ECE 333 – Renewable Energy Systems

Lecture 16: *PV* Status and Issues

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OUTLINE

- *PV* solar system status
- *PV* technology benefits
- Key drivers of the *PV* system growth
- *PV* system installation costs
- Major challenges facing the *PV* solar resources

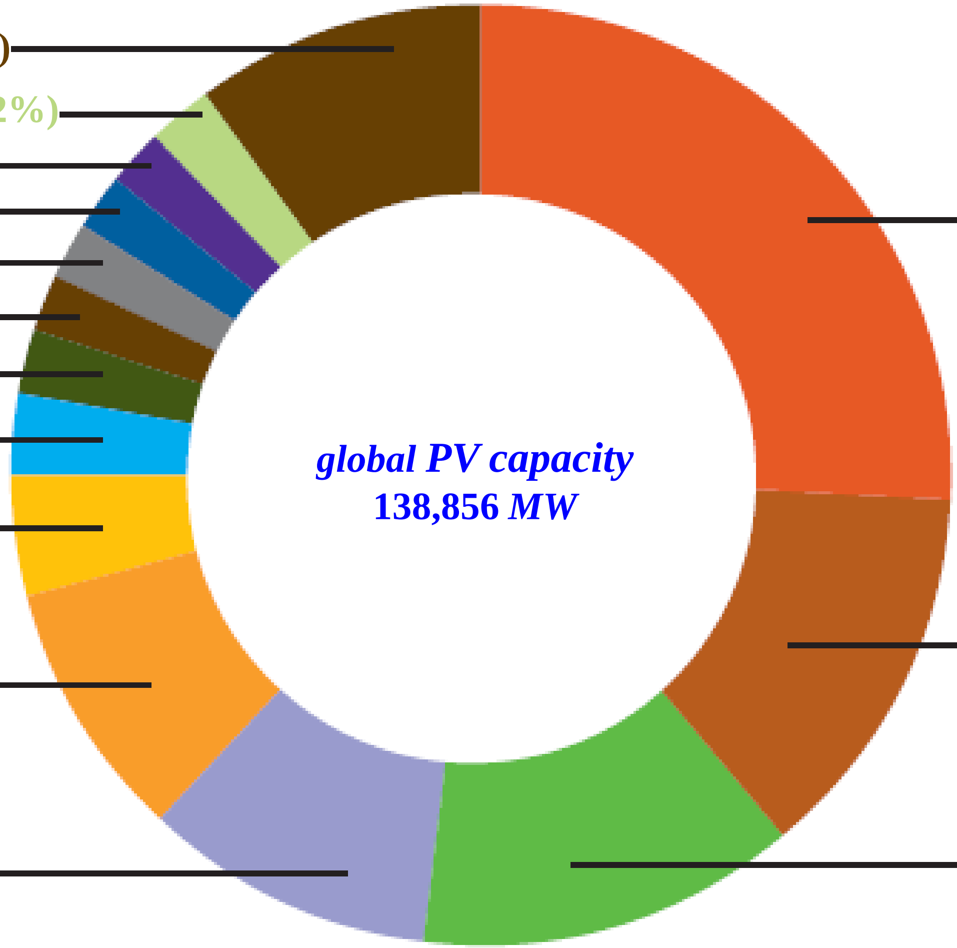
2013 WORLD STATUS OF THE *PV* SYSTEMS

- The new capacity additions of 38.4 *GW* increased the worldwide cumulative *PV* capacity to 138.9 *GW*
- Europe with 81.5 *GW* remains the world's leading region in terms of cumulative installed capacity – about 59 % of the world's total *PV* capacity and a decrease from 70 % in 2012

2013 WORLD STATUS OF *PV* SYSTEMS

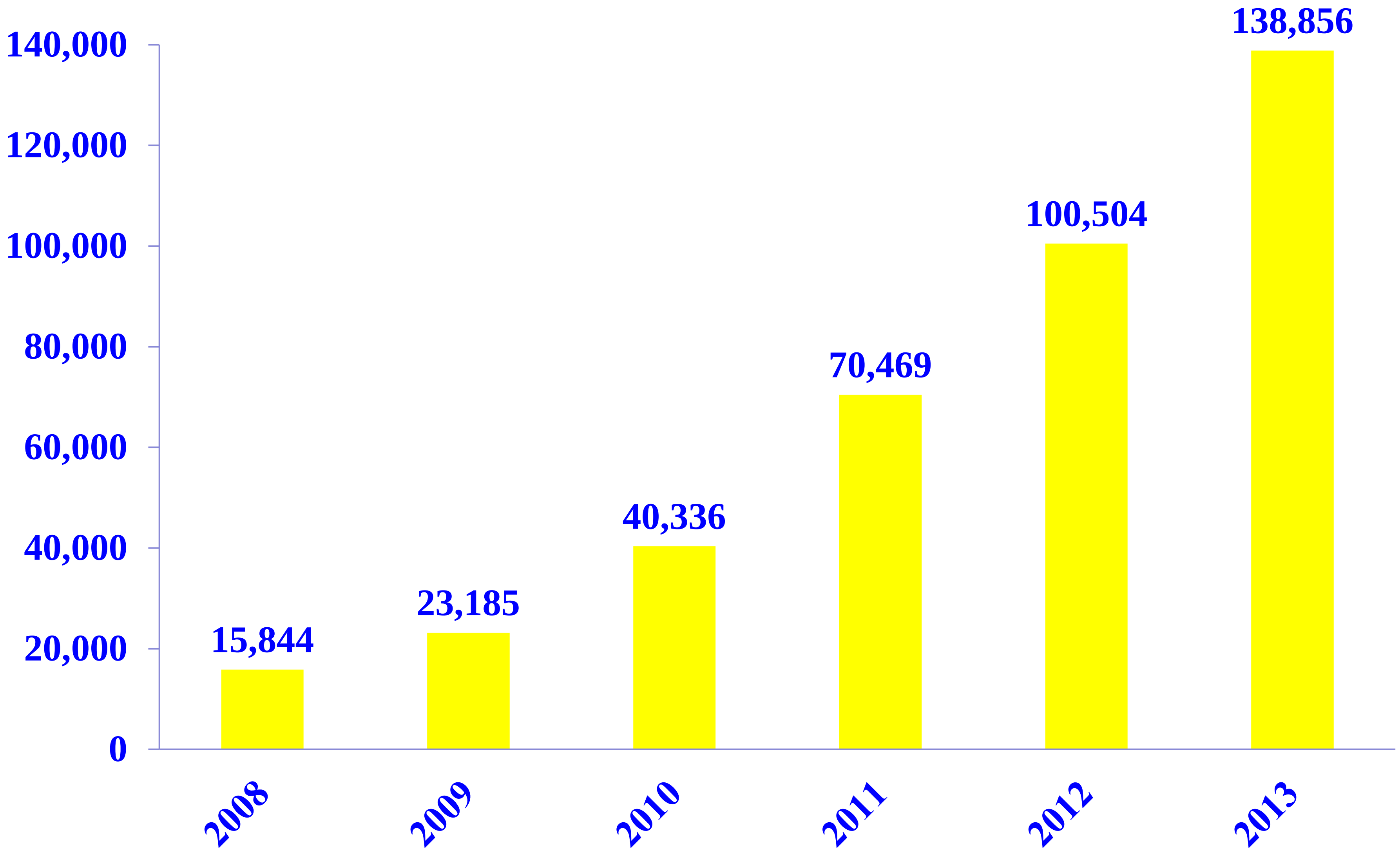
- European markets for *PV systems* did not perform well due to the reduction of solar incentives
- Outside Europe, markets for *PV systems* continued to grow at a reasonable pace
- Asia became the leader in terms of new for *PV system* installations for the first time
- China's added installed capacity was highest with 11.9 *GW*, followed by Japan (6.9 *GW*) & *USA* (4.6 *GW*)

2013 WORLD CUMULATIVE *PV* CAPACITY



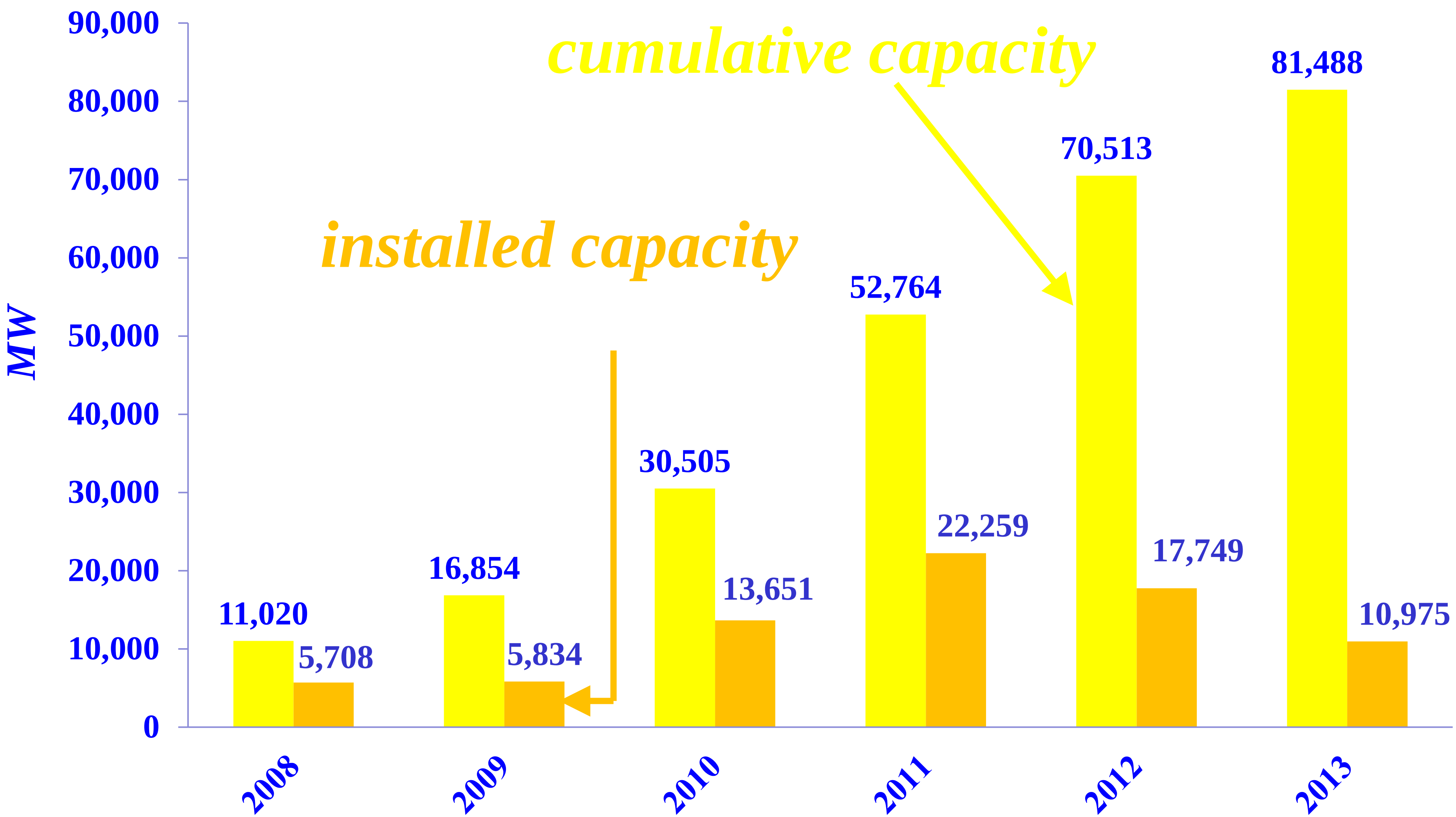
Source: http://www.epia.org/news/publications/

2008 – 2013 GLOBAL CUMULATIVE *PV* CAPACITY



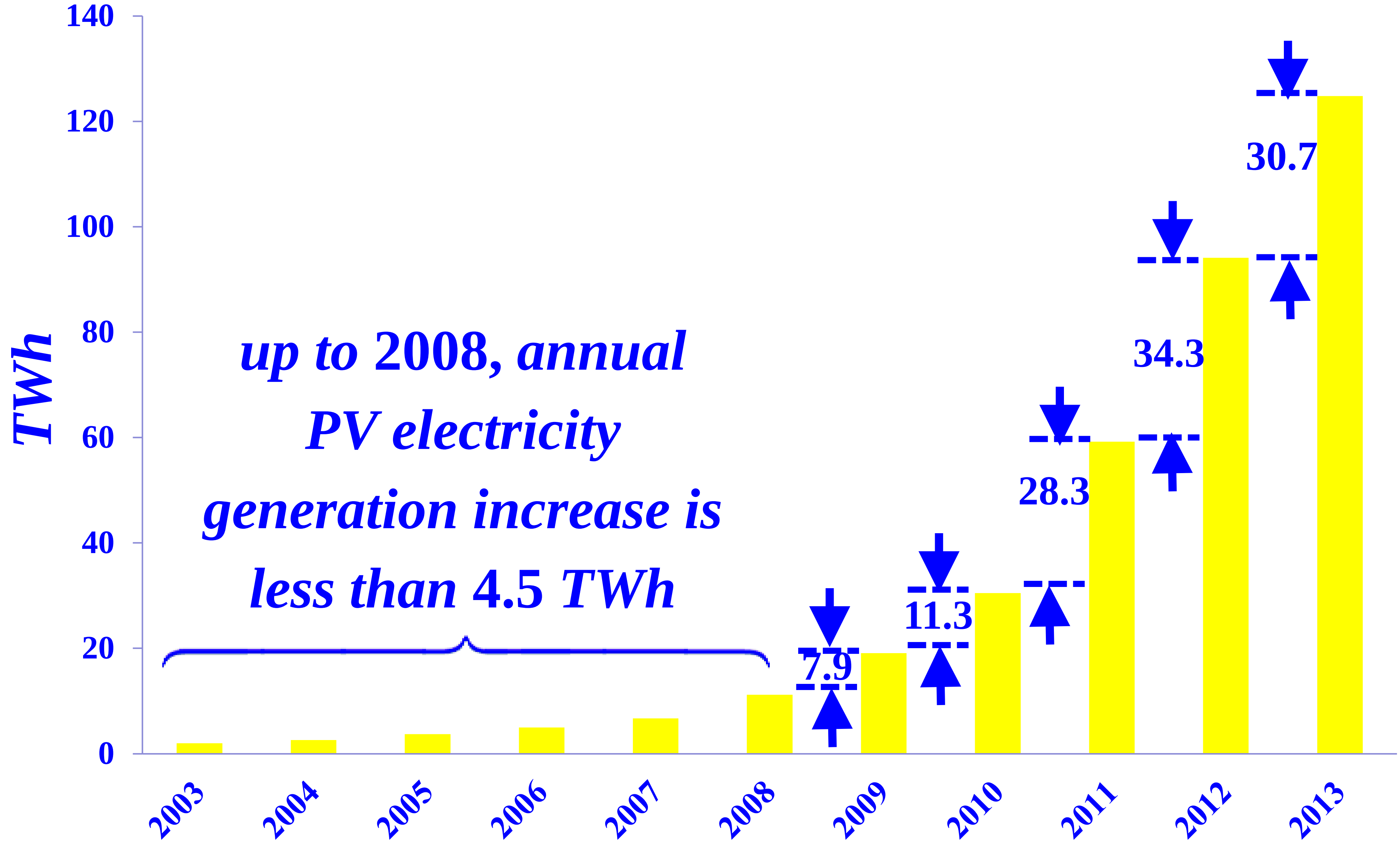
Source: www.epia.org/fileadmin/user_upload/Publications/EPIA_Global_Market_Outlook_for_Photovoltaics_2014-2018_-_Medium_Res.pdf

2008 – 2013 EUROPE CUMMULATIVE & ANNUAL INSTALLED *PV* CAPACITY



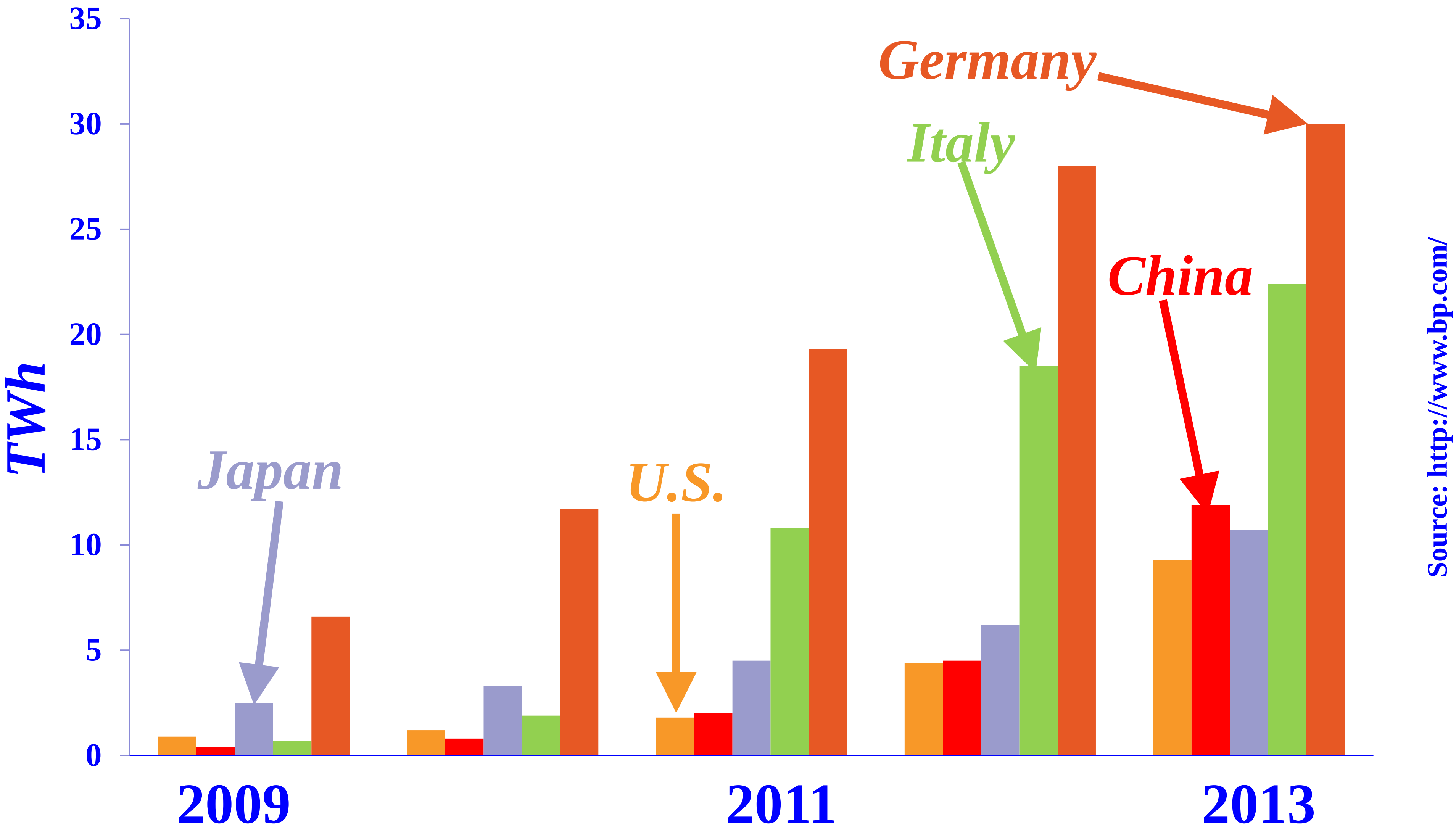
Source: www.epia.org/fileadmin/user_upload/Publications/EPIA_Global_Market_Outlook_for_Photovoltaics_2014-2018_-_Medium_Res.pdf

2003 – 2013 WORLDWIDE ELECTRICITY GENERATION FROM *PV*

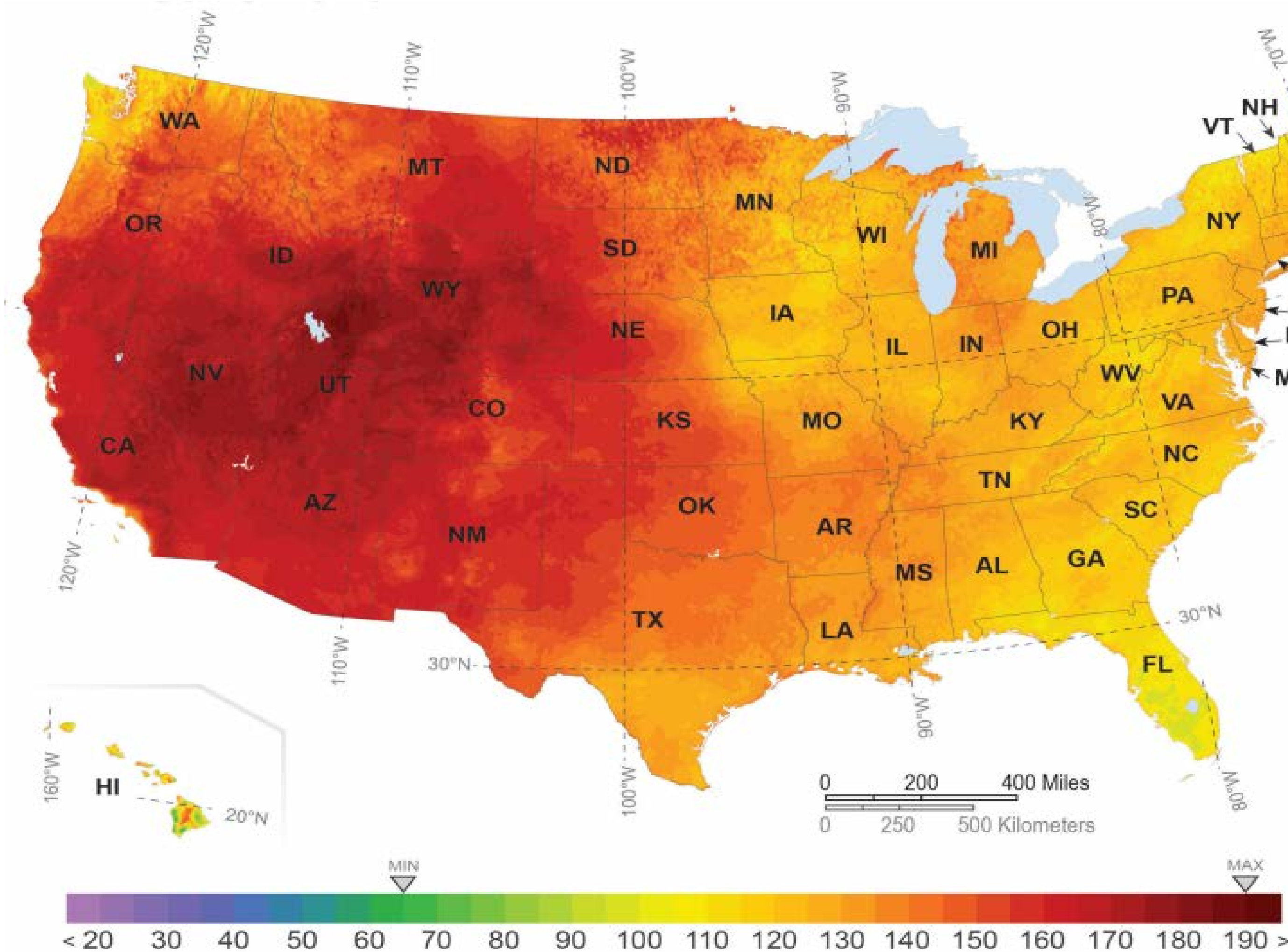


Source: www.epia.org/fileadmin/user_upload/Publications/EPIA_Global_Market_Outlook_for_Photovoltaics_2014-2018_-_Medium_Res.pdf

2008 – 2013 *PV* ELECTRICITY GENERATION BY LEADING NATIONS



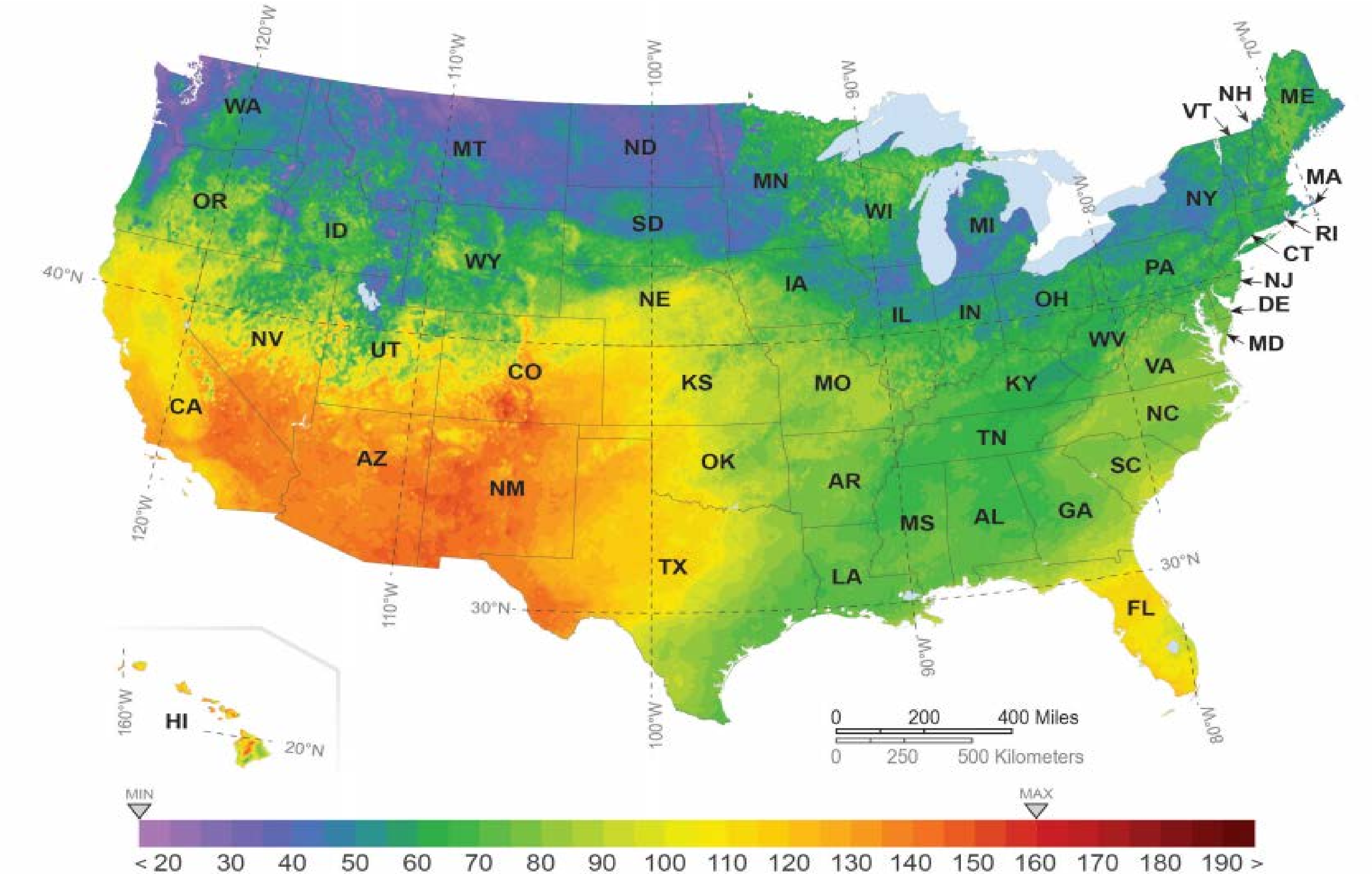
JUNE 2013 *U.S. PV* ENERGY/CAPACITY MAP



$$\frac{\textit{monthly energy output}\ (kWh)}{\textit{PV system capacity}\ (kW_p)}$$

Source: http://www.cleanpower.com/

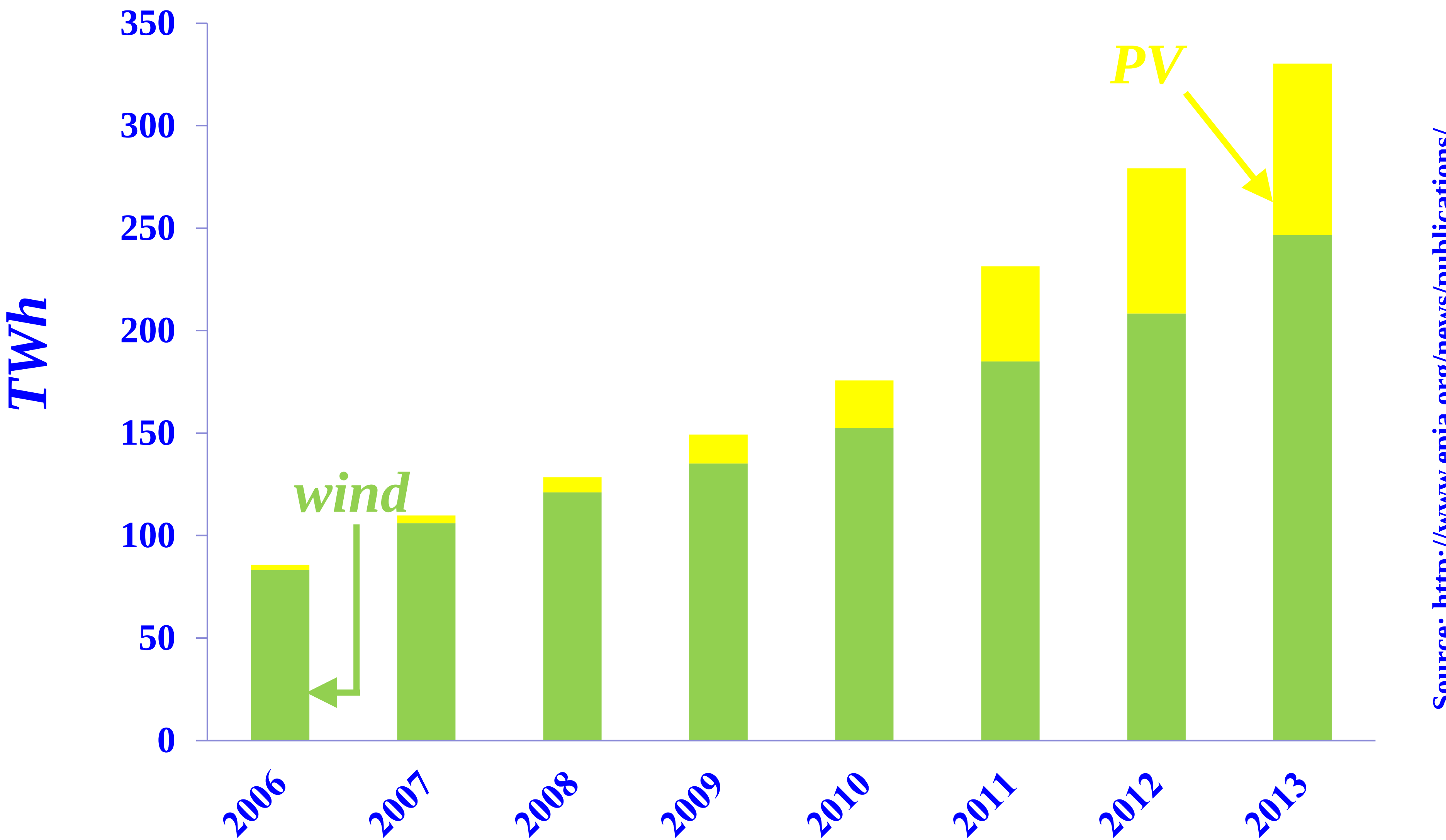
DECEMBER 2013 *US PV* ENERGY/CAPACITY RATIO MAP



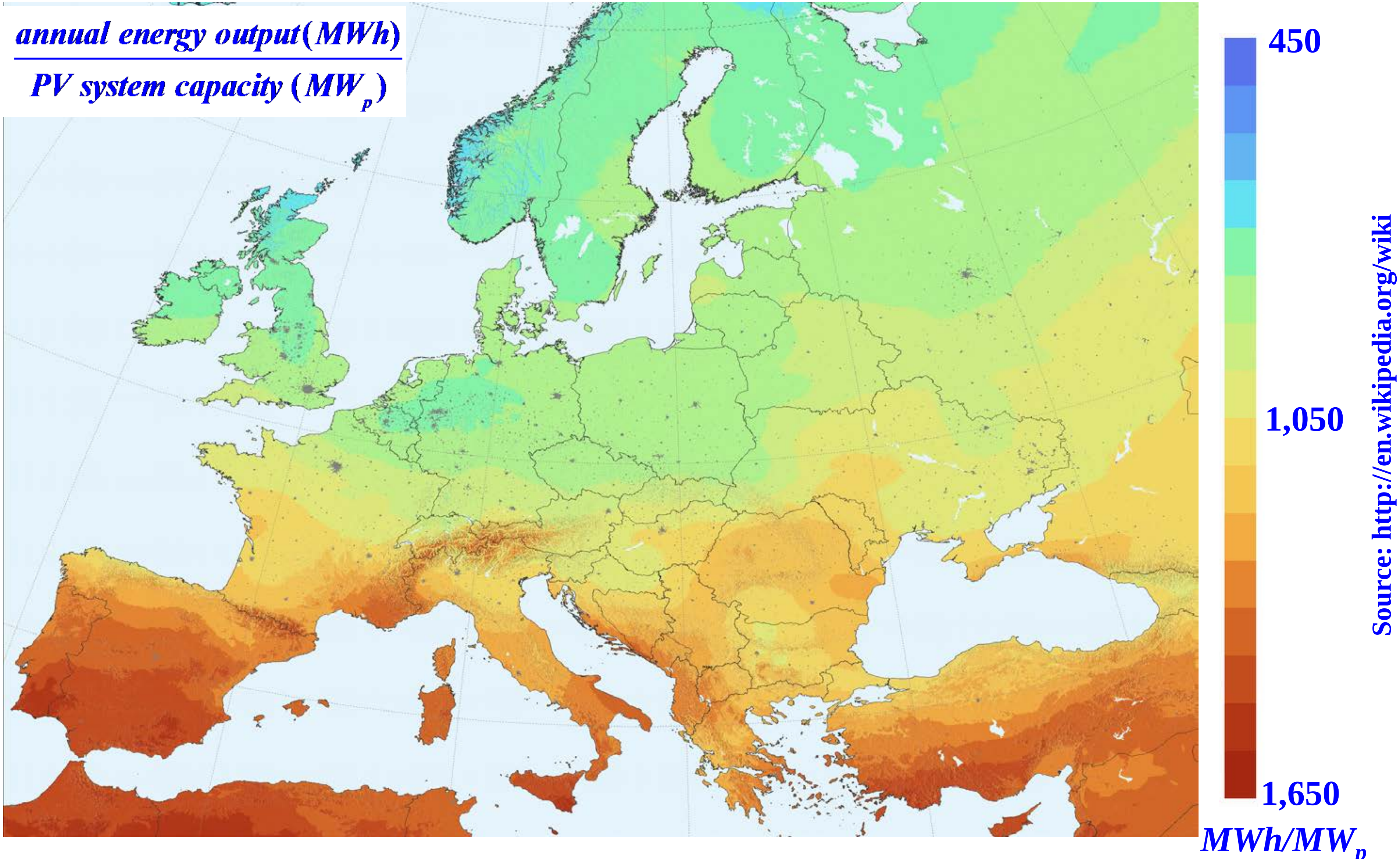
$$\frac{\textit{monthly energy output}\,(kWh)}{\textit{PV system capacity}\,(kW_p)}$$

Source: http://www.cleanpower.com/

2006 – 2013 EUROPEAN ELECTRICITY GENERATION FROM WIND AND *PV*



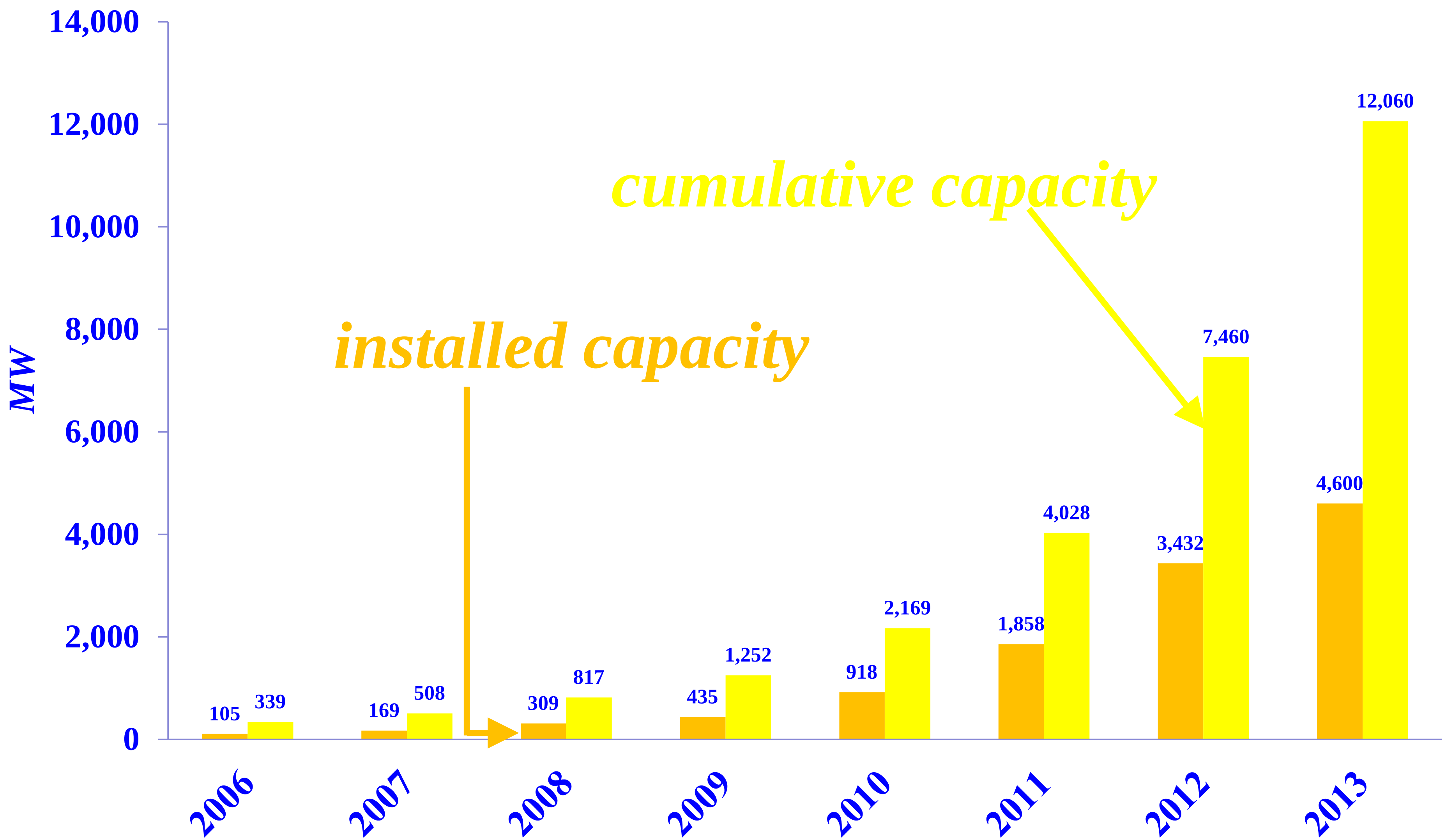
2013 ANNUAL EUROPE *PV* ENERGY/CAPACITY MAP



THE 2013 STATUS OF *US* *PV* SYSTEMS

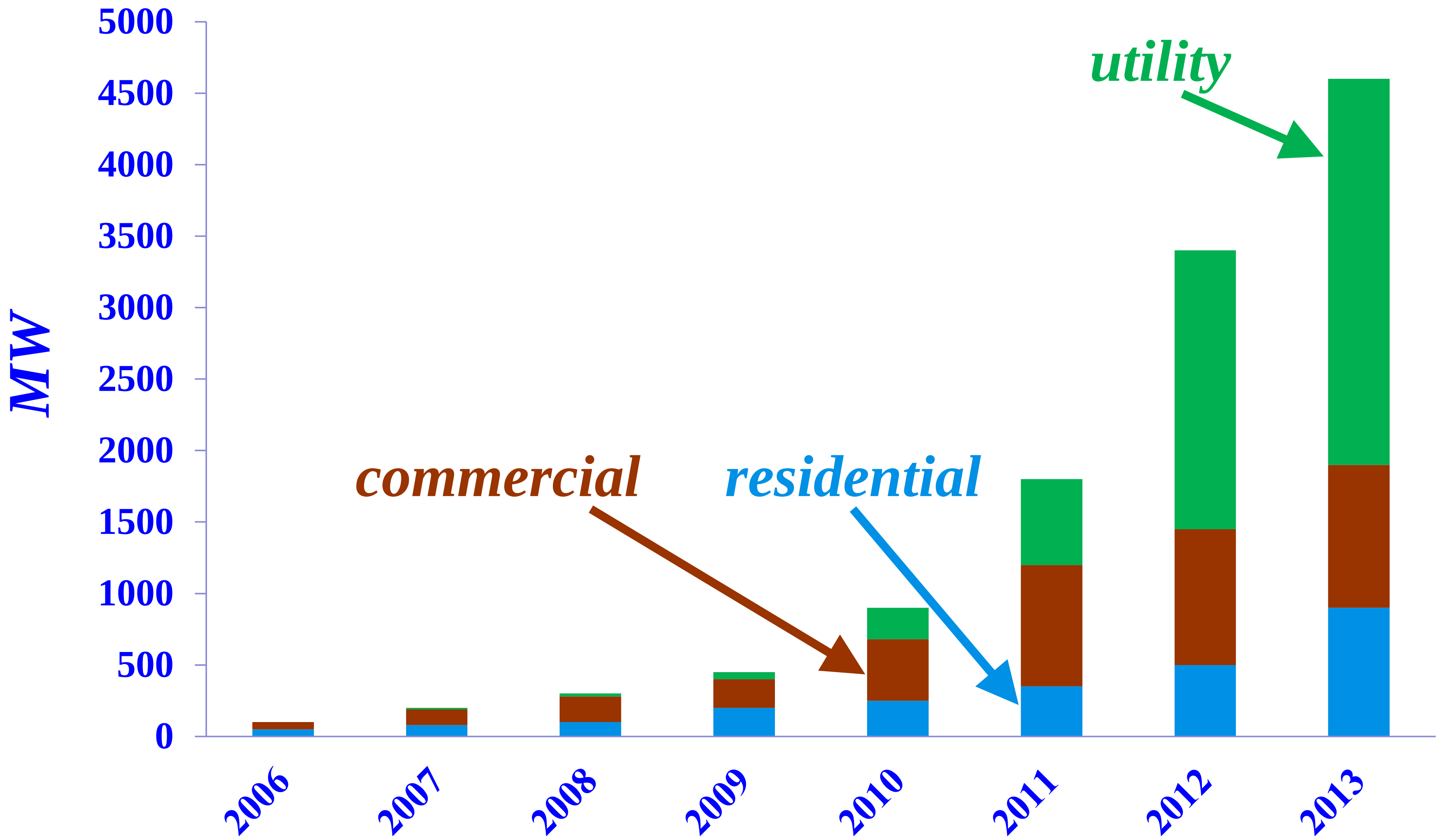
- *US* is a small, but growing, part of the global solar capacity and energy
- The 2013 *US* cumulative *PV* capacity increased to roughly 12.1 *GW*, with 4.6 *GW* of new *PV* capacity added in 2013
- The 4.6 *GW* *PV* capacity installed in 2013 was over 10 times the 2009 amount of installed *PV* capacity

2006 – 2013 *US* CUMMULATIVE AND INSTALLED *PV* CAPACITY



Source: http://www.irecusa.org//

2006 – 2013 *US* ANNUAL *PV* CAPACITY ADDITIONS

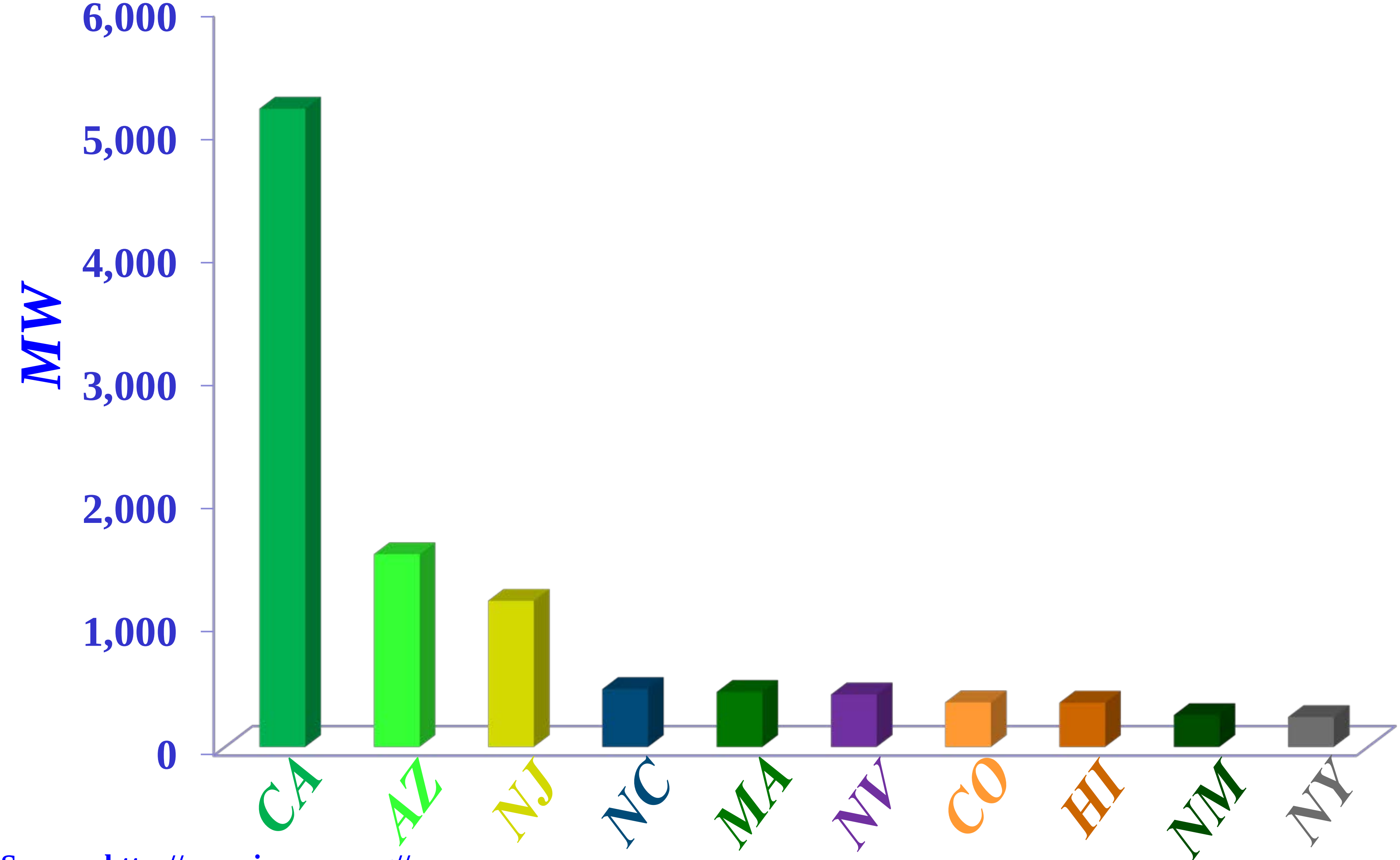


Source: http://www.irecusa.org//

2013 *US* STATUS OF *PV* SYSTEMS BY STATES

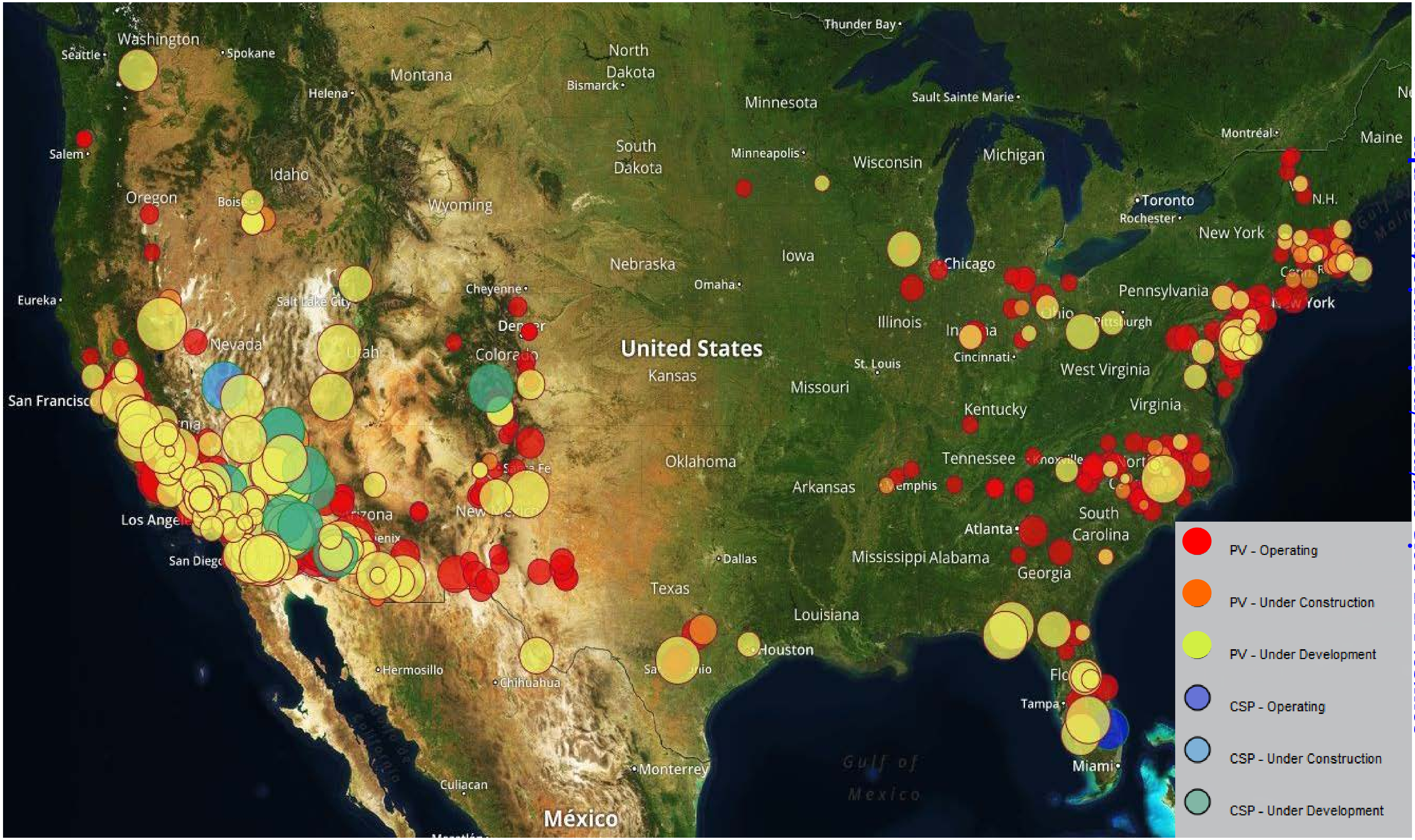
- More than three-quarters of the *US PV* capacity installations were in *CA*, *AZ* and *MA*
- *CA*, *AZ* and *NJ* account for nearly two-thirds of the cumulative *PV* capacity in the *U.S*.
- *HI* was among the top 10 states due to large growth in distributed *PV* installations in 2013

U.S. TOP 10 STATES WITH LARGEST CUMULATIVE *PV* CAPACITY IN 2013



Source: http://www.irecusa.org//

U.S. UTILITY-SCALE SOLAR PROJECTS



source: www.seia.org/map/majorprojectsmap.php

THE 5 LARGEST 2013 *U.S. PV* INSTALLATIONS

plant	*location*	*capacity (MW)*	*year built*	*owner*	*electricity purchaser*
Topaz Solar Farm	*San Luis Obispo, CA*	500*	2013	*Mid American Solar*	*PG&E*
Desert Sunlight Solar Farm	*Riverside County, CA*	490	2013	*NextEra, Sumitomo*	*PG&E & SCE*
Agua Caliente	*Yuma, AZ*	397	2014	*NRG Energy; MidAmerican Solar*	*PG&E*
California Valley Solar Ranch	*San Luis, CA*	292	2012-13	*NRG Energy*	*PG&E*
Mesquite Solar 1	*Arlington, AZ*	207	2011-2012	*Sempra U.S. Gas & Power*	*PG&E*

* Includes amount constructed through 2013. Plants are still under construction and final sizes will be larger

Source: http://www.irecusa.org

TOPAZ SOLAR FARM

source: http://gizmodo.com/new-interactive-map-explores-state-of-u-s-solar-power-1540513575

TOPAZ SOLAR FARM

- **The *Topaz Solar Farm*, the largest *PV* solar facility in the world, is located near San Luis Obispo, *CA***
- ***First Solar* designed and built an array with fixed-tilt *CdTe PV* module panels, which generate electricity with zero emissions and with possibly the smallest CO_2 footprint among all the *PV* modules deployed in the nation**

TOPAZ SOLAR FARM

- **The project is still under construction and had attained a 500 *MW* capacity by the end of 2013**
- **The expected annual generation from the *Topaz Solar Farm* is above 400 *GWh***
- **The *PG&E PPA* is aimed to meet its 2020 *RPS* goals; the reduction in CO_2 emissions from generation units is approximately 377,000 *tons* annually**

LONGYANGXIA DAM SOLAR PARK

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

LONGYANGXIA DAM SOLAR PARK

- **China's largest *PV* plant is the 320-*MW Longyangxia Dam Solar Park*, which is located in, Qinghai Province, China**
- **Construction began in March 2013 and the project was commissioned on December 4, 2013**
- **The expected annual generation is 483 *GWh***
- **Qinghai province has a total of 570 *MW* of solar parks, many of which are located in the Golmud desert cluster**

SOLARPARK MEURO

source: http://www.habdank-pv.com/de/unter-griechischer-sonne.html

SOLARPARK MEURO

- **With a total capacity of 166 *MW*, *Solarpark Meuro* is the largest *PV* plant in Europe**
- **This solar park is located in Meuro, Germany, and was constructed on the grounds of a former lignite mine**
- **The *Solarpark Meuro* is expected to produce more than 200-*GWh* electricity annually**

ROOFTOP SOLAR

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

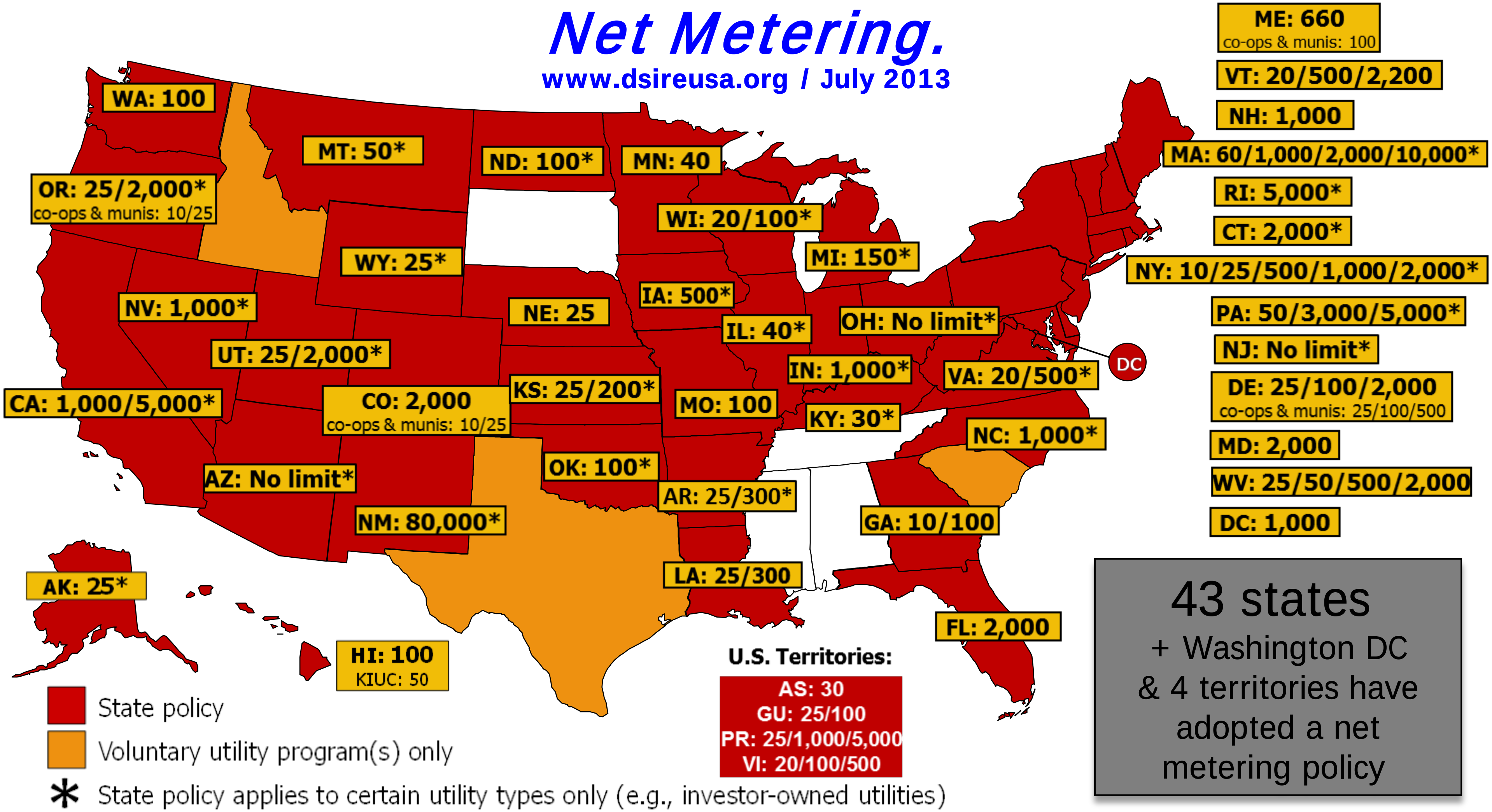
ROOFTOP SOLAR IN *U.S.*

- **As of July 2013, the *U.S.* Energy Information Administration (*EIA*) indicates that rooftop solar electricity represents less than 0.25 % of the *U.S.* electricity generation**
- **Government incentives aimed to promotes solar energy have made the installations of rooftop solar widespread in the Western states – *CA*, *AZ*, *CO* and *NV***

ROOFTOP SOLAR IN *U.S.*

- Incentives include tax credits, installation cost rebates and *net metering* for customers with rooftop solar panels; incentives are location dependent
- At present 43 states, the *District of Columbia* and 4 territories offer net metering

U.S. NET METERING MAP



Note: Numbers indicate individual system capacity limit in kilowatts. Some limits vary by customer type, technology and/or application. Other limits might also apply. This map generally does not address statutory changes until administrative rules have been adopted to implement such changes.

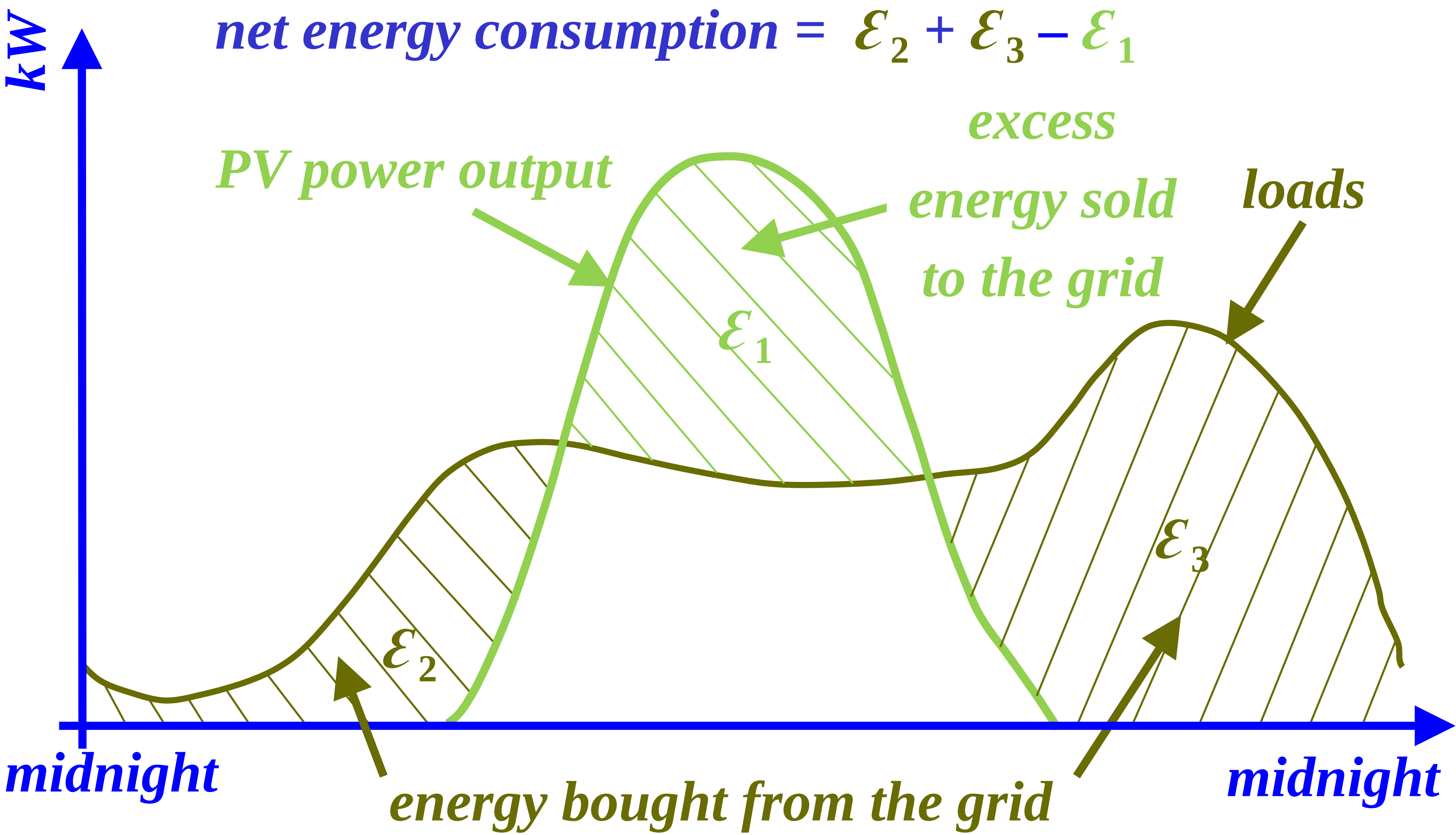
NET METERING

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

NET METERING

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

NET METERING



NET METERING

- The implementation of net metering varies from one jurisdiction to another
- In *CA*, solar owners receive federal tax credits, rebates under the *CA Solar Initiative*, which is being phased out, and net metering; from 2010 to 2012, the *kW* installed increased at 160 % annually

NET METERING

- The payment 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; utilities view this development as the “death spiral ”

RENEWABLE ENERGY CERTIFICATE (*REC*)

- **The *REC*, also known as the *green tag* or *renewable energy credit* is a tradeable and non-tangible energy commodity that provides proof of the production of 1-*MWh* electricity from a renewable resource**
- **Every renewable energy resource gets paid for its production from two sources: the energy is compensated through sales into the organized electricity markets or *PPA*s and the trading of the *REC*s that represent that energy production**

RENEWABLE ENERGY CERTIFICATES (*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 of each jurisdiction
- The *REC*s provide auditable proof of the amount of renewable energy production injected into the grid

*REC*s

- However, since the energy and the *REC*s are sold separately and possibly to different buyers, the consumption of the green energy 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 of each state
- *REC*s provide buyers and sellers flexibility in trading renewable energy across state borders

KEY *PV* BENEFITS

- Residential and commercial *PV* system installations reduce the amount of electricity such customers purchase from the local utility
- As *PV* systems produce the most power when the insolation is highest at noon, their contributions can reduce the need for the expensive and polluting fossil generation at those operating times

KEY *PV* BENEFITS

- *PV* systems as energy resources lessen the nation's dependence on fossil fuels
- The electricity generated by *PV* systems is clean and renewable, which helps reduce the amount of greenhouse gases – a major contributor to global climate change
- The growing *PV* industry provides local jobs and economic development opportunities to states and regions to support sustainable energy

THE KEY DRIVERS OF *U.S. PV* GROWTH

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

THE KEY DRIVERS OF *U.S. PV* GROWTH

preferential financing support to qualifying renewable energy projects;

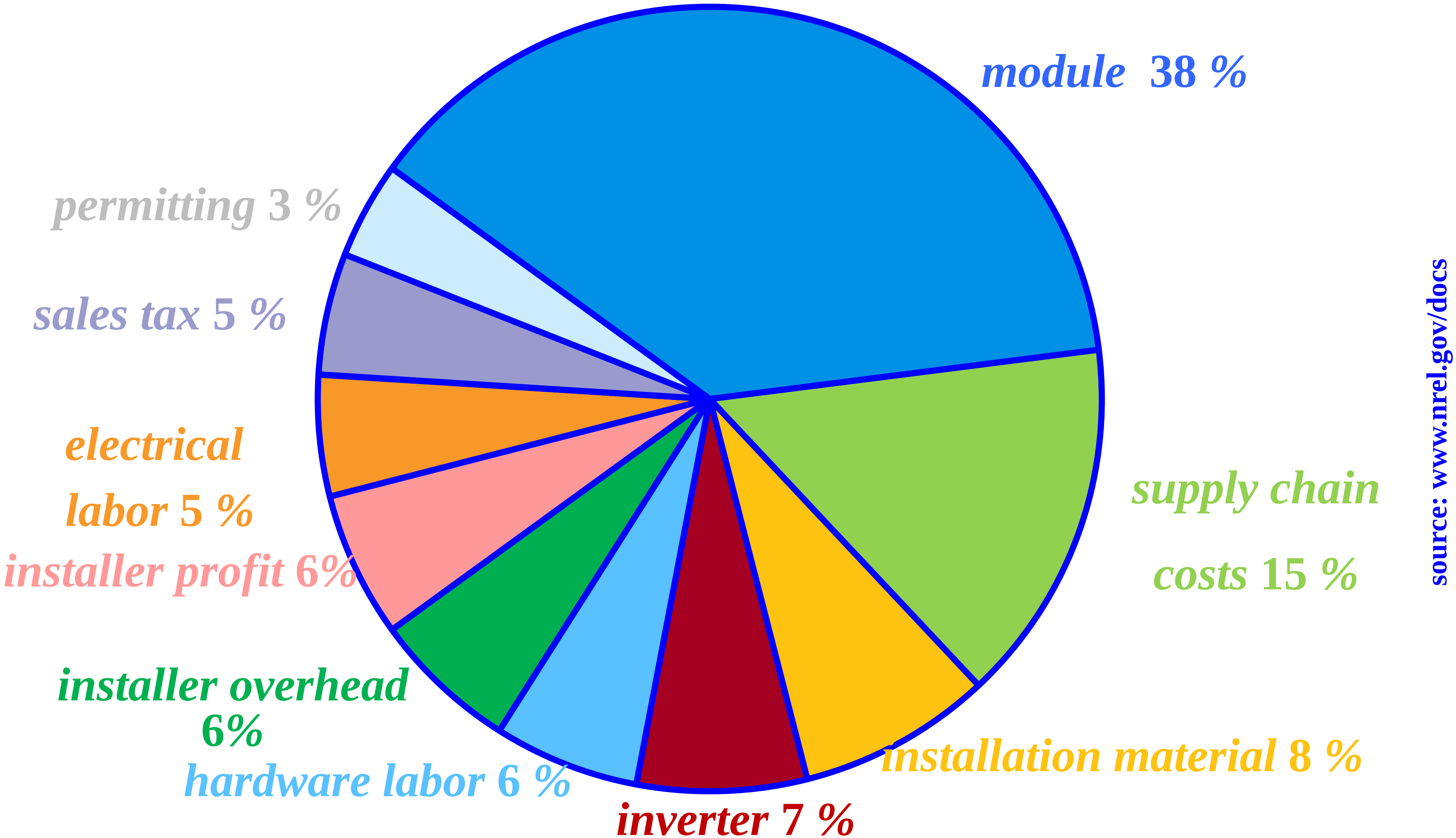
- *cash grants* that provided commercial installations with the alternative to the tax credit in the form of a cash grant

- At the state level, the drivers include
  - *RPS requirements* that encourage investments in solar plants to meet the prescribed goal of renewable resource electricity generation

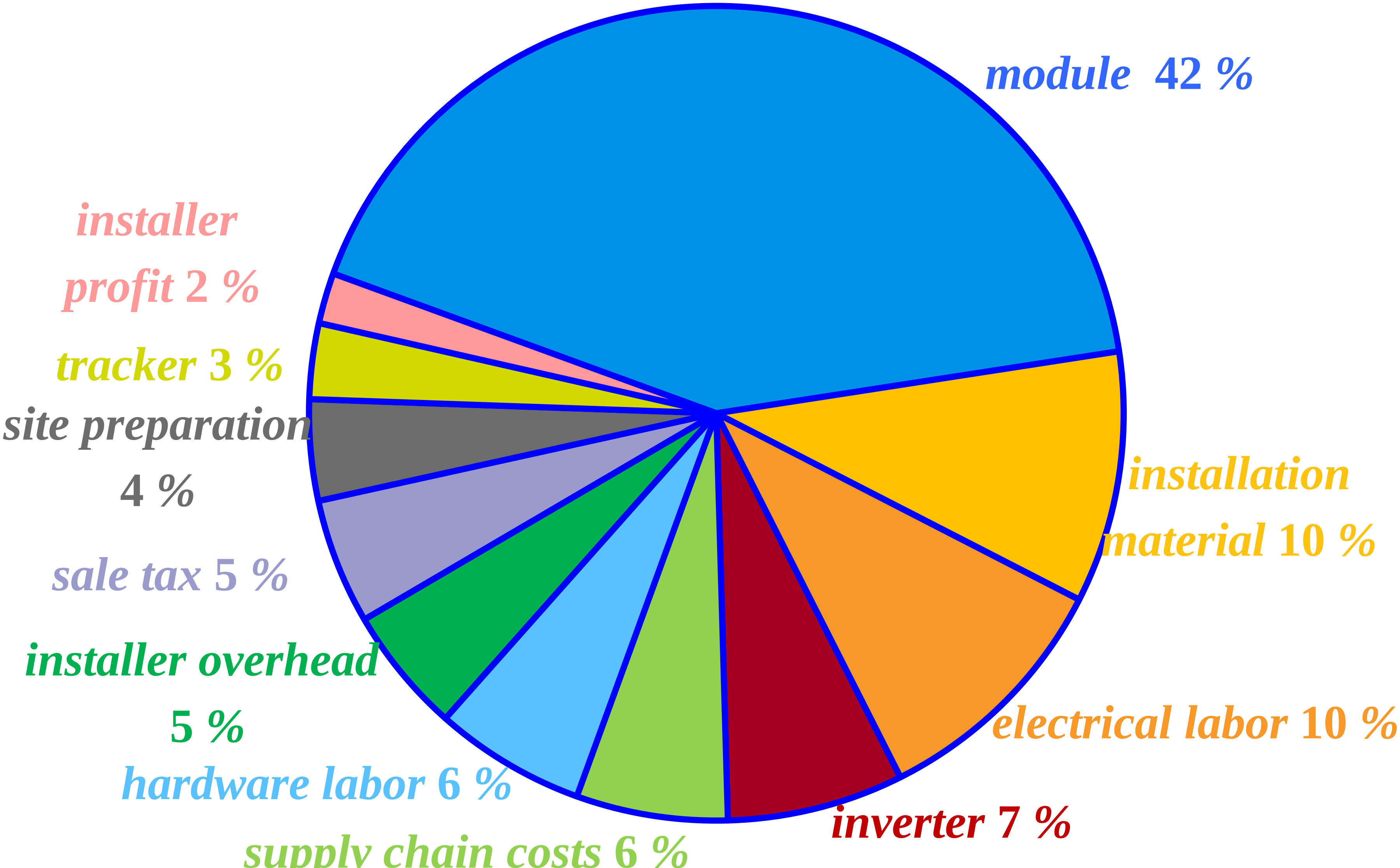
THE KEY DRIVERS OF *U.S. PV* GROWTH

- ***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 producing their own energy from the *PV* systems and even selling excess energy to the grid**

2012 END *US* RESIDENTIAL *PV* INSTALLATION COST COMPONENTS

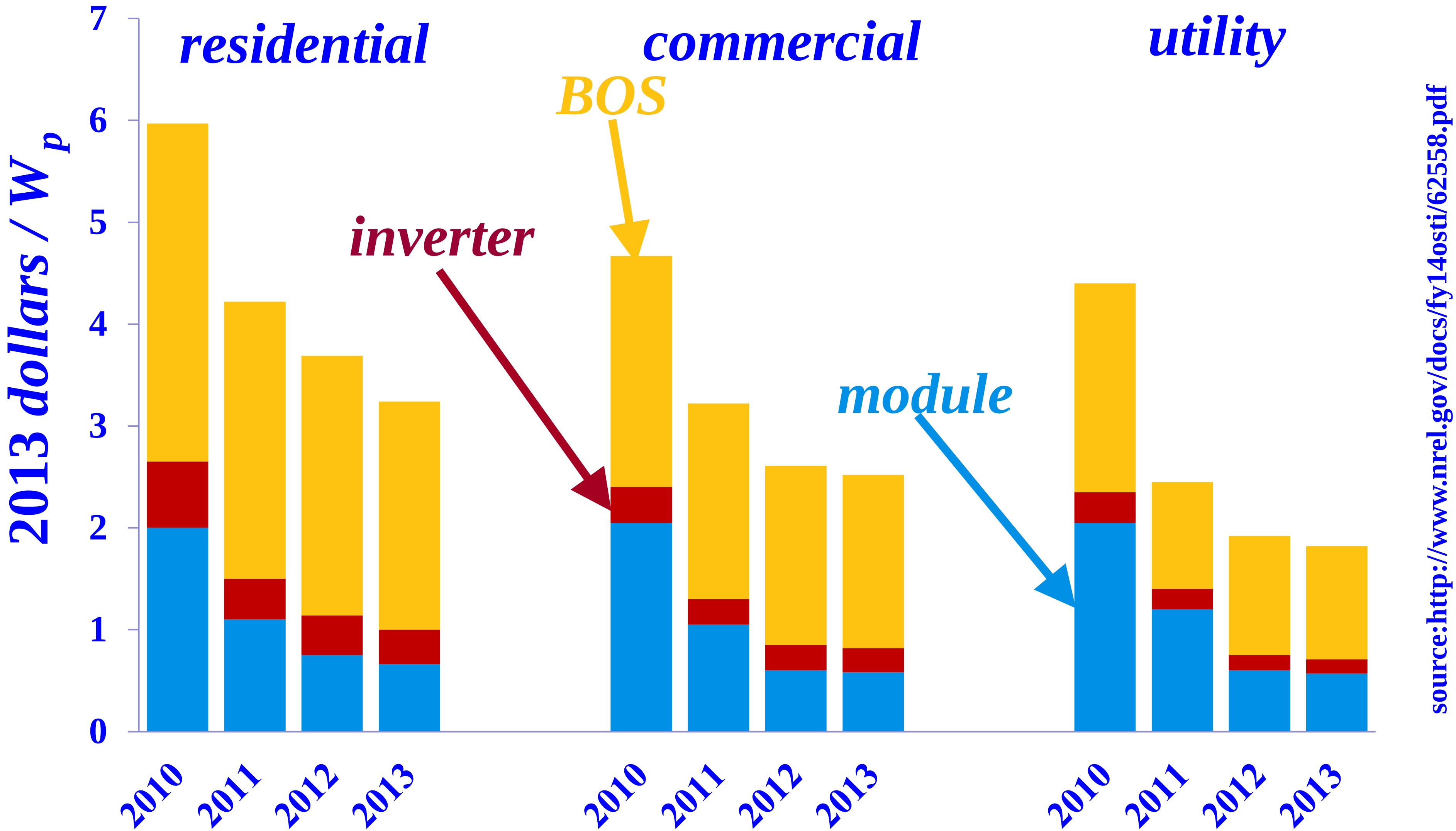


2012 END *U.S.* UTILITY-SCALE *PV* INSTALLATION COST COMPONENTS

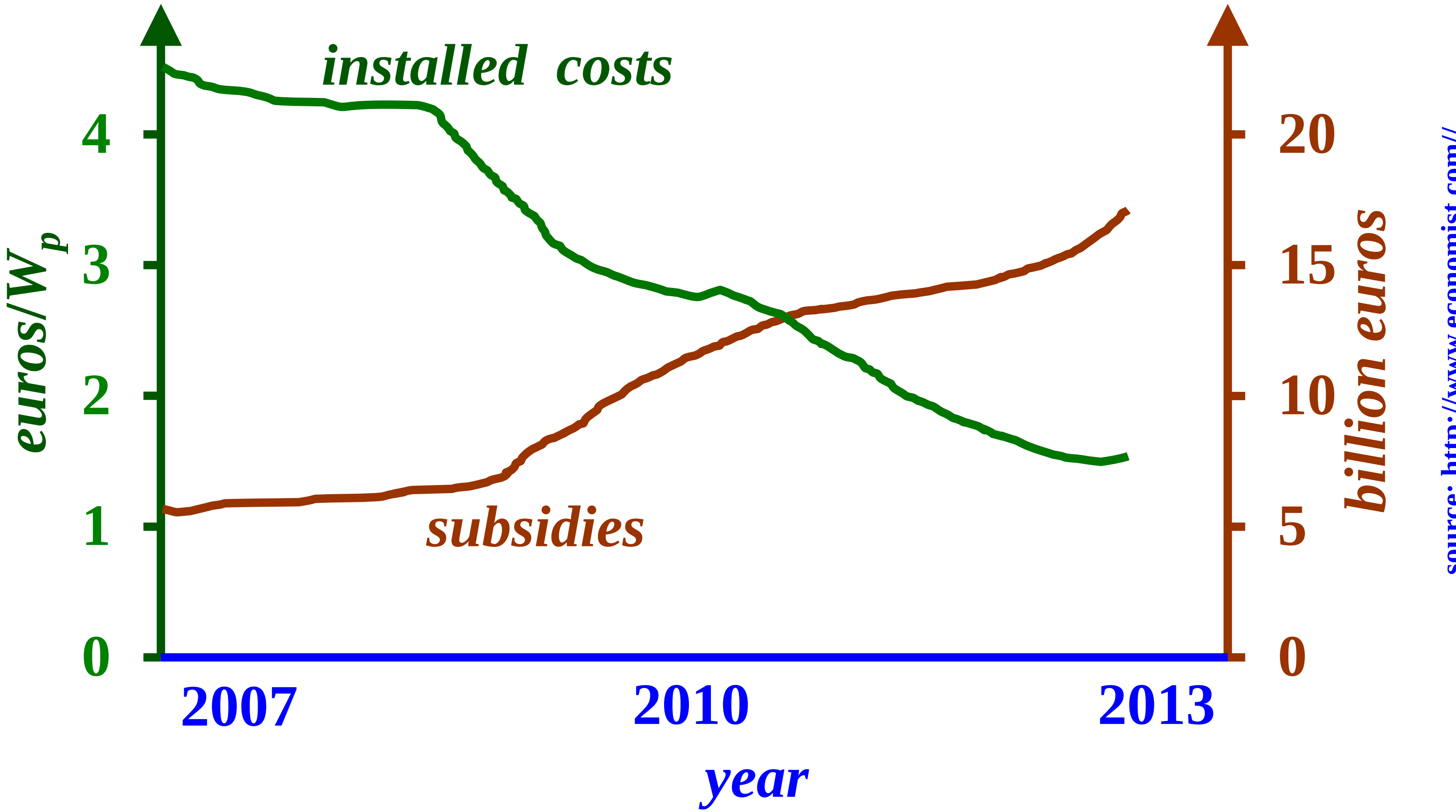


source: www.nrel.gov/docs

INSTALATION COSTS BY SECTORS



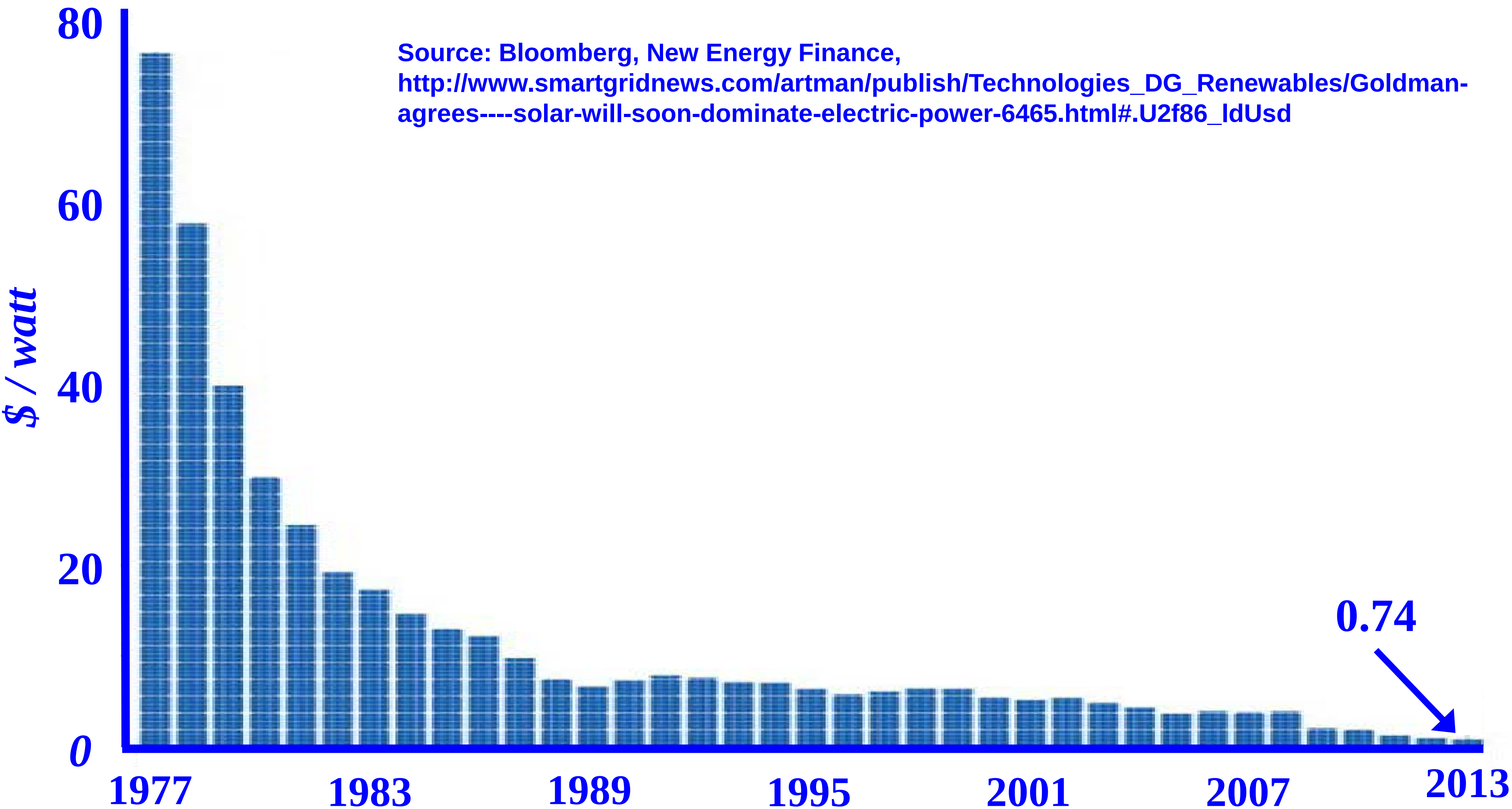
GERMANY *PV* INSTALLATION COSTS AND SUBSIDY



2013 INSTALLED COST TREND

- **The total installed costs for residential and commercial systems fell by 12 % - 15 % from 2012**
- **The installed cost decline in 2013 was even greater for utility-scale installations due to economies of scale**
- **All cost components have fallen but the reduced module cost over the years is the primary reason for the steep *PV* system cost decline**

PV SOLAR CAPACITY PRICE DECLINE



2013 *PV* MODULE MANUFACTURING STATUS

- The top-10 manufacturing companies supplied over 18 *GW* of *PV* modules in 2013, representing a 40 % increase over 2012 levels
- Five of the top-10 companies were publicly-listed, vertically-integrated, China-based crystalline silicon (*c-Si*) solar panel manufacturers

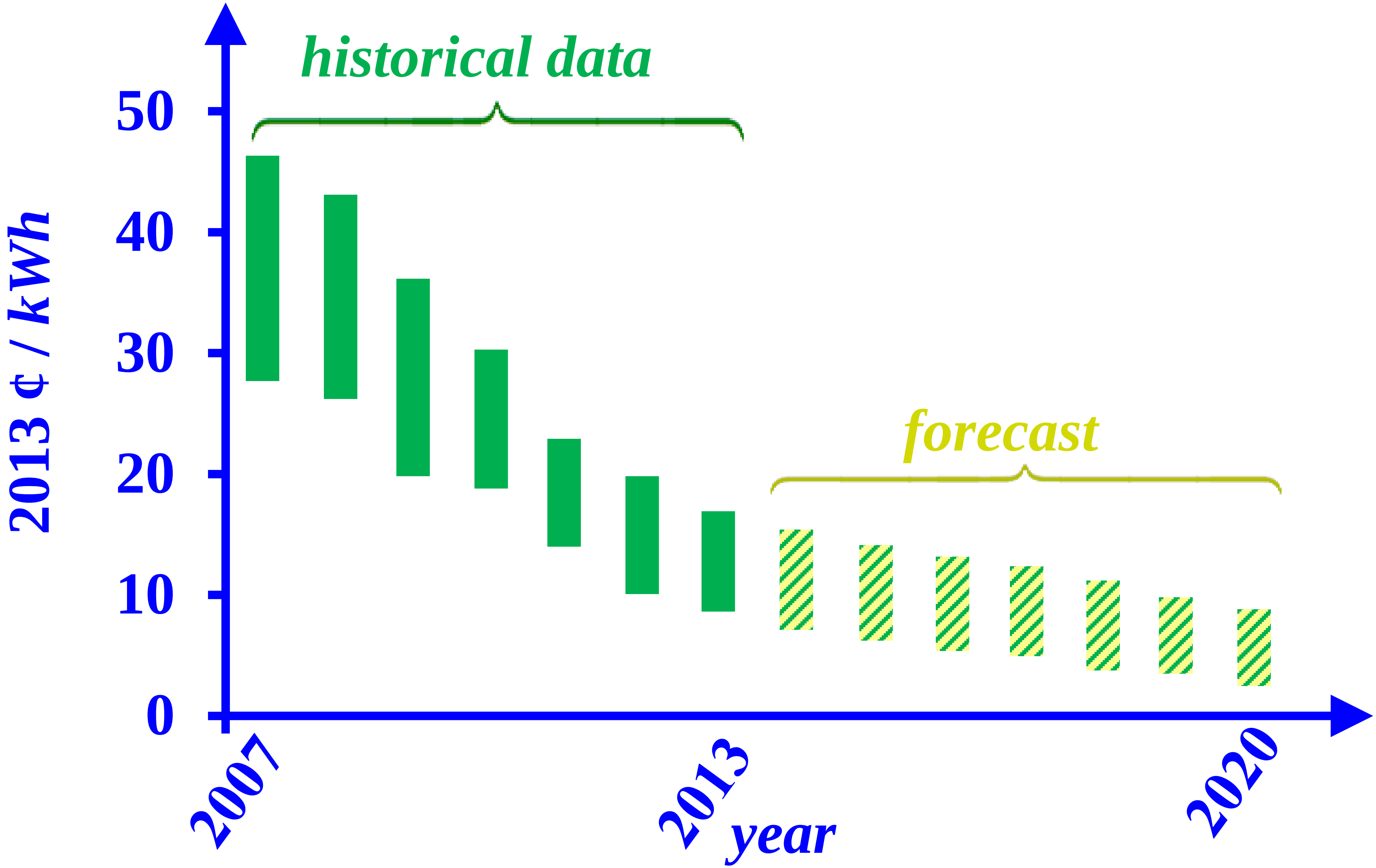
2013 *PV* MODULE MANUFACTURING STATUS

- ***First Solar*** **and** ***SunPower*** **are the leaders in module shipments to meet** ***U.S.*** **market needs**
- **In Japan, the leading domestic** ***PV*** **module suppliers are** ***Sharp*****,** ***Kyocera*** **and** ***Panasonic***
- **The top two suppliers in European** ***PV*** **module market are** ***Schott Solar*** **and** ***SolarWorld***

2013 TOP 10 *PV* MODULE MANUFACTURERS

company	*country*
Yingli Green Energy	*China*
Trina Solar Ltd.	*China*
Sharp	*Japan*
Canadian Solar	*Canada*
Jinko Solar Holding Co. Ltd.	*China*
ReneSola	*China*
First Solar	*U.S.*
Trina Solar Ltd.	*China*
First Solar	*U.S.*
Schott Solar	*Germany*

GLOBAL *PV LCOE* TRENDS



source: http://climatecommercial.wordpress.com/page/2/

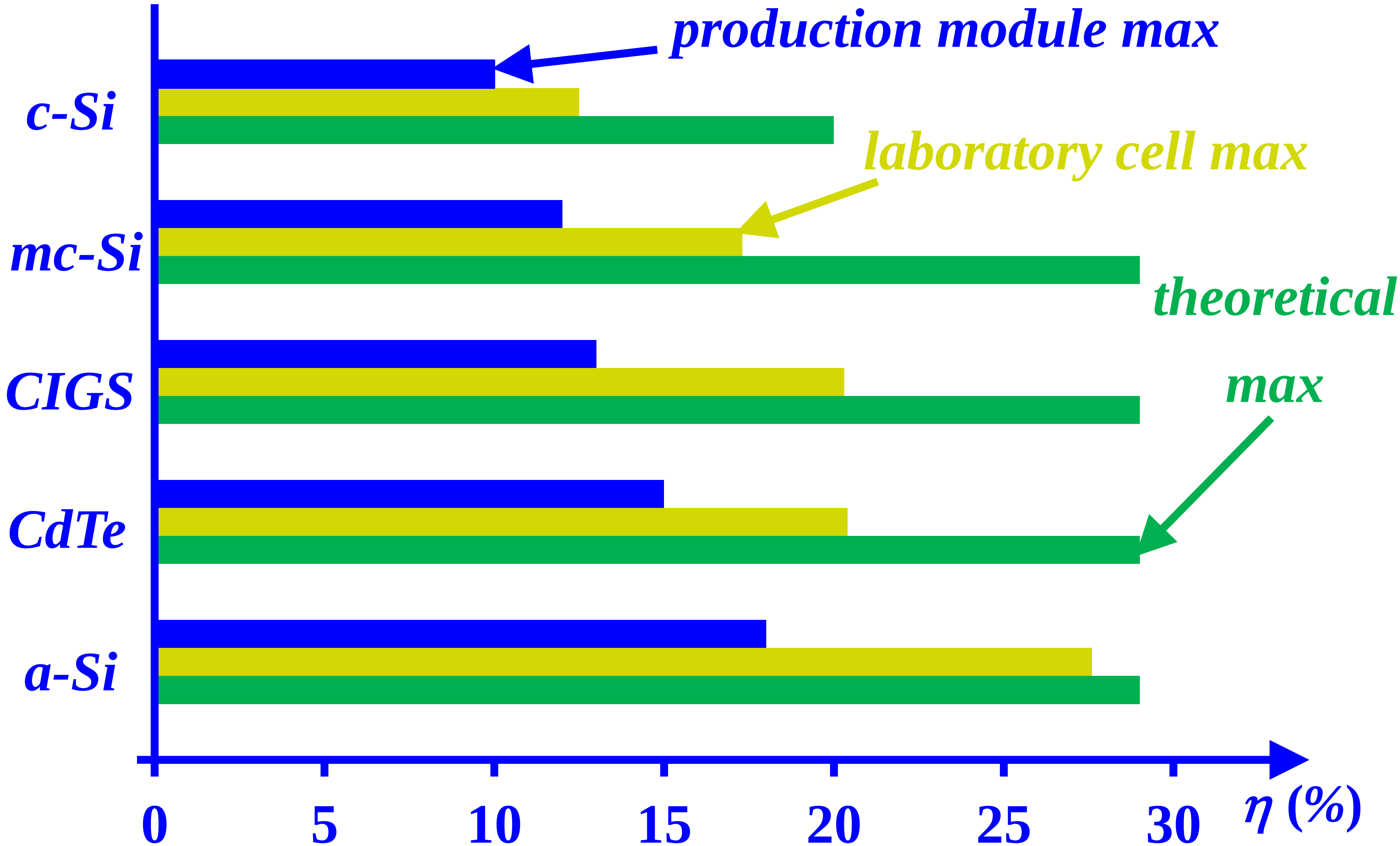
DOE SOLAR PROGRAM GOALS

- The *U.S.* Department of Energy *Sunshot Initiative* is a national collaborative effort to make solar energy cost-competitive with fossil-fired generation technology by the end of this decade
- The goals for *PV* by 2020 are 4 – 5 ¢/*kWh* in the residential sector, 5 – 6 ¢/*kWh* in the commercial sector, and 4 – 6 ¢/*kWh* in the utility sector

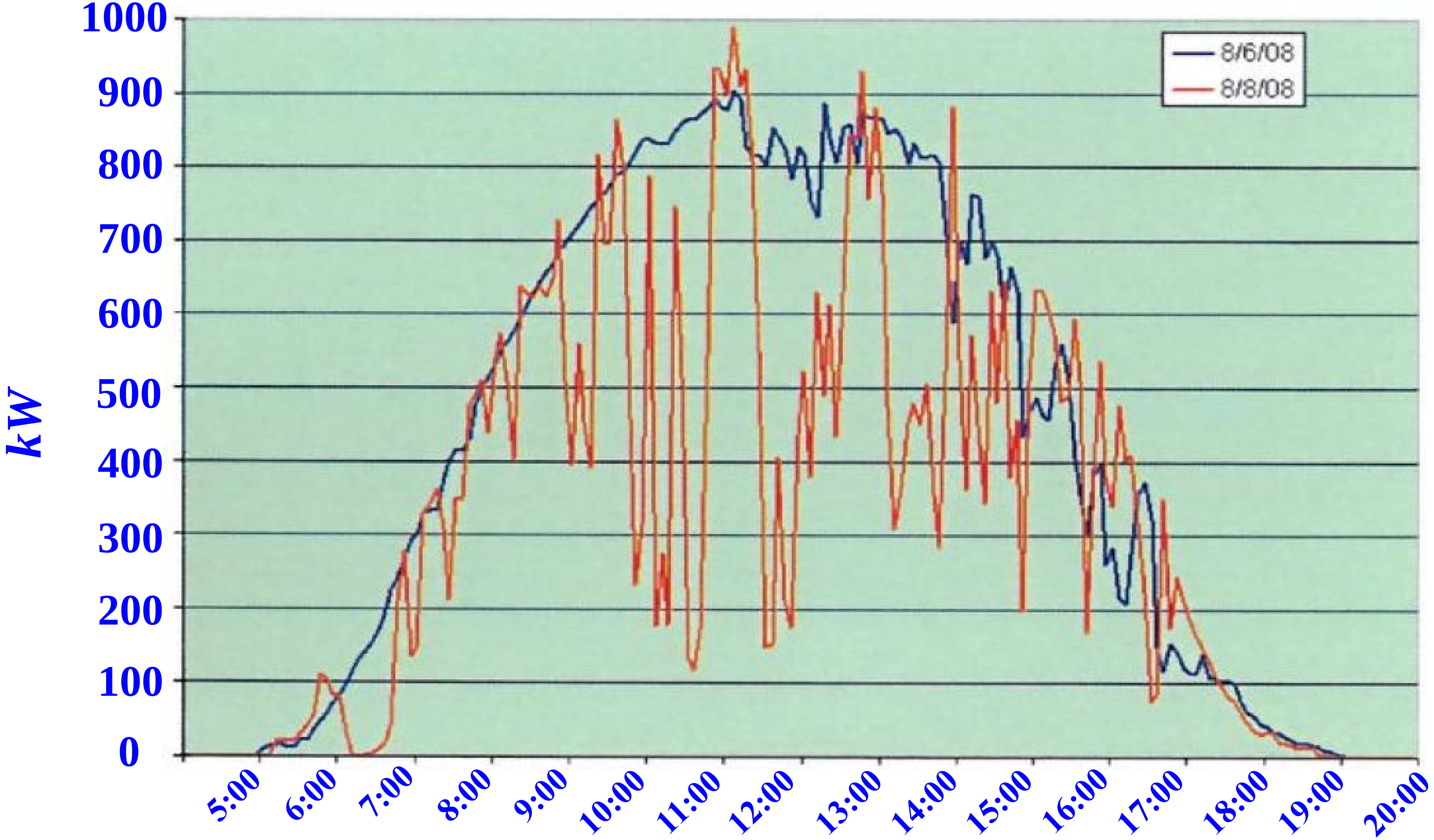
MAJOR CHANLLENGES FOR *PV* DEVELOPMENT

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

PV EFFICIENCY BY MATERIAL



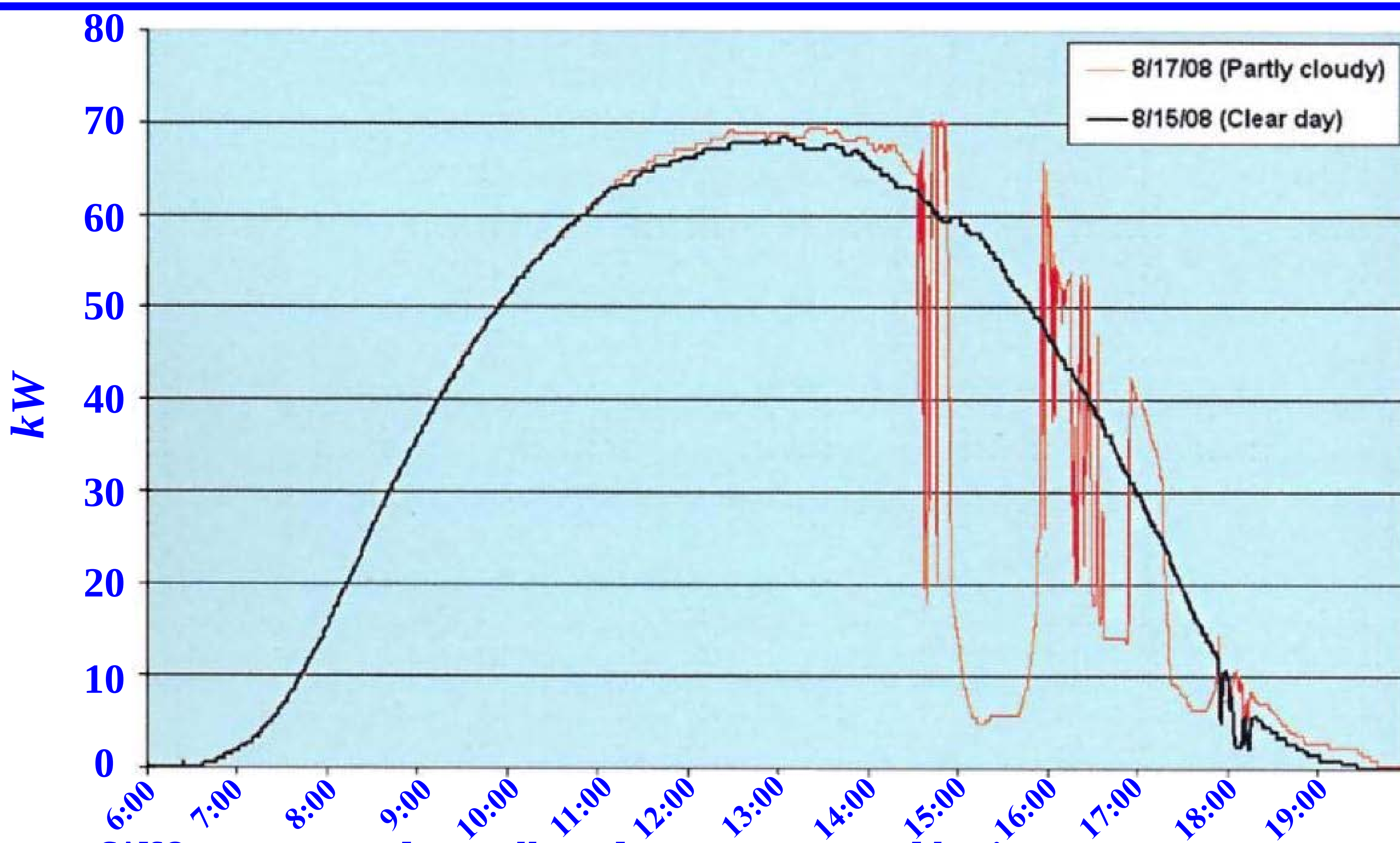
PV POWER OUTPUT OF 1 – *MW CdTe* ARRAY IN GERMANY



source: CAISO

samples collected on a 5 – minute basis

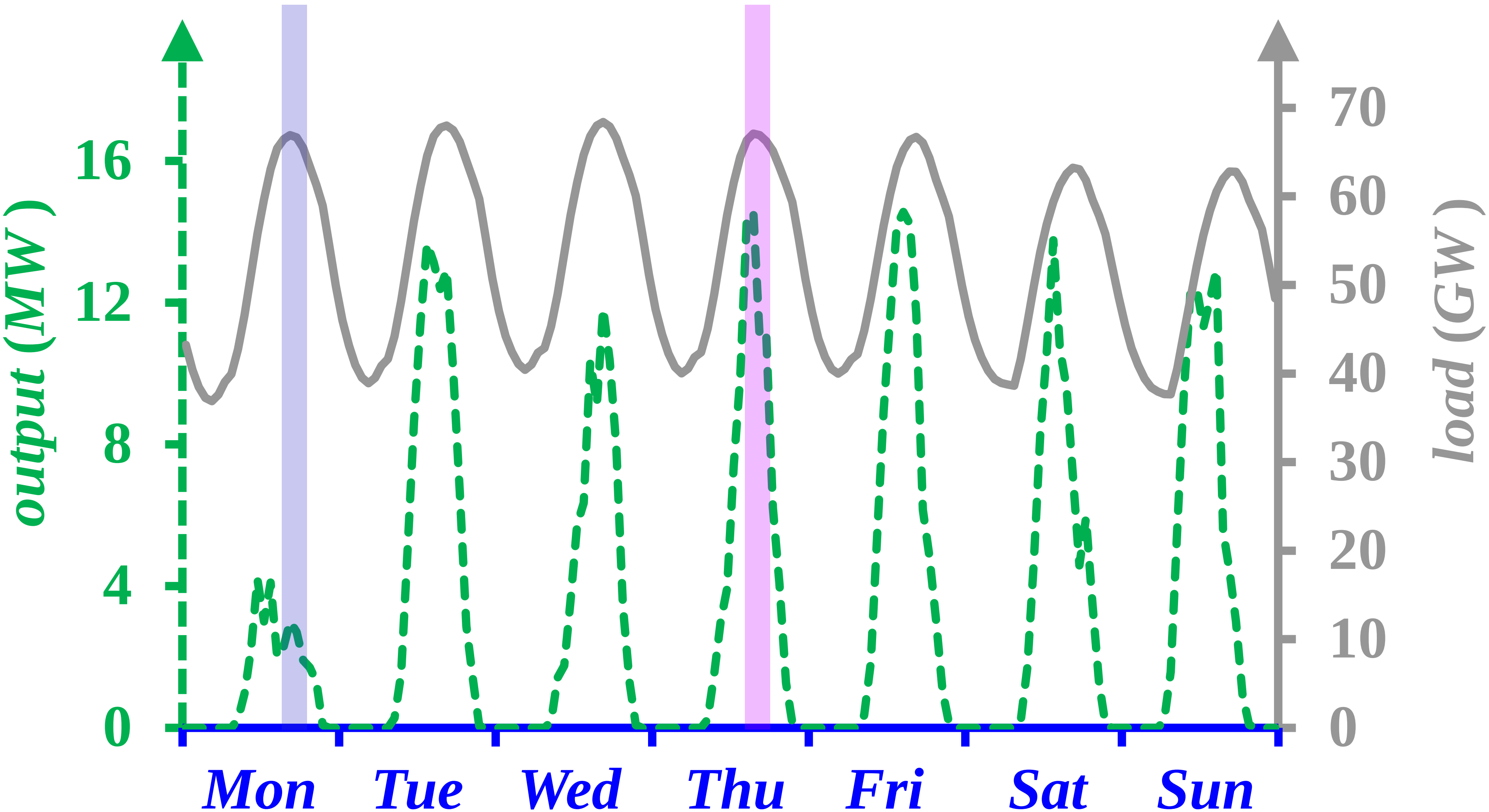
PV POWER OUTPUT AT THE NEVADA 70 *kW* POLYCRYSTALLINE ARRAY



source: CAISO

data collected on a 10 – second basis

CHRONOLOGICAL *PV* OUTPUT AND *ERCOT* LOAD PATTERNS



source: ttp://www.ercot.com/gridinfo/

