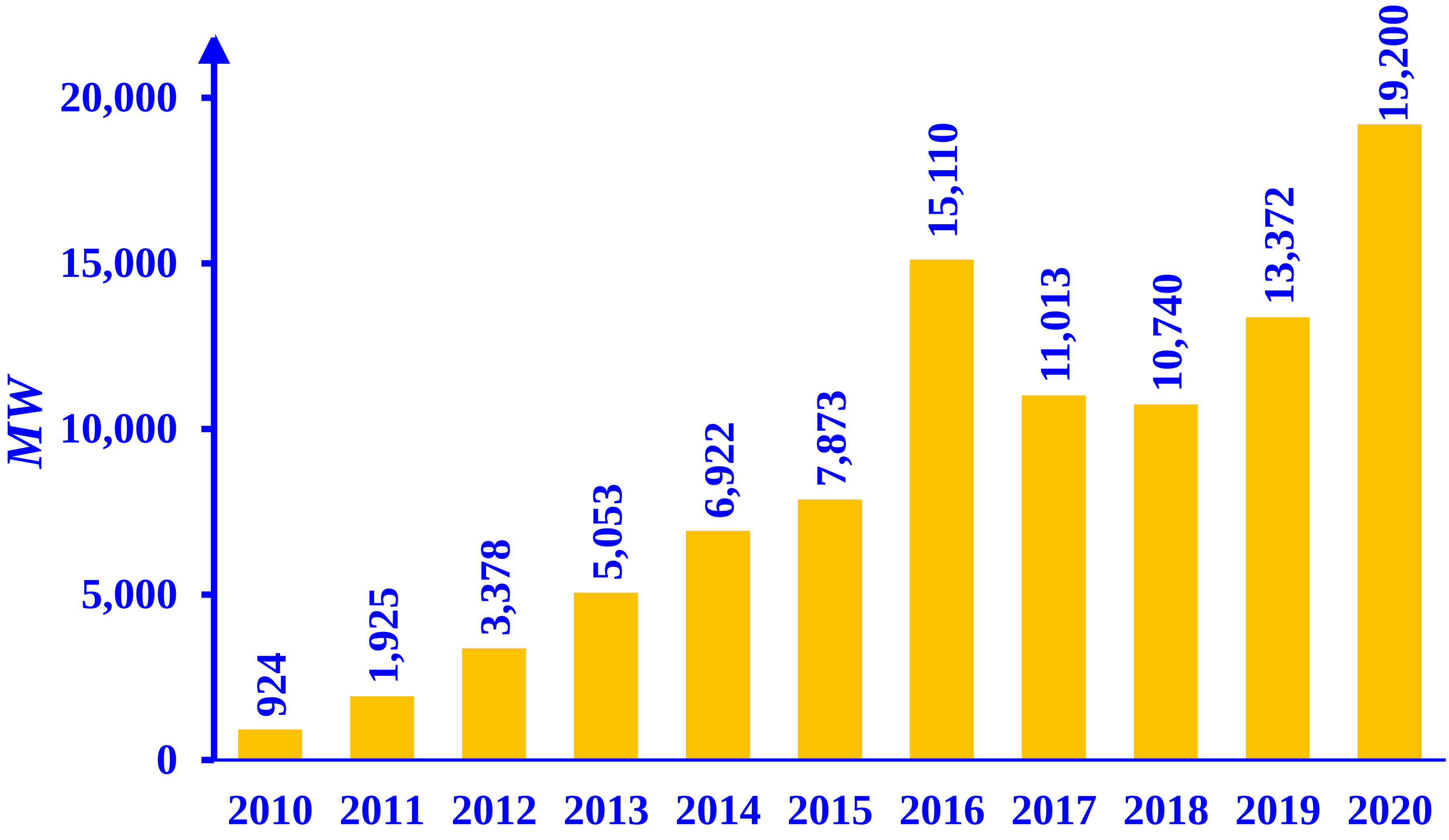
Source: BP Statistical Review of World Energy 2021, pg. 57; https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

ANNUAL *US* SOLAR *PV* ADDITIONS BY CONSUMER SECTOR: 2010 – 2020

Source: *SolarPower Europe, Global Market Outlook for Solar Power 2021-2025; p.81; all prices in 2019 USD; available at https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863*

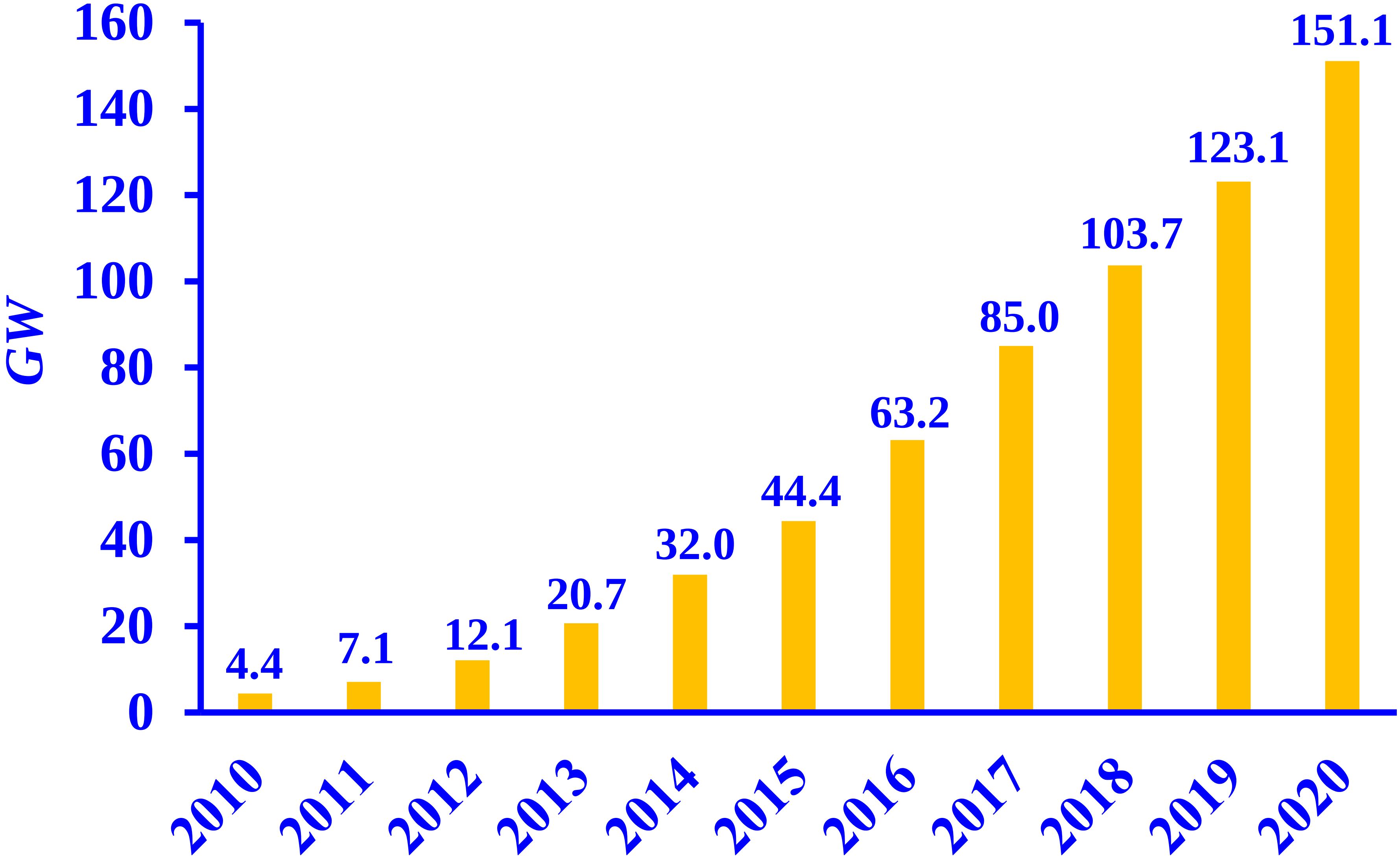


2002 – 2020 *US* ANNUAL *PV* CAPACITY ADDITIONS



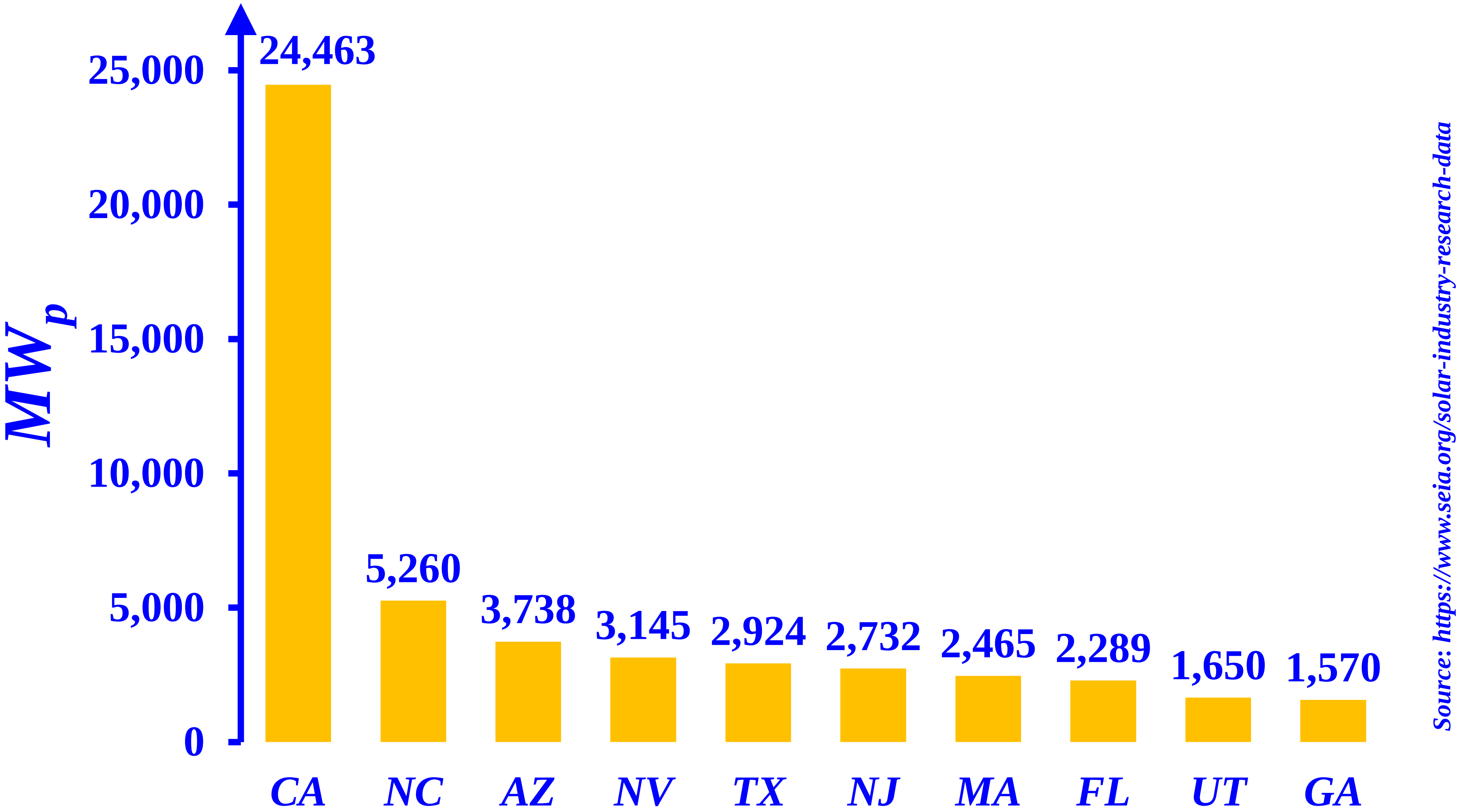
Source: Global Market Outlook for Solar Power 2020-2024. p. 11; https://www.solarpowereurope.org/wp-content/uploads/2020/07/31-SPE-GMO-report-hr-hyperlinks.pdf?cf_id=18419; SEIA; available at https://www.seia.org/solar-industry-research-data

US CUMULATIVE SOLAR CAPACITY: 2010 – 2020

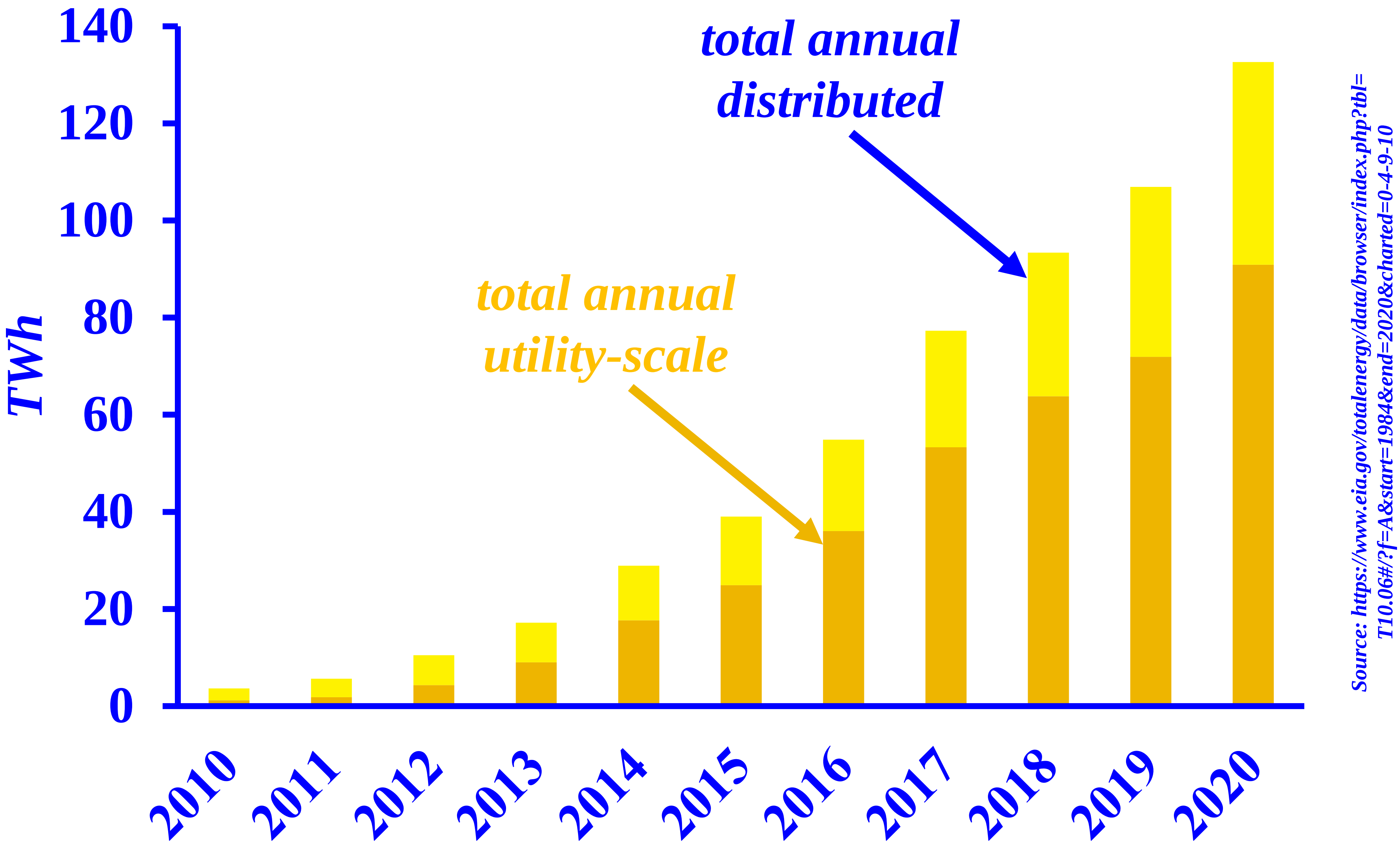


Source: https://www.eia.gov/outlooks/aeo/electricity/sub-topic-02.php

THE TOP 10 *US* STATES WITH THE LARGEST 2021 *PV* CAPACITY

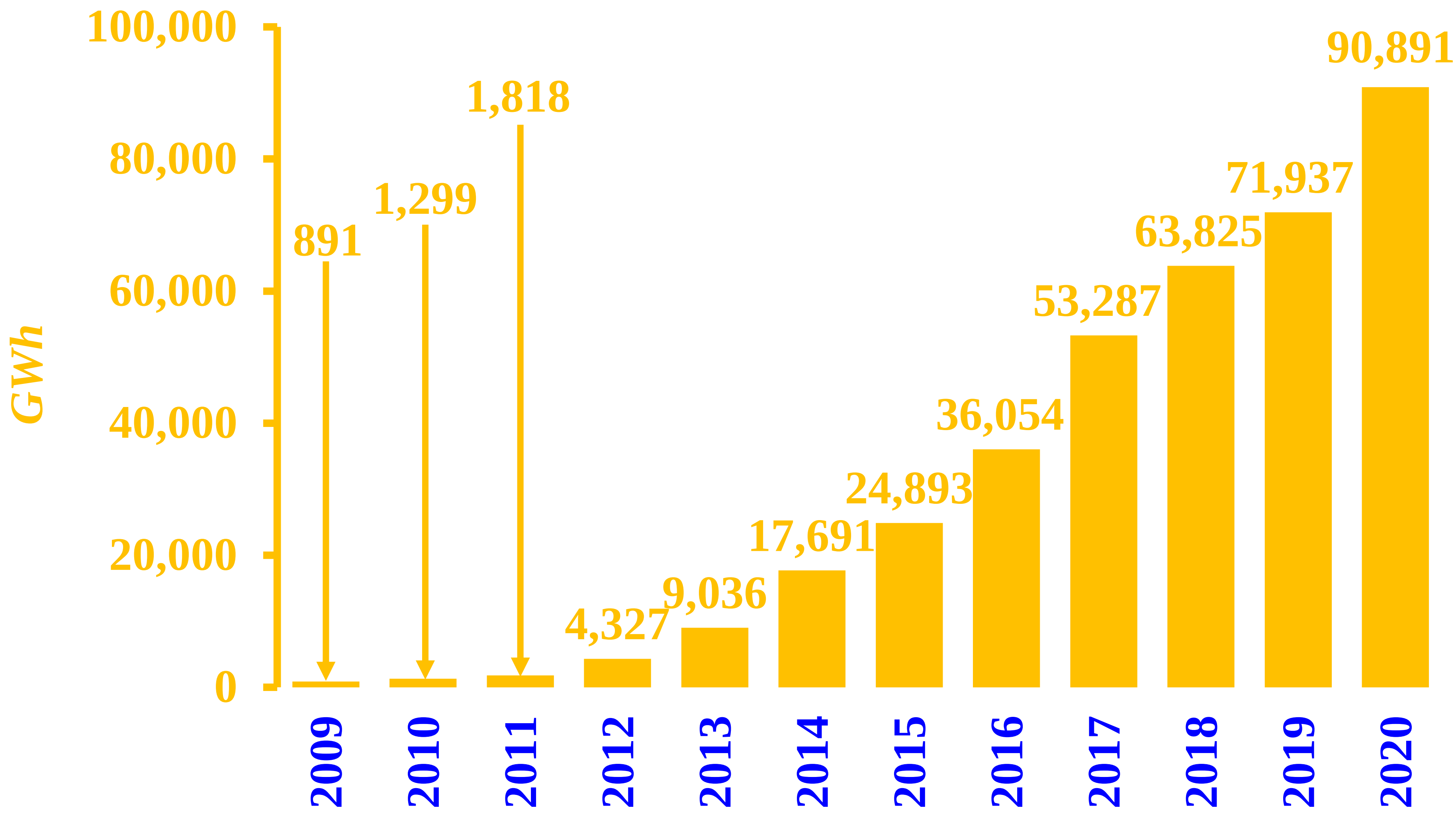


US NET SOLAR GENERATION 2010 – 2020

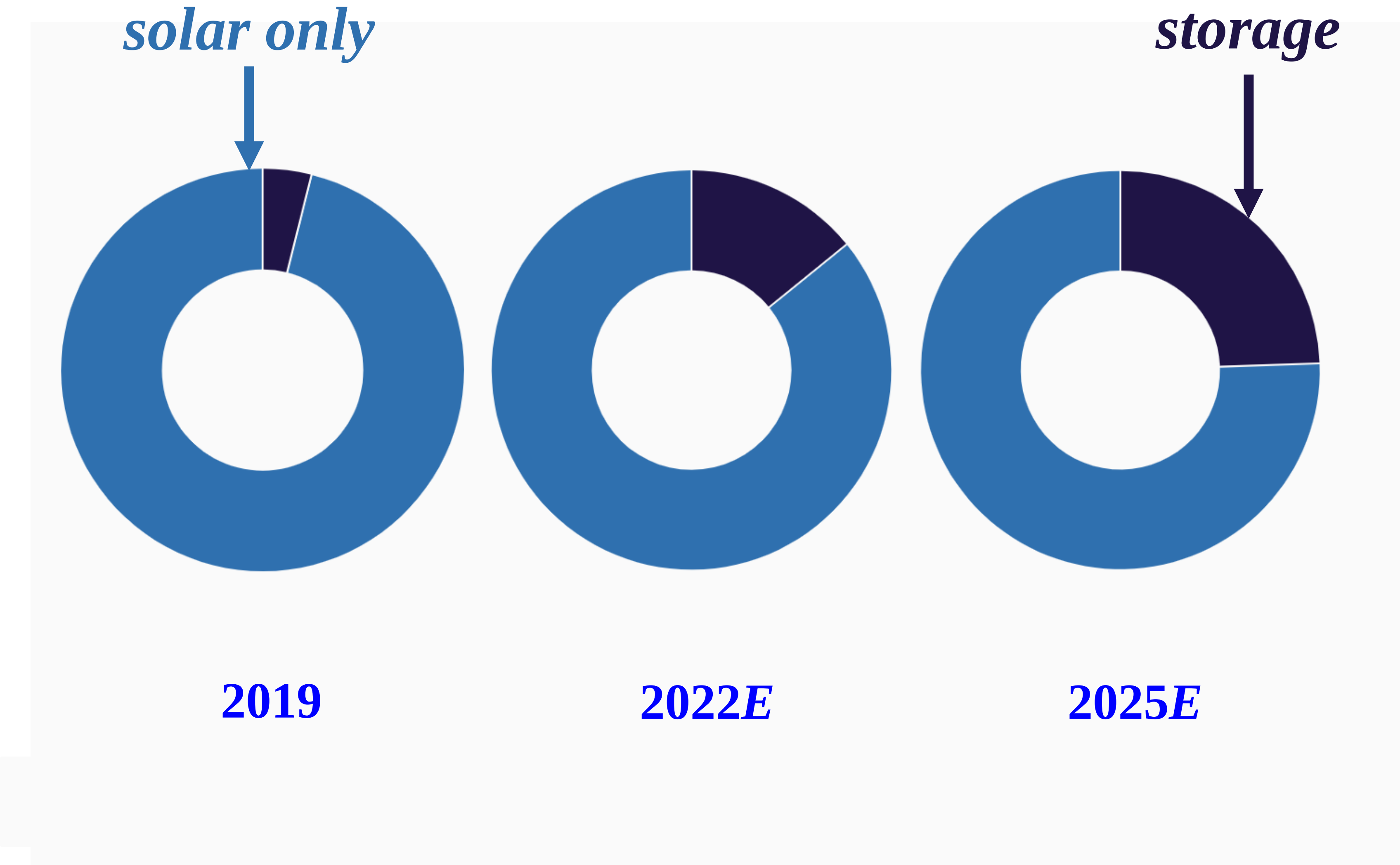


US SOLAR UTILITY – SCALE GENERATION: 2009 – 2020

Source*: *https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2,0,1&fuel=0045u&geo=vvvvvvvvvvvvo&sec=g&linechart=ELEC.GEN.SUN-US-99.A&columnchart=ELEC.GEN.SUN-US-99.A&map=ELEC.GEN.SUN-US-99.A&freq=A&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0



FRACTION OF DISTRIBUTED SOLAR SYSTEMS WITH ENERGY STORAGE



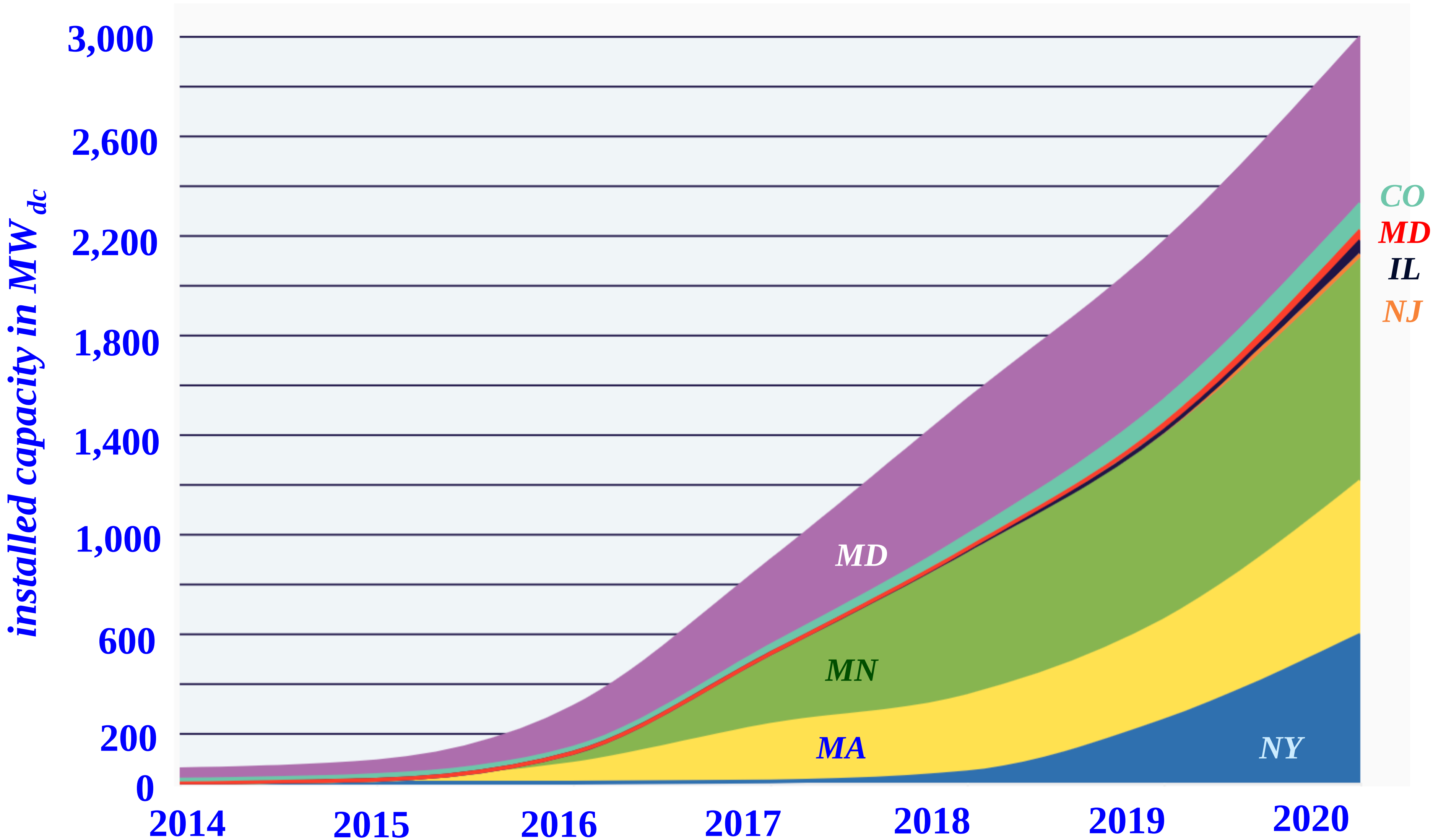
Source: Solar Energy Industries Association, available online at https://www.seia.org/solar-industry-research-data

A COMMUNITY SOLAR PROJECT: CORTLAND SOLAR 2 IN *CORTLAND, IL*

source: Chicago Tribune; available at https://www.chicagotribune.com/news/breaking/ct-illinois-clean-energy-law-consumer-opportunities-0930-20211006-cijpq7i2cnbqficudcmh2xxeoy-story.html

CUMULATIVE *US* COMMUNITY SOLAR INSTALLATIONS

Source: SEIA/Wood Mackenzie power & renewables US solar market insight 2020 Q2, available online at https://www.seia.org/solar-industry-research-data



2020 *US* STATUS OF *PV* SYSTEMS BY STATES

- *CA*, *TX* and *NC* account for over a third of the *US* cumulative *PV* capacity
- The solar industry in *NC* is growing rapidly due to the state's *Renewable Energy and Energy Efficiency Portfolio Standard (REPS)* that allowed *clean energy entities* to compete with *utilities* to offer customers choice in their energy supply and the 2017 *NC* law that authorized solar leasing

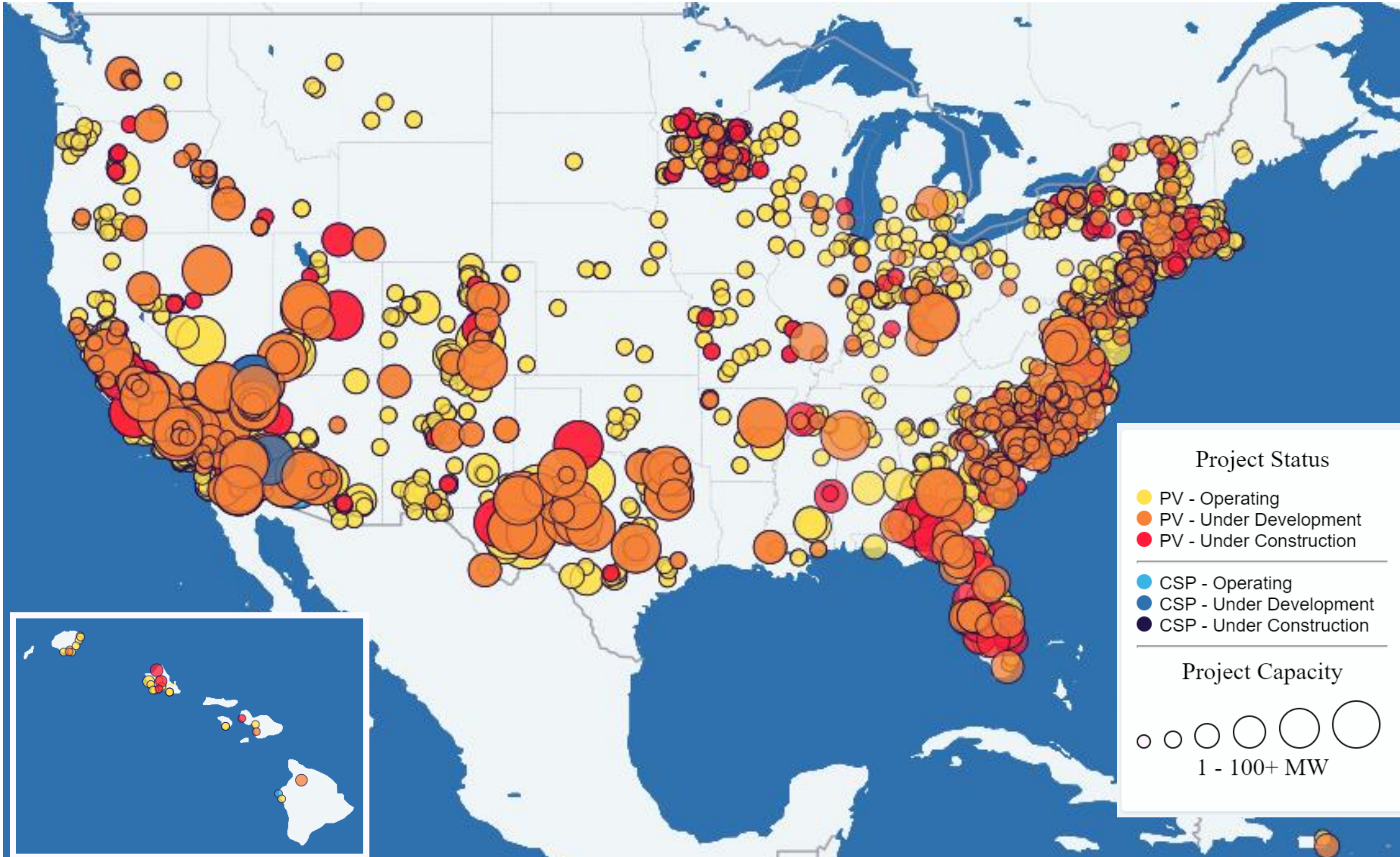
THE 2020 STATUS OF *US PV* SYSTEMS

- *US* is a major player in the global *PV* solar capacity and energy arena
- The 2020 *US* cumulative utility-scale *PV* capacity increased to roughly 99.3 *GW*, due to the numerous utility-scale projects in the added 19.2 *GW* of new *PV* capacity in 2020
- The community solar grew 35 % from 1,523 *MW* in 2018 to 2,056 *MW* in 2019 and to 3,000 *MW* in 2020

US SOLAR ENERGY IS BOOMING

- *PV* solar installation costs fell more than 70 *%* since 2010
- Conformance with state *RPS* requirements is no longer as key a driver as earlier; many new corporate procurements of off–site solar projects, typically, use various *PPA* mechanisms
- Since 2018, *US* had over 2 *million* solar installations

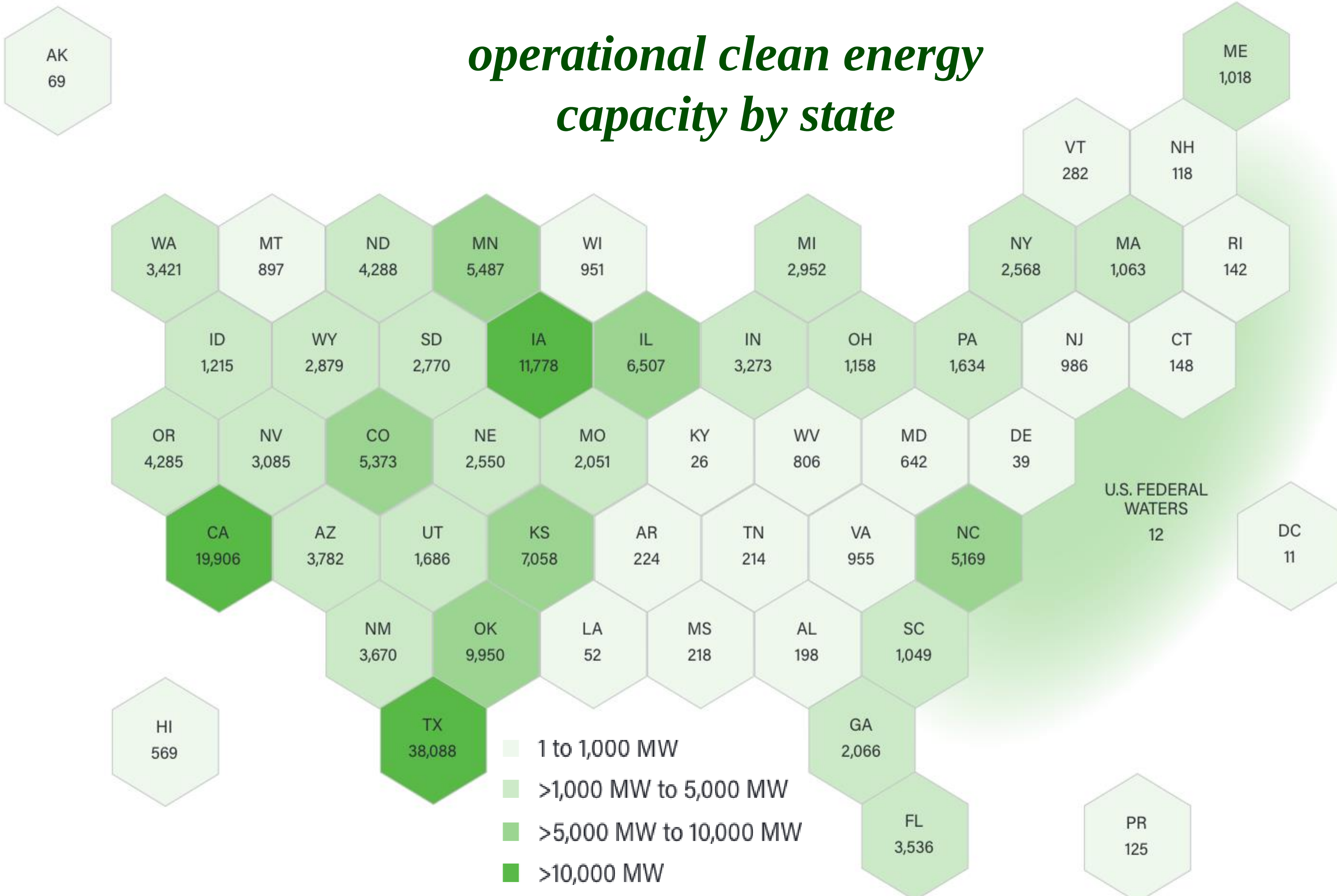
2019 *US* UTILITY – SCALE SOLAR PROJECTS



Source: 2019 data: https://www.seia.org/research-resources/major-solar-projects-list

CLEAN POWER CAPACITY GROWTH BY STATE

operational clean energy capacity by state



Source: American clean power 2021, q1; available at https://cleanpower.org/wp-content/uploads/2021/05/CPQ-2021Q1_public.pdf; p. 6

THE 2021 FIVE LARGEST *US PV* INSTALLATIONS

plant	*location*	*capacity (MW)*	*year built*	*owner*	*electricity purchaser*
Solar Star	*Rosamond, CA*	579	2015	*BHE Renewables*	*SCE*
Copper Mountain Solar Facility	*Boulder City, NV*	552	2016	*Sempra Generation*	*PG&E & SC Public Power Authority*
Desert Sunlight Solar Farm	*Riverside County, CA*	550	2015	*NextEra, Sumitomo*	*PG&E & SCE*
Topaz Solar Farm	*San Luis Obispo, CA*	550	2014	*Berkshire Hathaway Energy*	*PG&E*
Mount Signal Solar	*Calexico, CA*	460	2018	*8minutenergy Renewables*	*SCE & SDG&E*

Source: https://en.wikipedia.org/wiki/List_of_photovoltaic_power_stations

SOLAR STAR FARM

Source: http://www.techspot.com/images2/news/bigimage/2014/11/2014-11-28-image-4.jpg

SOLAR STAR FARM

- **The *Solar Star Farm* is a 579–*MW PV* power station located in *Antelope Valley* near Rosamond, *CA***
- **Completed in June 2015 by *SunPower*, *Solar Star* became the world's largest solar farm in terms of capacity from the 1.7 *million* solar panels installed on a 13 km^2 (3,200 *acres*) area**

SOLAR STAR FARM

- **Compared to other large plants, *Solar Star* uses a fewer arrays, with each array mounted on a single–axis tracker**
- **Generation of clean electricity form the farm is expected to power about 255,000 homes and avoid the annual emission of 570,000 *tons* of CO_2**

LONGYANGXIA DAM SOLAR PARK

Source: //http://www.chinadaily.com.cn/m/powerchina/2014-01/02/content_17210451.htm

LONGYANGXIA DAM SOLAR PARK

- **The world's largest *PV* plant is the 850-*MW* *Longyangxia Dam Solar Park*, which is located in, *Qinghai* Province, *China***
- **Construction began in March 2013 and the first phase of the project (530 *MW*) was commissioned on December 4, 2013**
- **The second phase of the project was completed in 2015**
- **The expected annual generation is 824 *GWh***

CESTAS SOLAR FARM

Source: http://solar.schneider-electric.com/new-300-mw-solar-farm-to-be-built-in-cestas-france/

CESTAS SOLAR FARM

- **With a total capacity of 300 *MW*, *Cestas Solar Farm* is the largest *PV* plant in Europe**
- **This solar park is located at *Cestas*, in Southwest *France*, and is expected to supply electricity to meet the needs of 250,000 people**
- **Electricity is sold under a 20–*year PPA* with the French utility *EDF* at a price of 105 €/*MWh***

ROOFTOP *PV* SOLAR

Source: http://assets.inhabitat.com/wpcontent/blogs.dir/1/files/2012/12

ROOFTOP *PV* SOLAR IN *US*

- **Rooftop solar electricity still represents a small portion of *US* electricity generation**
- **Residential solar continues to grow from quarter to quarter even since the onset of the *COVID*-19 pandemic in total installed residential capacity**
- **State government incentives to promote solar energy have led to widespread rooftop solar in the Western states – *CA*, *AZ*, *CO* and *NV* – and in *NC* due to the law that authorized solar leasing**

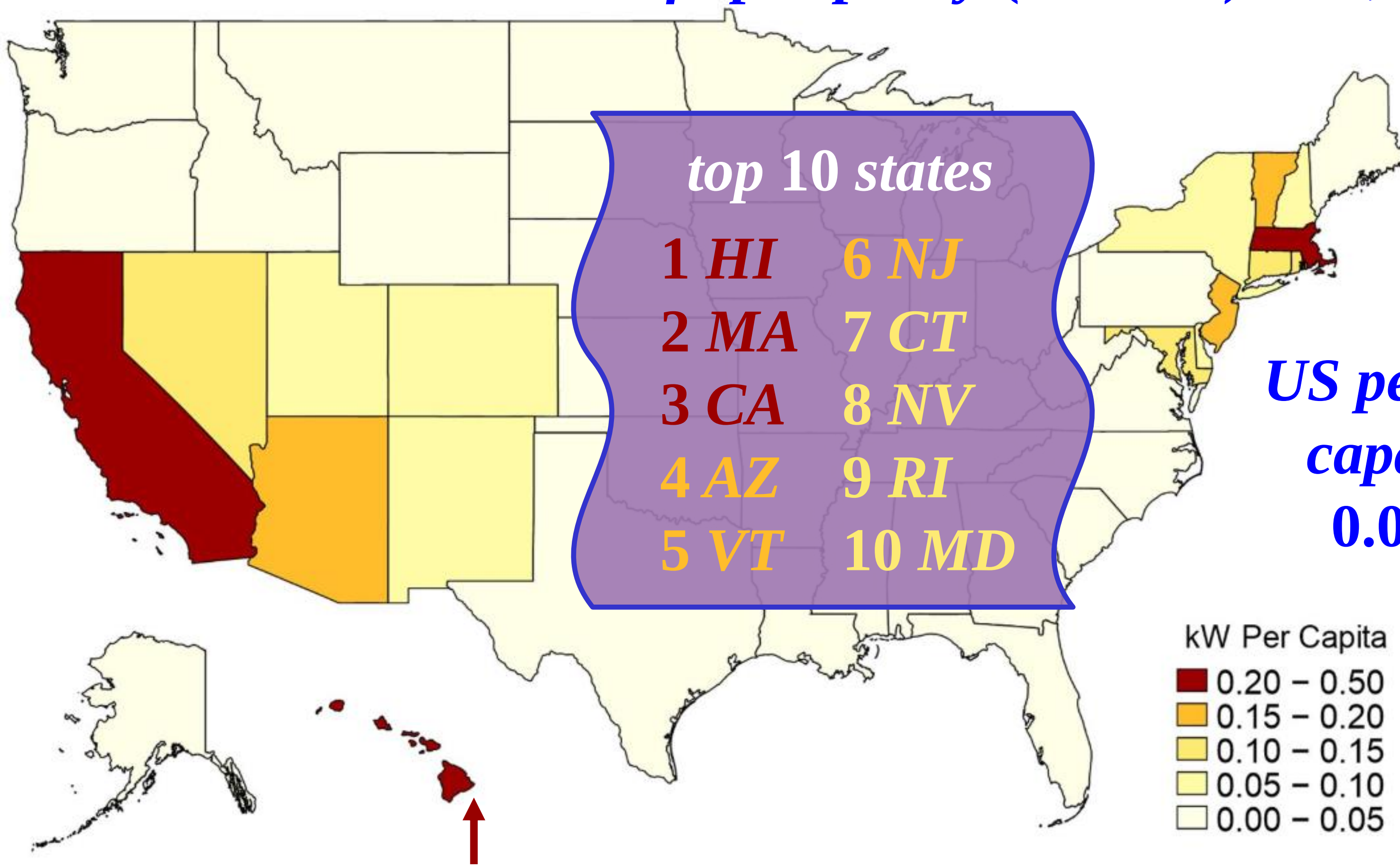
ROOFTOP *PV* SOLAR IN *US*

- Location–dependent incentives for utility customers to install rooftop solar panels vary from state to state and include tax credits, installation cost rebates and *net metering*
- At present 40 states, the *District of Columbia* and 3 territories offer net metering
- *EIA* in 2019 noted that rooftop electricity is less than 0.25 % of the *US electricity generation*

NOVEMBER 2019: *US* ROOFTOP SOLAR CAPACITY PER CAPITA

Source*: *L. Davis, "Putting Solar in All the Wrong Places", Energy Institute Blog, available at https://energyathaas.wordpress.com/2020/02/03/putting-solar-in-all-the-wrong-places/; data source is EIA at https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_02_b

US total rooftop capacity* (< 1 *MW*) = 22, 705 *MW

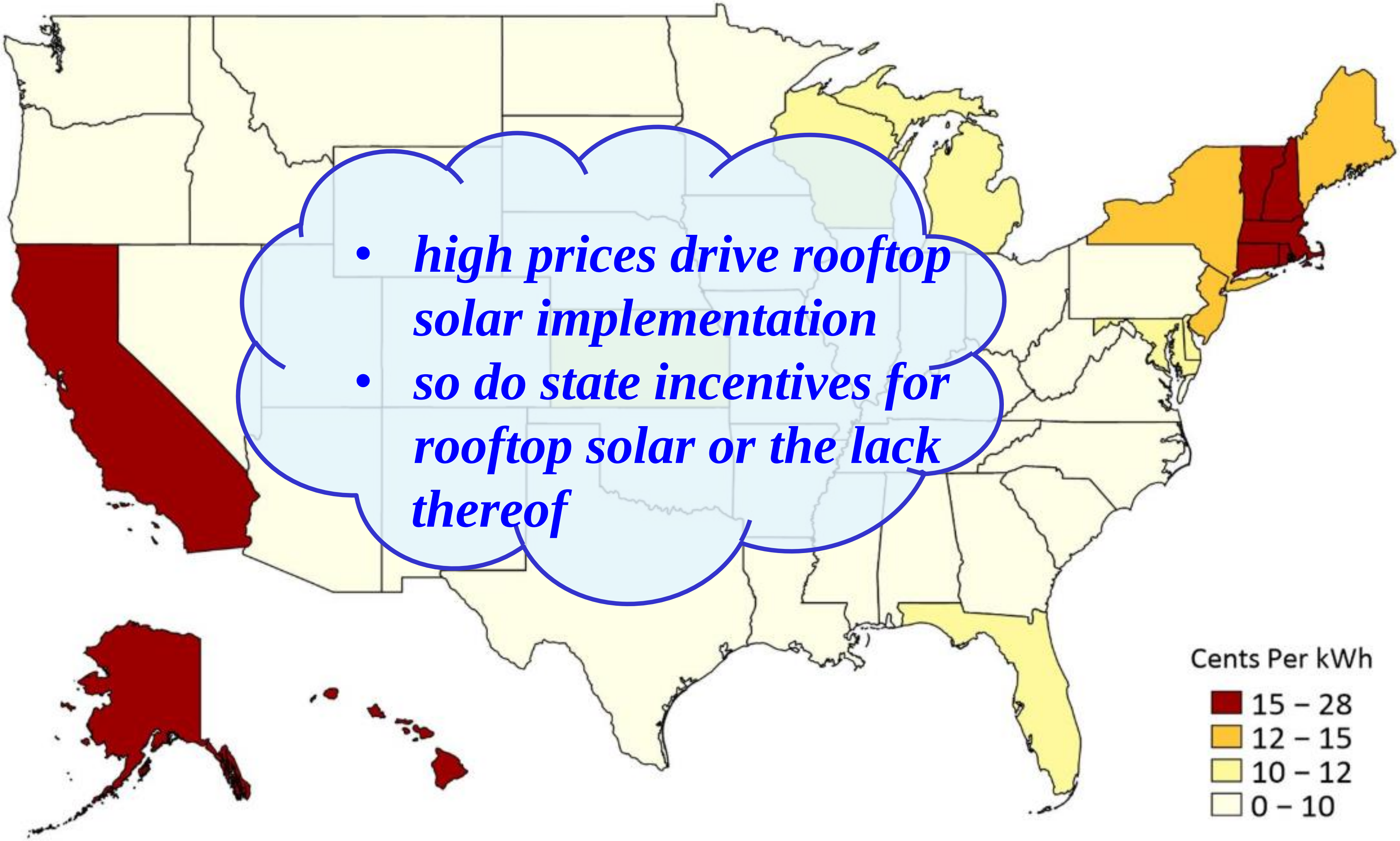


US per capita capacity* = 0.07 *kW

HI: highest per capita capacity* = 0.50 *kW

NOVEMBER 2019: *US* AVERAGE RETAIL ELECTRICITY PRICES BY STATES

Source: L. Davis, "Putting Solar in All the Wrong Places", Energy Institute Blog, available at https://energyathaas.wordpress.com/2020/02/03/putting-solar-in-all-the-wrong-places/; based on electricity prices by state for November 2019 from the EIA Data Browser



- ***high prices drive rooftop solar implementation***
- ***so do state incentives for rooftop solar or the lack thereof***

NET METERING

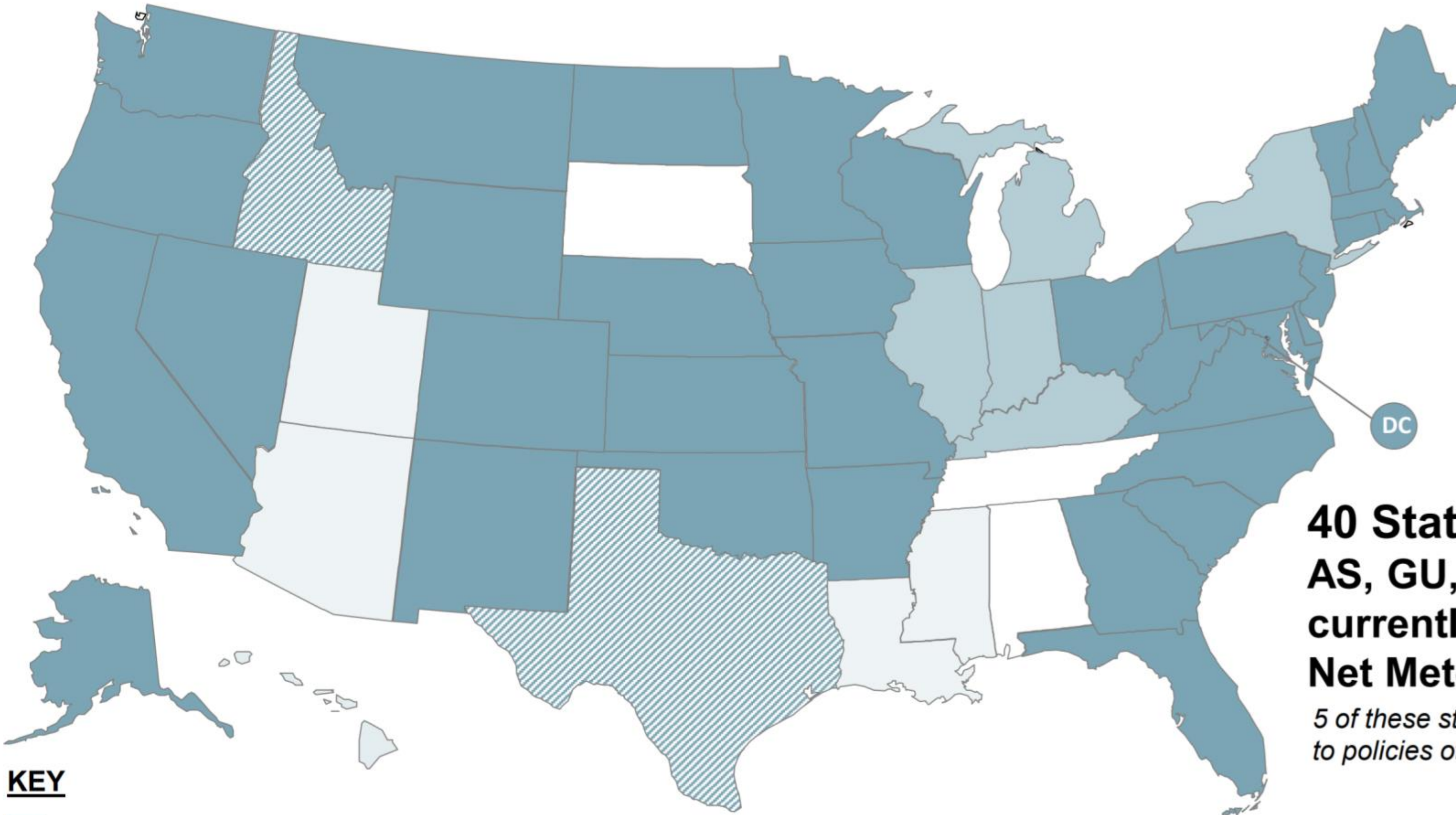
- **Under net metering – a billing mechanism that credits solar energy system owners for the energy injected into the grid – customers pay only for the electricity consumed that exceeds the amount fed into the grid, the so-called *net energy***

NET METERING

Source: http://www.seia.org/policy/distributed-solar/net-metering//

US NET METERING STATUS

Source*: *DSIRE 2020, available at https://s3.amazonaws.com/ncsolarcen-prod/wp-content/uploads/2020/06/DSIRE_Net_Metering_June2020.pdf



40 States + DC, AS, GU, PR, & USVI currently have mandatory Net Metering rules

5 of these states are in transition to policies other than net metering

KEY

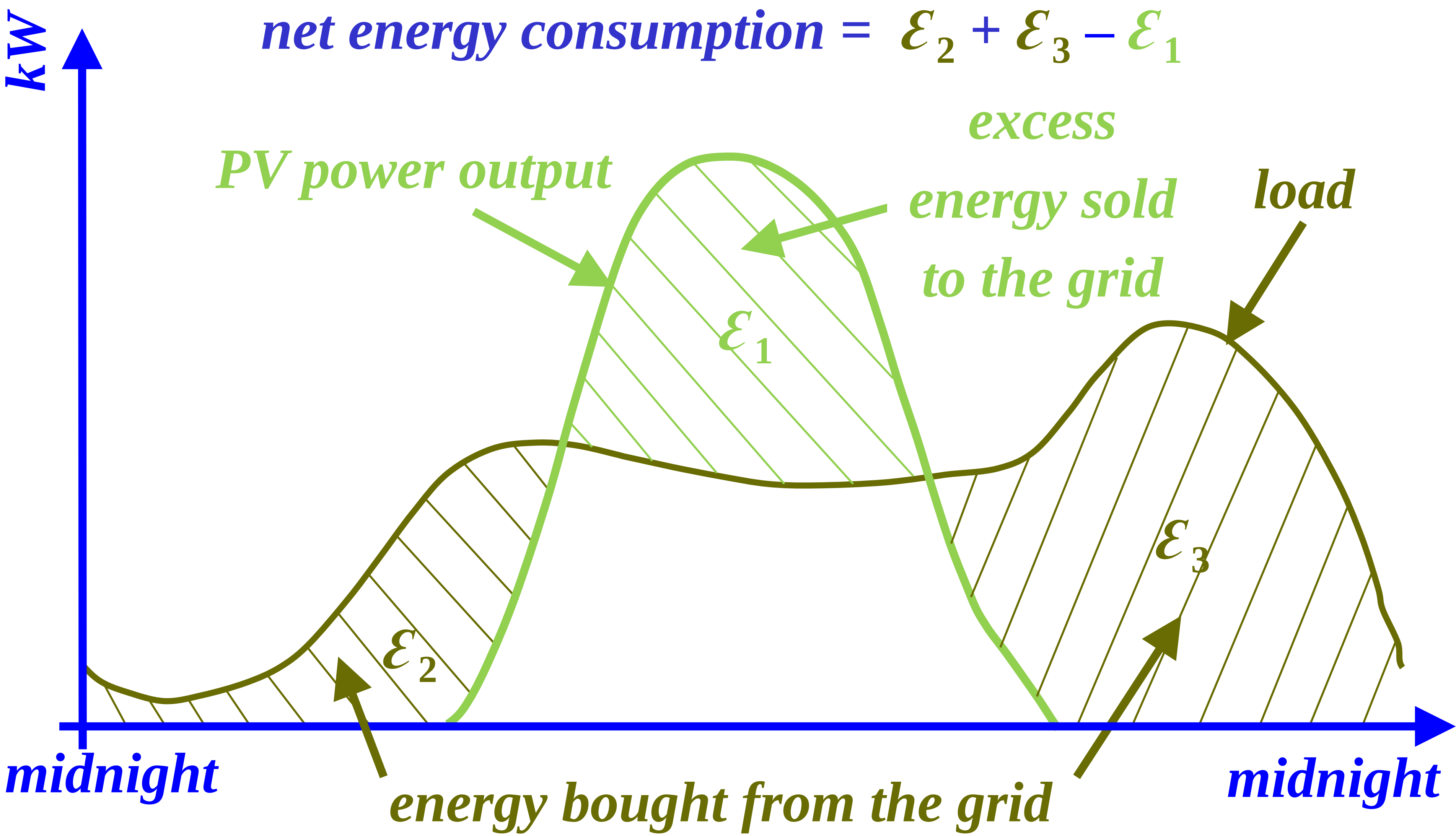
- State-developed mandatory rules for certain utilities (35 states + DC+ 4 territories)
- In transition to statewide distributed generation compensation rules other than net metering (5 states)
- Statewide distributed generation compensation rules other than net metering (5 states)
- No statewide mandatory rules, but some utilities allow net metering (2 states)

U.S. Territories:

AS PR

VI GU

NET METERING



NET METERING

- The implementation of net metering varies from one jurisdiction to another
- In *CA*, solar owners have received federal tax credits, rebates under the so–called *CA Solar Initiative*, which has been phased out, and net metering; *CA* has the nation's largest quantity of installed solar *PV* capacity

NET METERING

- The payments foregone by the net metered solar owners are pushing the distribution utilities to shift the collection of the electricity infrastructure to the non–solar–owner customers; many utilities have viewed this development as the so-called "death spiral "; but, the various changes in net metering have lessened such concerns

RENEWABLE ENERGY CERTIFICATE (*REC*s)

- The *REC*s, known as the *renewable energy credit*s or *green tag*s, are tradable and non–tangible energy commodities that provide proof of the production of 1 *MWh* of electricity by a renewable resource
- Every renewable energy resource gets paid for its production from two sources: the energy is compensated through sales into the electricity markets or via *PPA*s; in addition, the sale by the *solar/wind* resource of *REC*s, which represent its energy generation, is a *separate revenue stream*

*REC*s

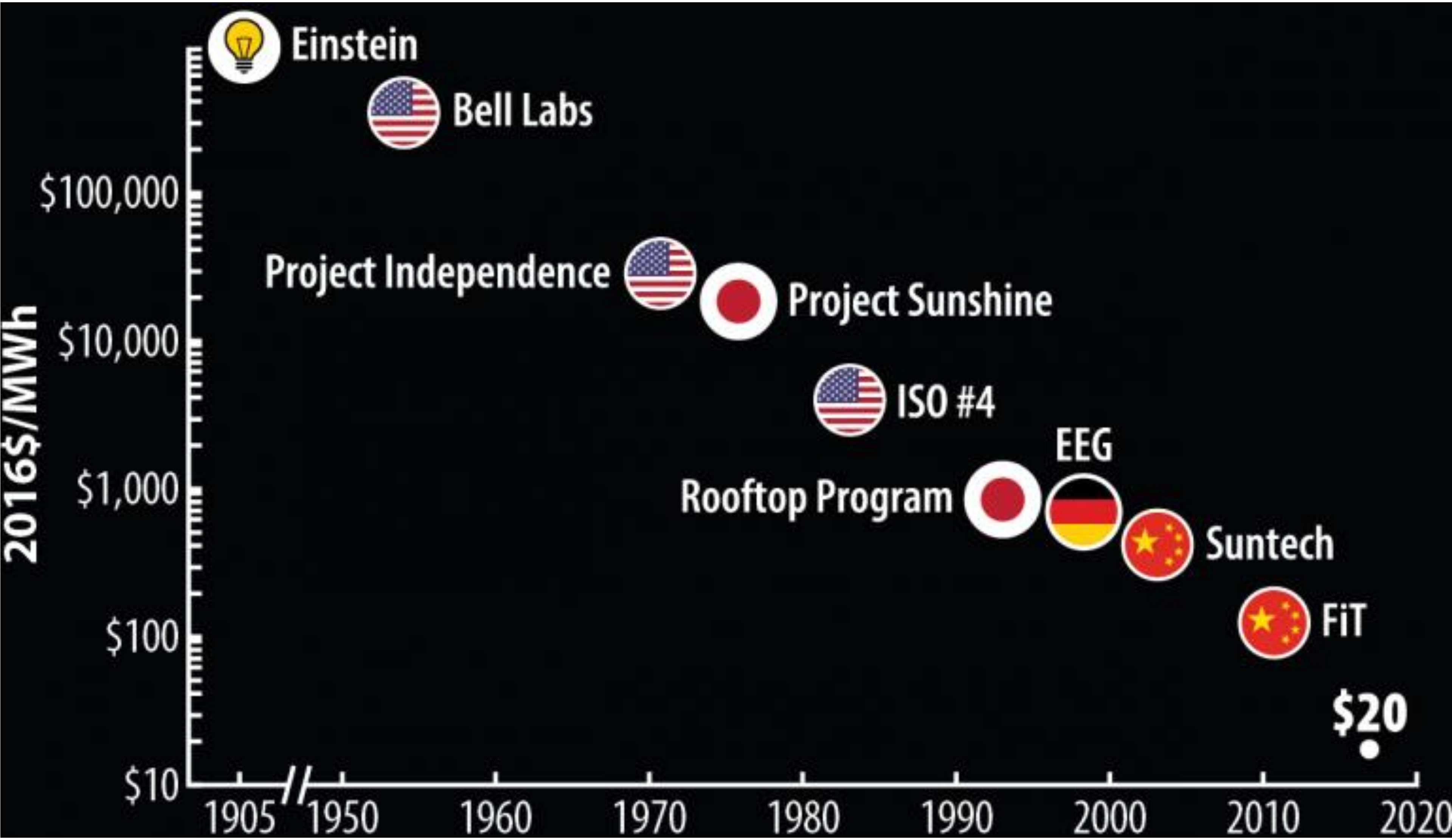
- Since the energy and the *REC*s are sold separately and possibly to different buyers, the green energy *consumption* and the proof of the production may be in different jurisdictions
- The prices of *REC*s vary from one jurisdiction to another and their use across different states are subject to the *non-uniform rules* across the states
- *REC*s provide buyers and sellers flexibility in trading renewable energy across state borders

***REC*s**

- **The *REC*s convey the environmental benefits of the renewable resource electricity and, under a tracking mechanism, provide direct accounting to meet the *RPS* goals in each jurisdiction**
- **The *REC*s provide auditable proof of the amount of renewable energy production injected into the grid by solar/wind resources**

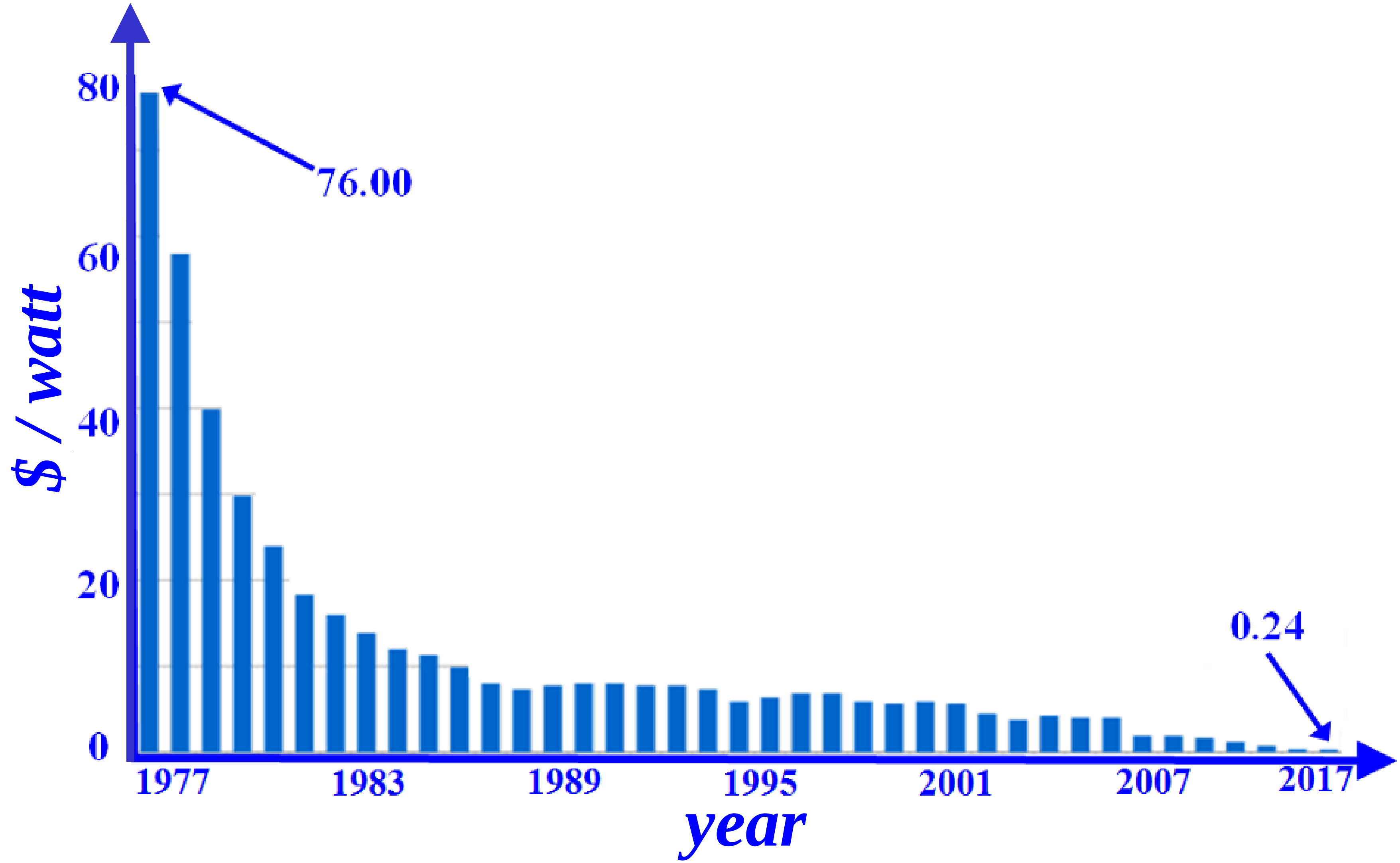
THE WAY SOLAR BECAME SO CHEAP

***Source*: *Gregory F. Nemet, "How Solar Energy Became Cheap," Routledge*, 2018**

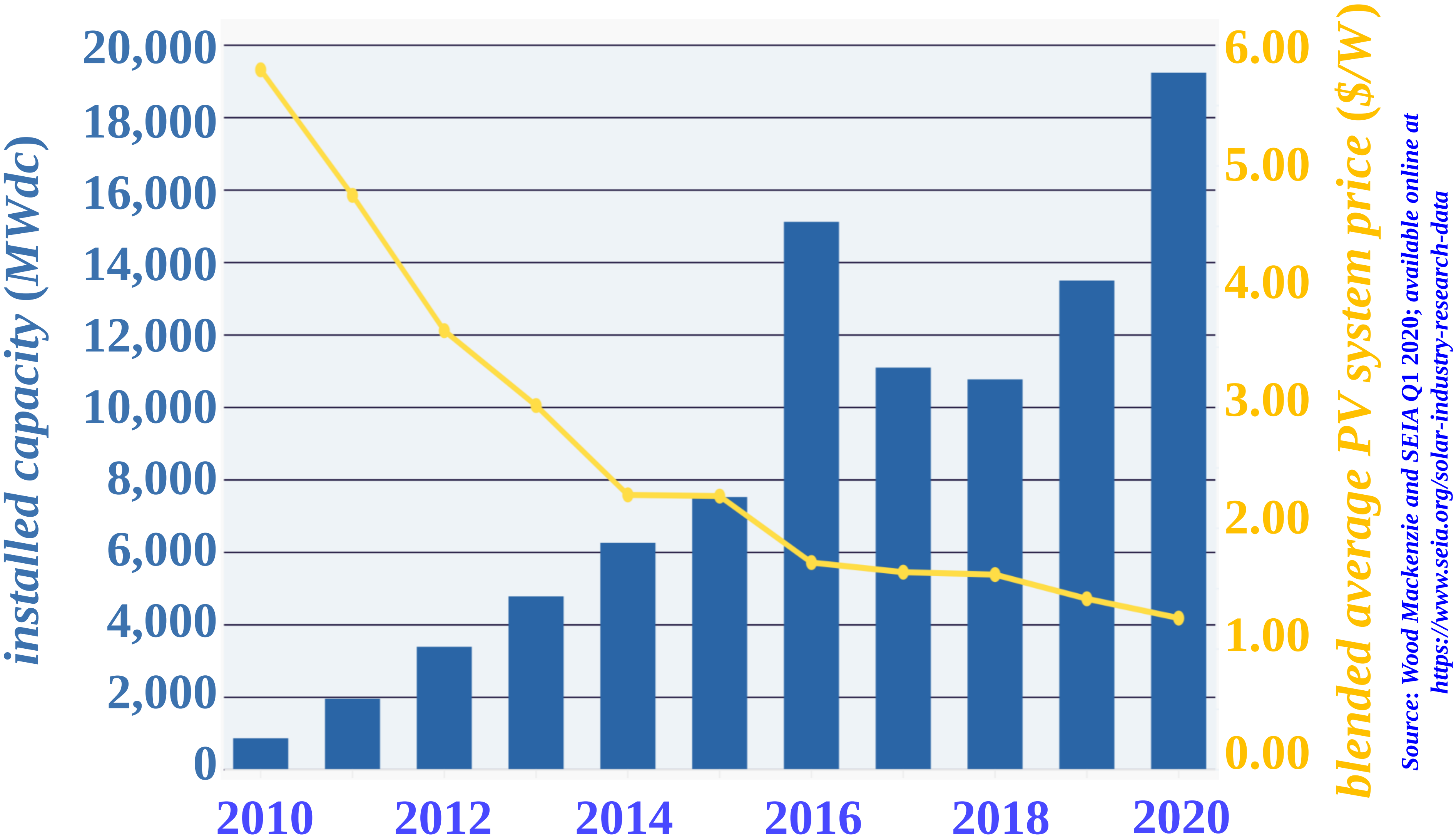


PV SOLAR CAPACITY PRICE DECLINE

Source: Bloomberg, New Energy Finance, and https://en.wikipedia.org/wiki/Growth_of_photovoltaics

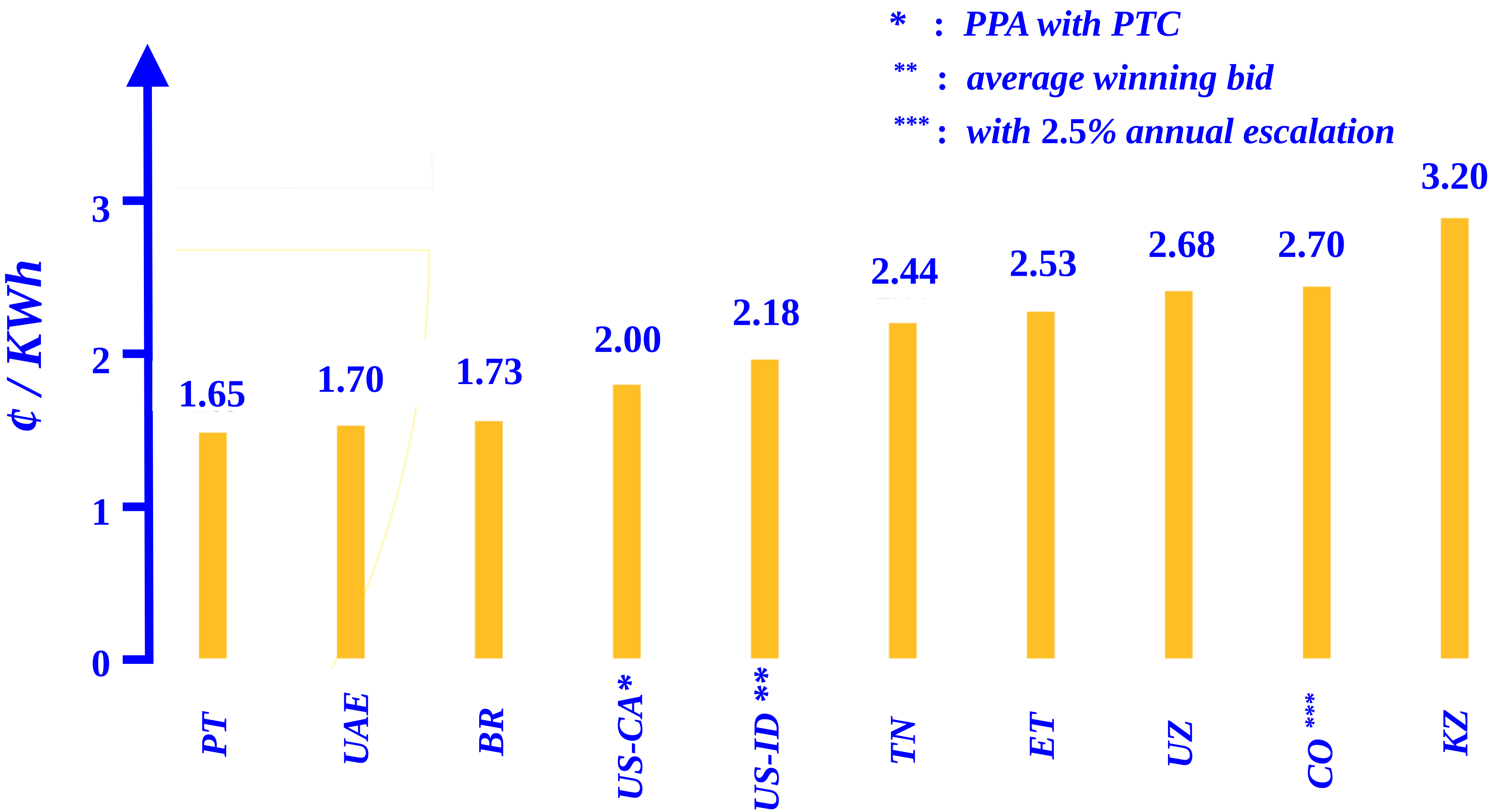


ANNUAL *US* SOLAR CAPACITY ADDITIONS AND PRICES



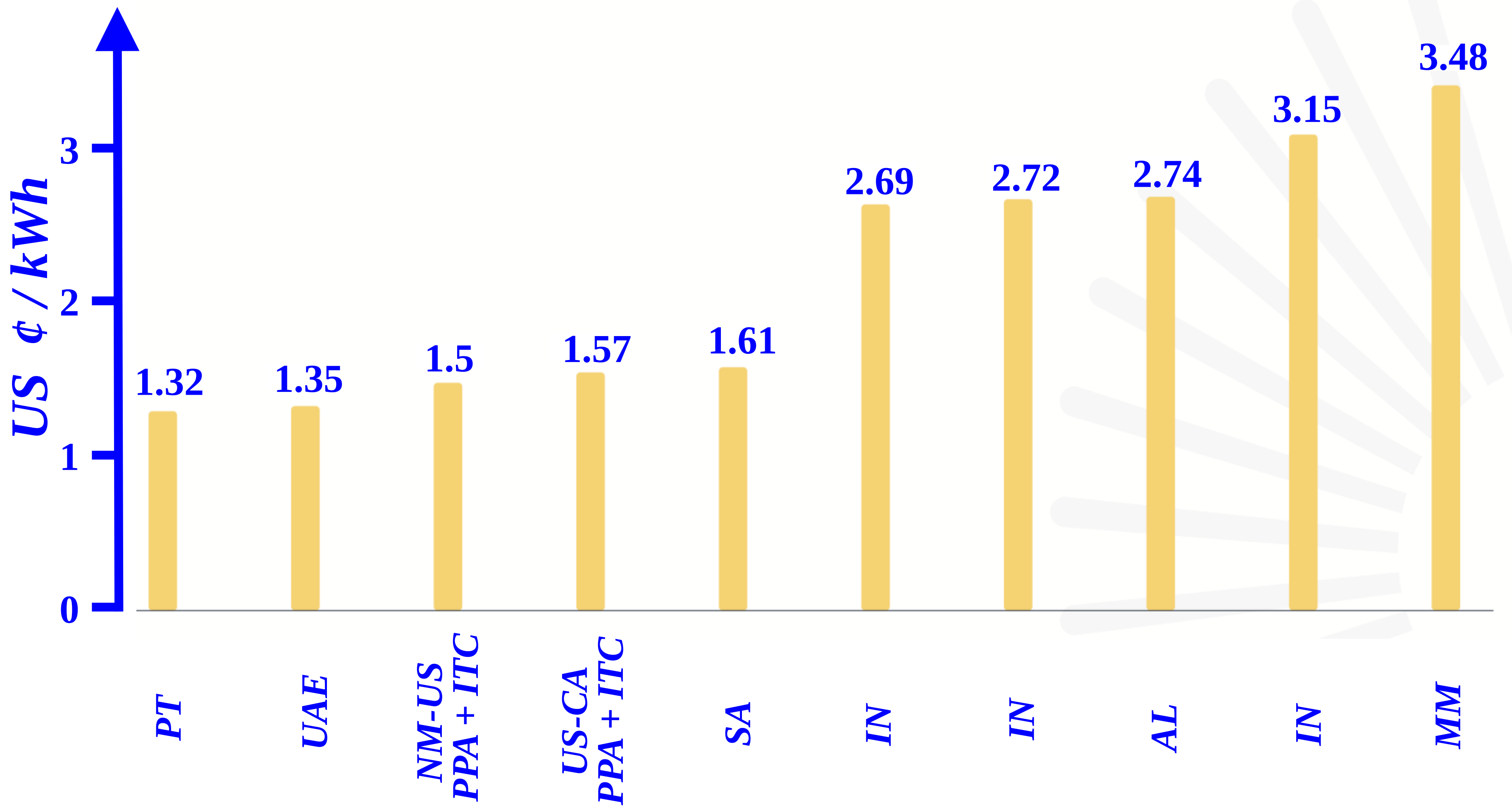
SOME LOW SOLAR PRICES IN THE 2019 AUCTIONS

***Source**: Solar Power Europe/ Global Market Outlook For Solar Power* 2020-2024; p.11; *available at https://www.solarpowereurope.org/wp-content/uploads/2020/07/31-SPE-GMO-report-hr-hyperlinks.pdf?cf_id=43253*



SOME LOW SOLAR PRICES IN THE 2020 AUCTIONS

***Source**: SolarPower Europe, Global Market Outlook for Solar Power* 2021-2025*; https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V2.pdf?cf_id=36863; p.11*



COMPETITIVE PRICES OF RENEWABLE ENERGY

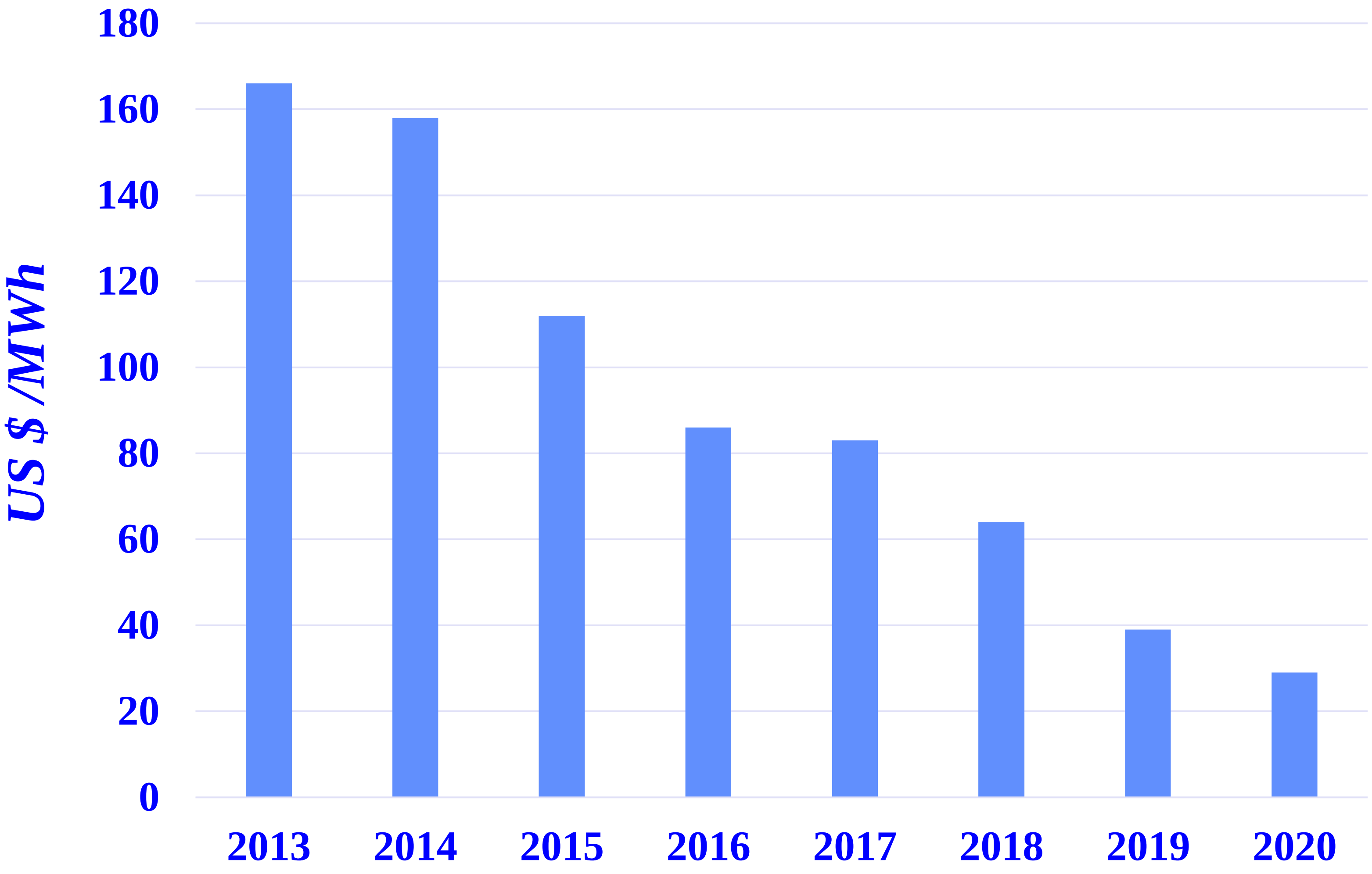
- Average solar *PV* price in the *Brazilian A–6 Auction* in October 2019 reaches 2.052 *¢/kWh*
- The average price for solar *PV* in *US* in 2020 was 2.9193 *¢/kWh*
- *Portugal's latest solar energy* auction in August 2020 had a bid for a solar price at 1.316 *¢/kWh*

COMPETITIVE PRICES OF RENEWABLE ENERGY

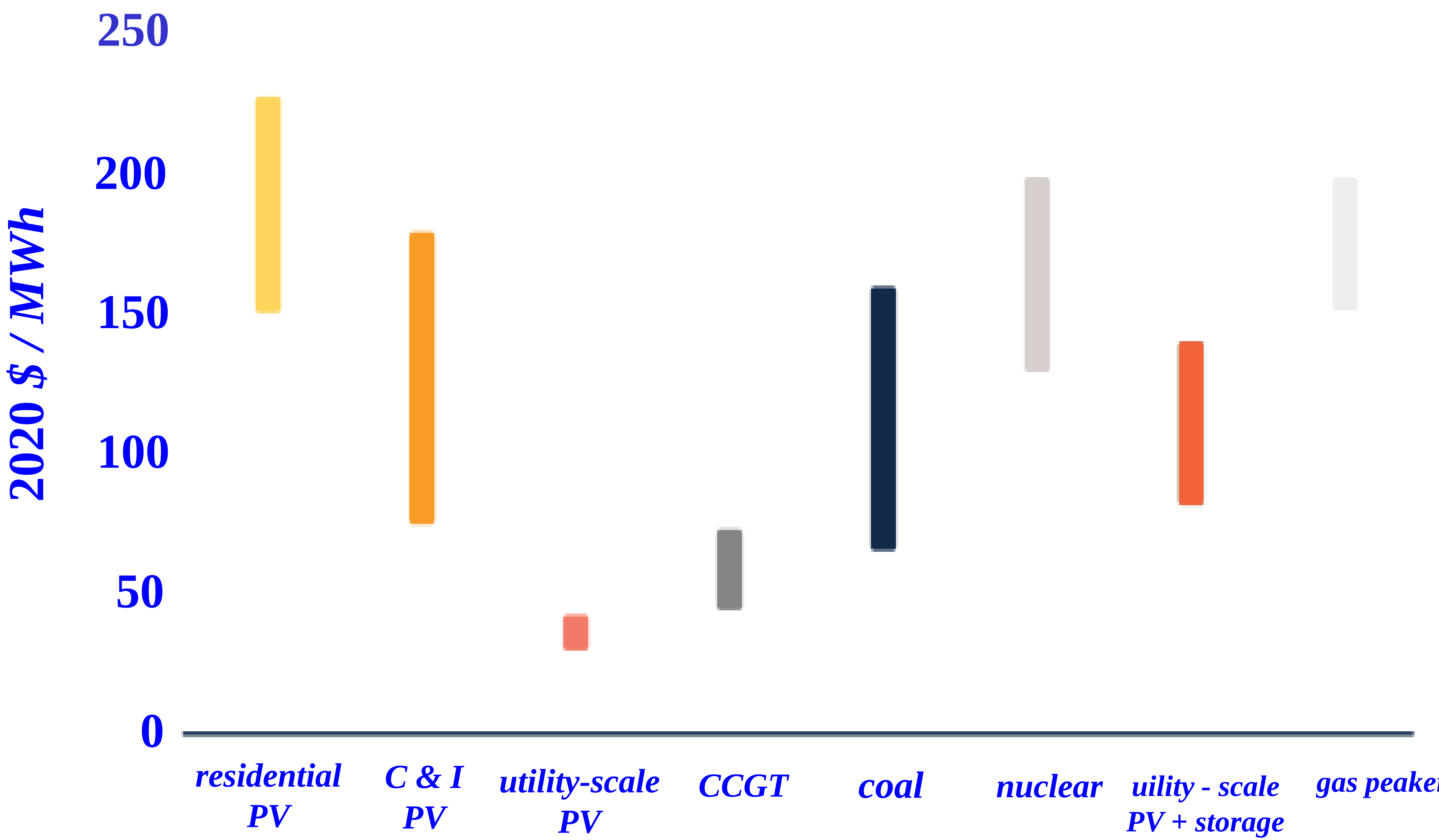
- **In the July 2020 *Abu Dhabi's 2 GW solar tender*, solar sold at about $0.0135 */kWh***
- ***Los Angeles Department of Water and Power* set a new *solar + battery* record in *US* at the price of 2.376 *¢/kWh***

EVOLUTION OF SOLAR *PV* AVERAGE AUCTION PRICES: 2013 – 2020

Source*: *https://www.iea.org/data-and-statistics/charts/announced-wind-and-solar-pv-average-auction-prices-by-commissioning-date-2012-2020

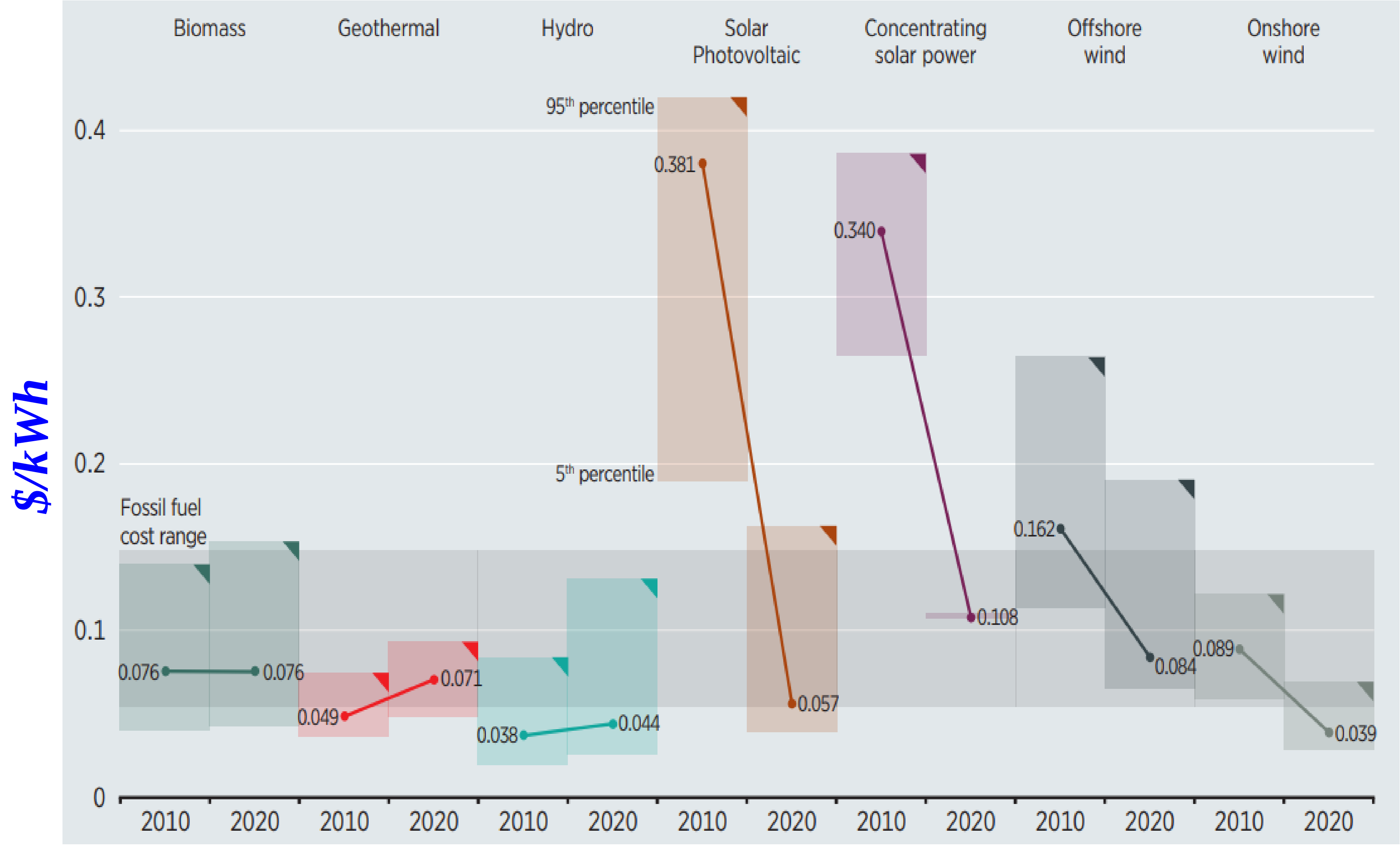


LCOE COMPARISON: 2020



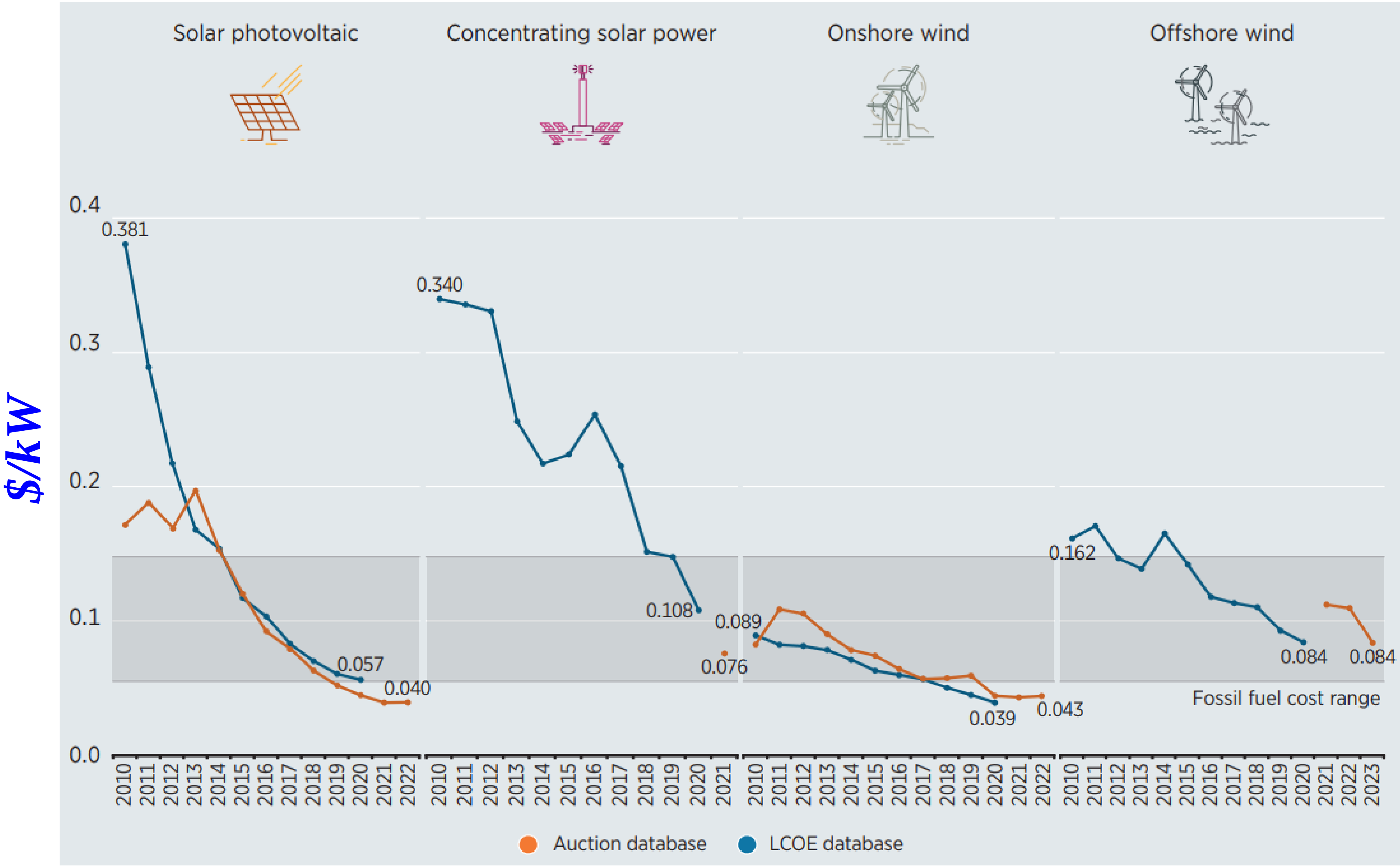
Source: Lazard (2021); all prices in 2020 USD, https://www.solarpowereurope.org/wp-content/uploads/2021/07/SolarPower-Europe_Global-Market-Outlook-for-Solar-2021-2025_V3.pdf?cf_id=38902; p. 10

LCOE OF UTILITY–SCALE RENEWABLE GENERATION: 2010 & 2020



Source: IRENA Renewable Power Generation Costs in 2020 p. 15;

GLOBAL WEIGHTED AVERAGE TOTAL INSTALLED COSTS SINCE 2010



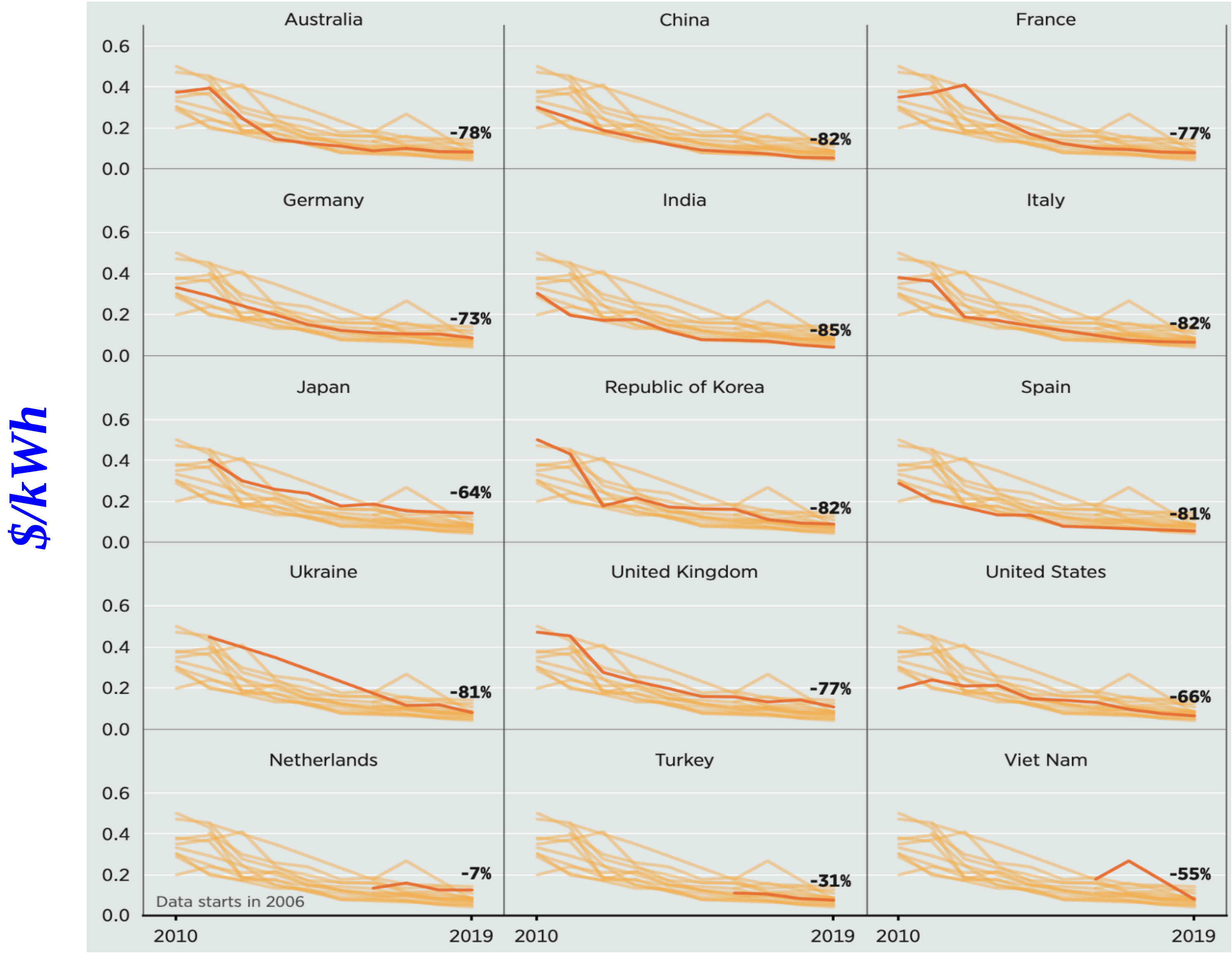
Source: IRENA Renewable Power Generation Costs in 2020 p. 17;

UTILITY–SCALE SOLAR *PV* TOTAL INSTALLED COSTS: 2010 – 2020

$/kW

Source: IRENA Renewable Power Generation Costs in 2020 p. 73;

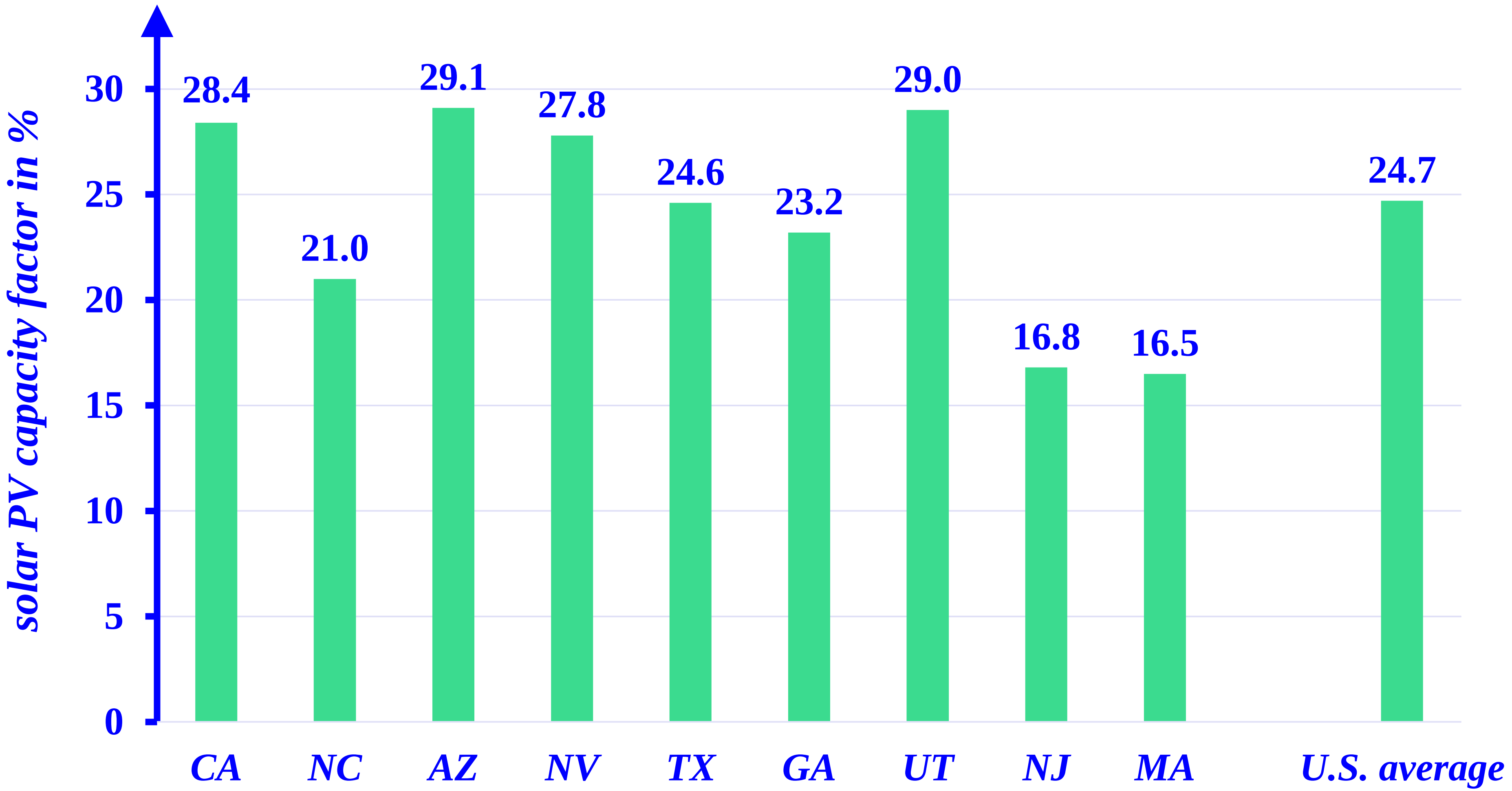
UTILITY–SCALE SOLAR *PV* WEIGHTED–AVERAGE *LCOE* TRENDS



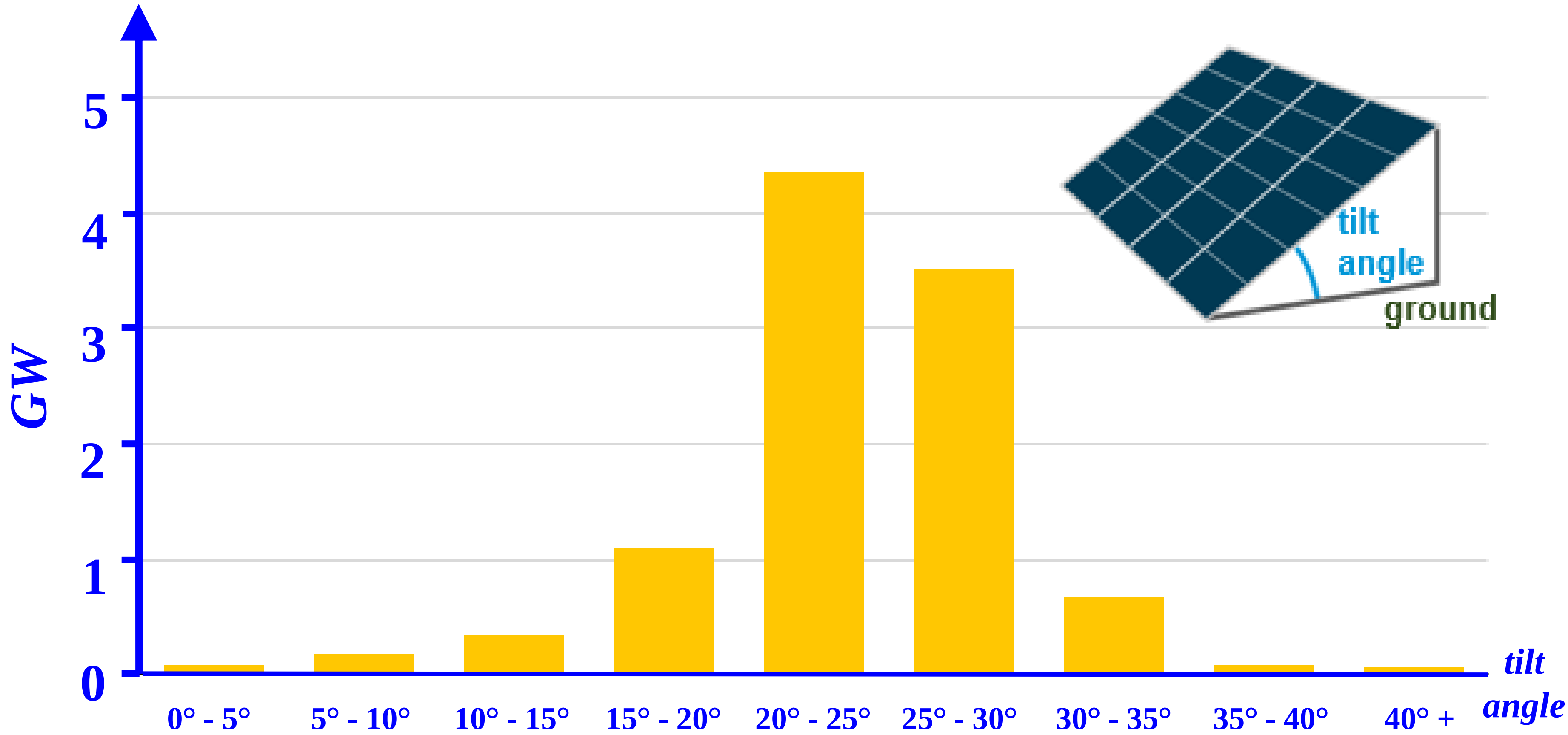
Source: IRENA Renewable Power Generation Costs in 2019, p. 72; available online at https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019

US UTILITY–SCALE *PV* SOLAR *c.f.*s: 2014 – 2017

Source: EIA, Annual Electric Generator Inventory and Annual Electric Utility Data, available at https://www.eia.gov/todayinenergy/detail.php?id=39832

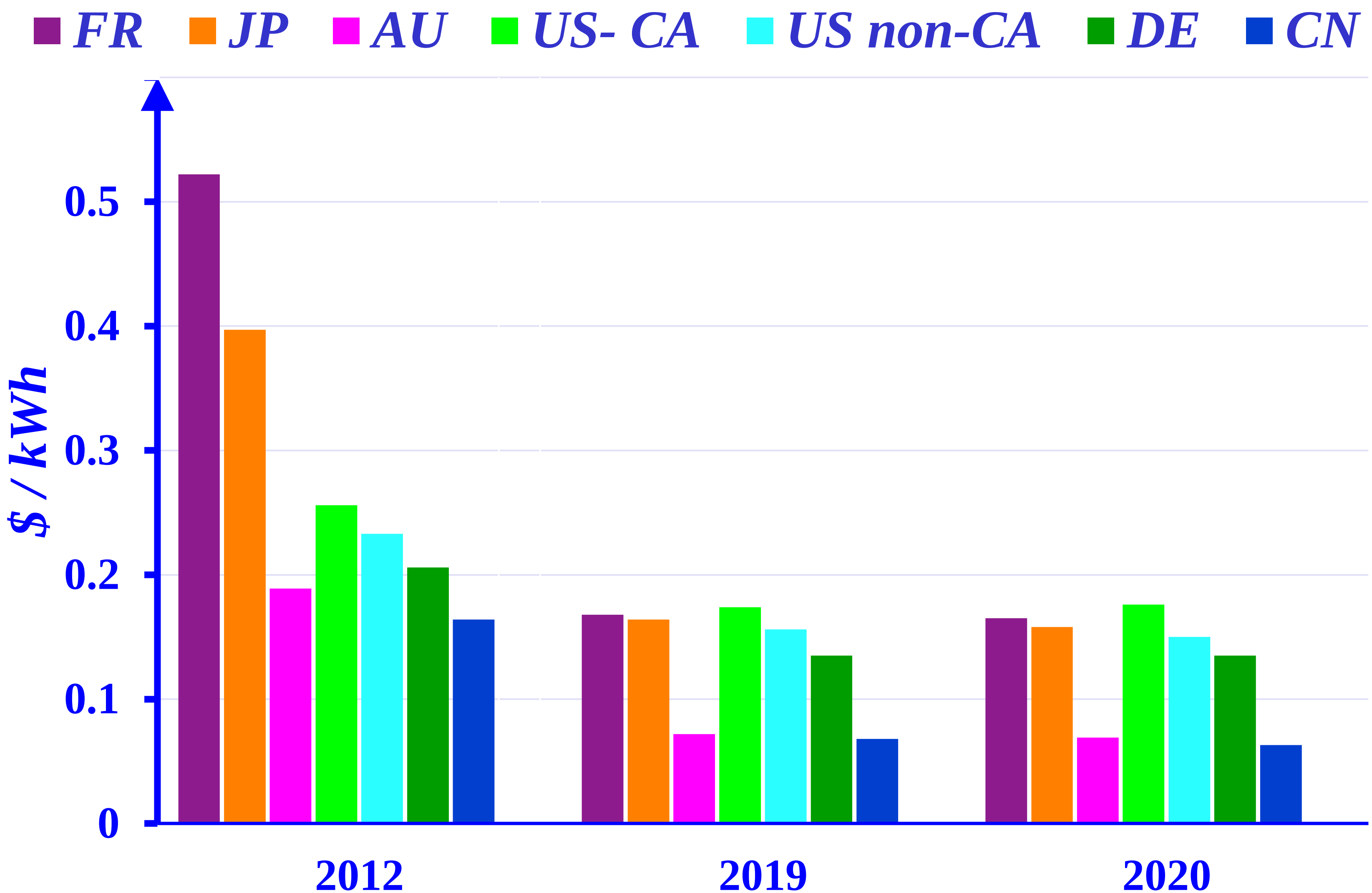


US FIXED – TILT UTILITY – SCALE *PV* SYSTEMS



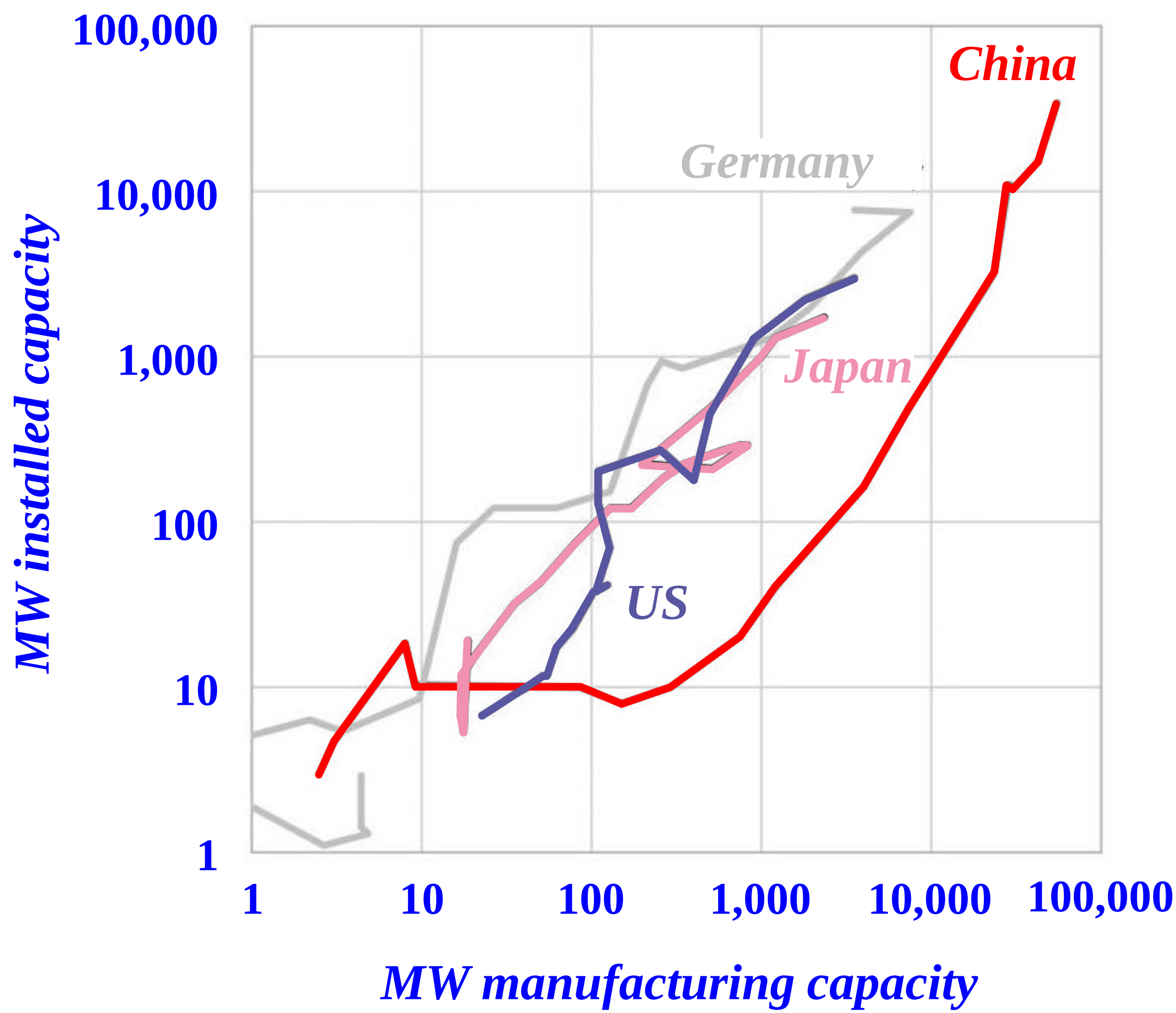
Source: EIA, Today in Energy, October 26, 2018; available online at https://www.eia.gov/todayinenergy/detail.php?id=37372

RESIDENTIAL *PV LCOE* BY LOCATION



Source: IRENA Global Renewable Energy Cost Trends, 2021, p.86; available at https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020

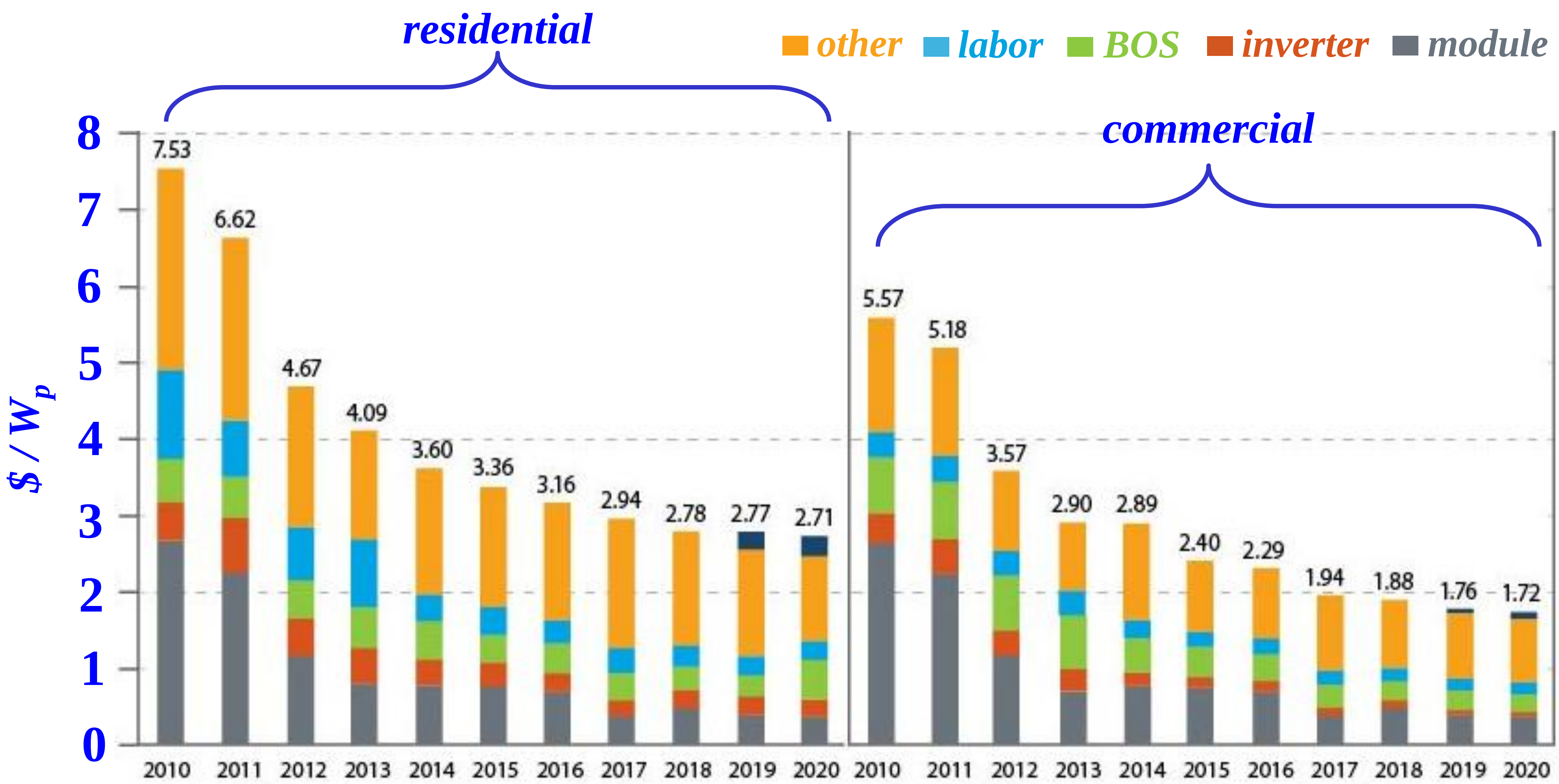
SOLAR PANEL INSTALLED CAPACITY *vs.* MANUFACTURING IN 4 NATIONS



Source: Gregory F. Nemet, "How Solar Energy Became Cheap," Routledge, 2018

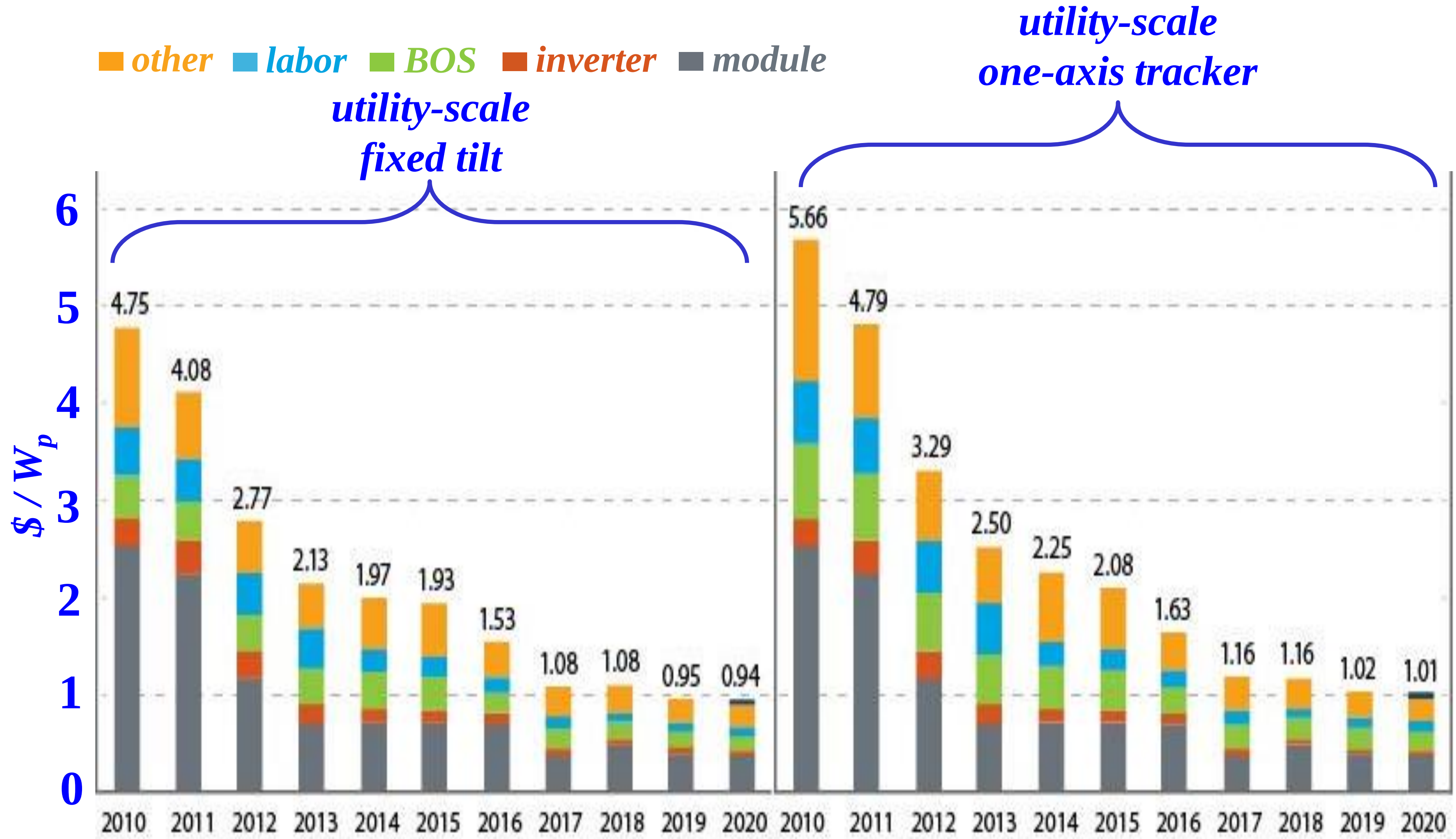
PV INSTALLATION COSTS BY SECTORS: *Q*1 2010 – 2020

Source: Clean Technica; available at https://cleantechnica.com/2021/02/13/charts-a-decade-of-cost-declines-for-pv-systems/



PV INSTALLATION COSTS BY SECTORS: *Q*1 2010 – 2020

Source: Clean Technica; available at https://cleantechnica.com/2021/02/13/charts-a-decade-of-cost-declines-for-pv-systems/



TOP 10 *PV* MODULE MANUFACTURERS IN 2020

company	*country*
LG energy	*South Korea*
SunPower	*US*
REC	*South Korea*
Q cells	*China*
Seraphim	*US*
Trina Solar	*China*
Jinko Solar	*China*
Canadian Solar	*Canada*
SunTech	*China*
JA Solar	*China*

Source: http://news.energysage.com/best-solar-panel-manufacturers-usa/

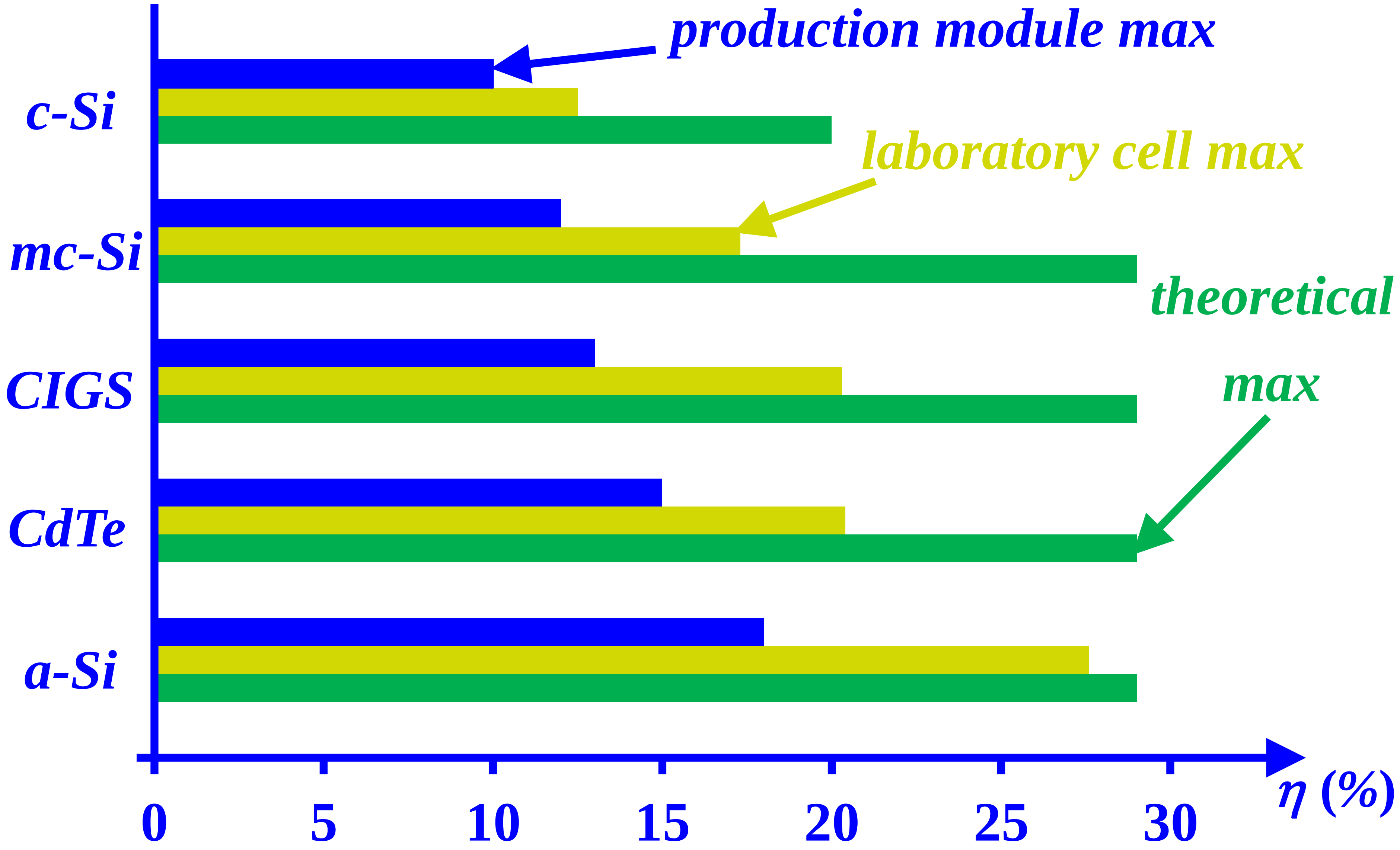
DOE SOLAR PROGRAM GOALS

- The *US* Department of Energy *Sunshot Initiative* is a national collaborative effort to make *PV* energy cost–competitive with fossil–fired generation has been met or, in some cases, surpassed
- The goals for *PV* by 2020 were set at 4 – 5 ¢/*kWh* in the residential sector, 5 – 6 ¢/*kWh* in the comercial sector, and 4 – 6 ¢/*kWh* in the utility sector

PV DEVELOPMENT CHALLENGES

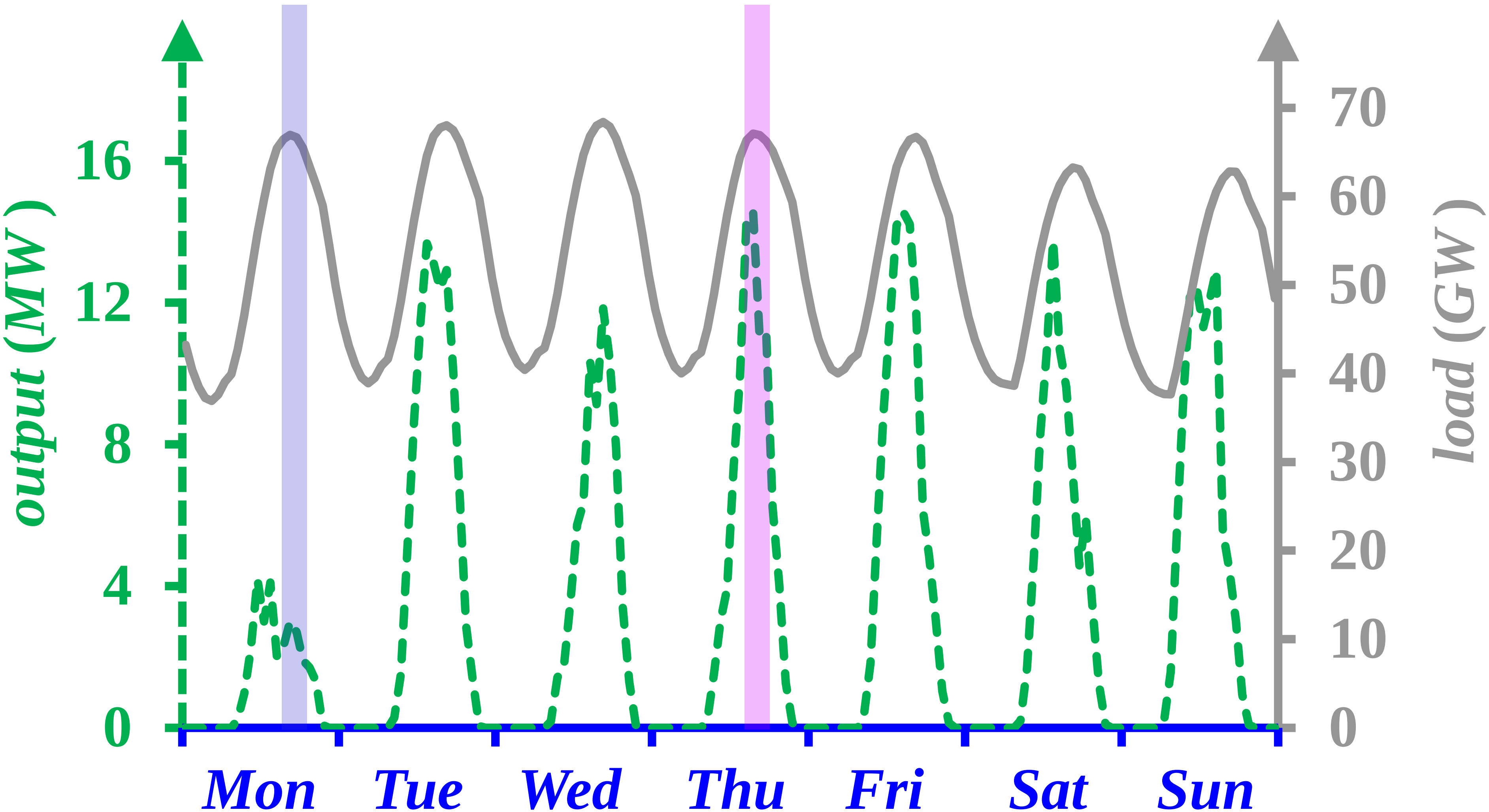
- The efficiency of typical *PV* modules used in energy production is still rather low
- Solar energy is highly uncertain, variable and intermittent renewable resource and the *PV* system electricity production has limited controllability and dispachability

PV EFFICIENCY BY MATERIAL



CHRONOLOGICAL *PV* OUTPUT AND *ERCOT* LOAD PATTERNS

source*: *http://www.ercot.com/gridinfo/



THE KEY DRIVERS OF *US PV* GROWTH

- **A most important driver is the *declining costs of installed PV*; in addition, the legislative and regulatory initiatives at the federal, state and local levels helped the growth of *US PV***
- **The federal drivers include:**
  - ***tax incentives* that were established to accele– rate investment into *PV* installations;**
  - ***loan guarantees* provided by the 2009 *American Recovery and Reinvestment Act* (*ARRA*) allowed the *US* Department of Energy to provide**

THE KEY DRIVERS OF *US PV* GROWTH

preferential financing support **to qualifying renewable energy projects;**

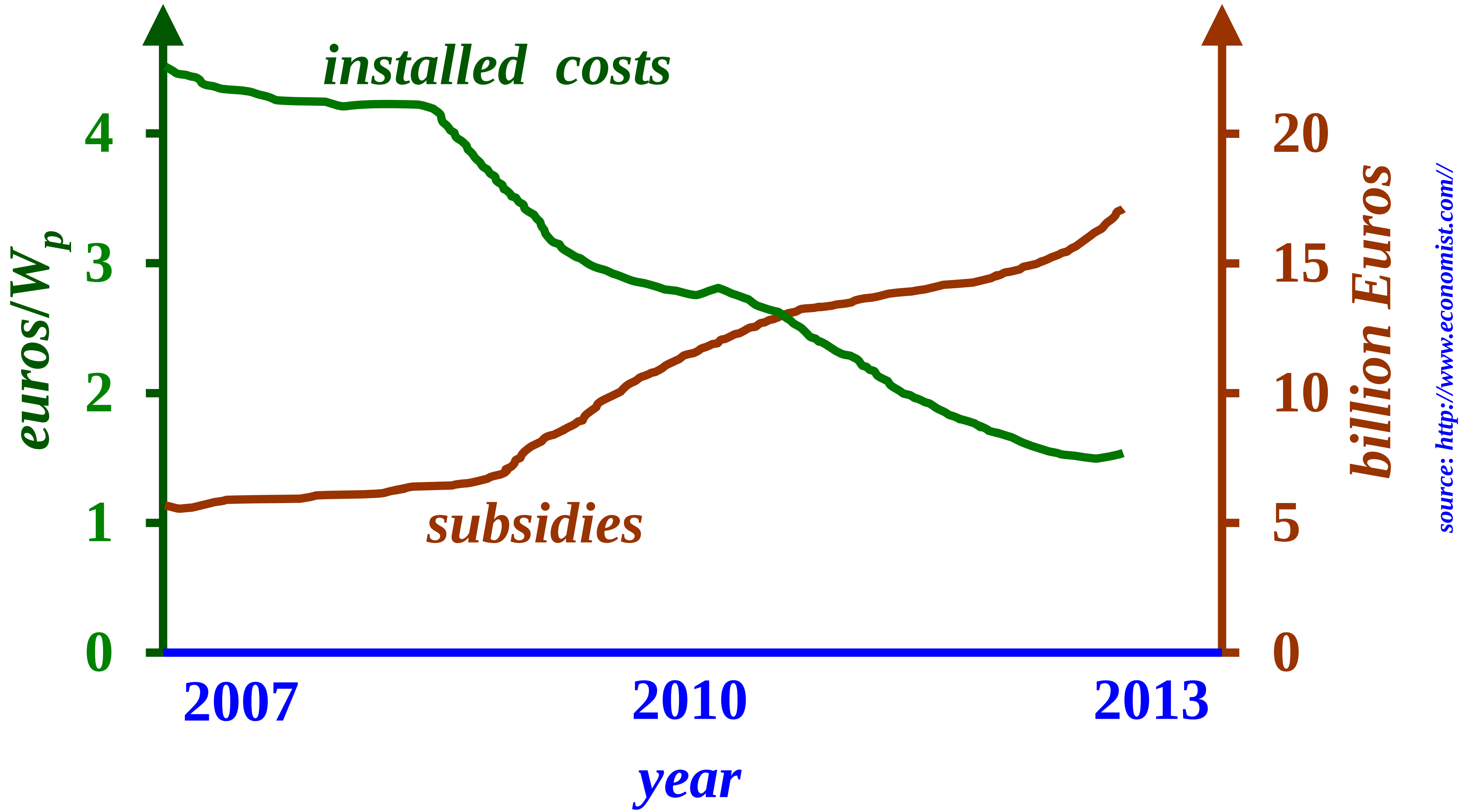
- ❍ *cash grants* **that provide** *direct cash infusion* **into commercial projects as an alternative to the tax credits**

- ❑ **At the state level, the drivers included**
  - ❍ *RPS requirements* **that stimulate investments in solar plants to meet the specified goal of renewable resource electricity generation**

THE KEY DRIVERS OF *US PV* GROWTH

- ***rebate programs*** **enacted to reduce the total investment costs of *PV* systems, especially for residential/commercial *PV* installations**
- ***net metering and TOU rates*** **that allow customers to offset their monthly electricity bills by the production of their own energy from their own *PV* outputs and the sale of the excess energy to the local distribution utility**

GERMANY *PV* INSTALLATION COSTS AND SUBSIDIES



KEY *PV* BENEFITS

- **Residential/commercial *PV* system installations reduce the amount of electricity these customers purchase from the local utility**
- **As *PV* systems produce the most power when the insolation is highest around solar noon, the gene– ration by solar reduces the need for and use of the expensive and polluting fossil generation units**

KEY *PV* BENEFITS

- ***PV*** **systems are important supply resources that lessen the nation's dependence on fossil fuels**
- **The clean *PV*–generated electricity helps reduce the amount of *GHG* – a major contributor to global climate change**
- **The growing *PV* industry provides local jobs and economic development opportunities to states and regions to create sustainable paths to meet the nation's energy needs**