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Photovoltaic (PV) Solar Energy along the U.S.-Mexico border

Some numbers and issues to consider

Martin Wosnik, UNH

1st workshop on Border Energy-Water-Opportunity (FEWIEP) @ UC San Diego, 28-29 June 2019

PV Solar near Mexico-U.S. Border

- Solar resource and solar energy cost
  - Sunshot Initiative, ITC
- Basic PV calculations for white paper
  - power vs energy, installed capacity, capacity factor
- Solar energy as part of an energy system
  - Examples
- Stakeholder Engagement

(Note: this presentation has evolved a bit from the one I arrived with yesterday)

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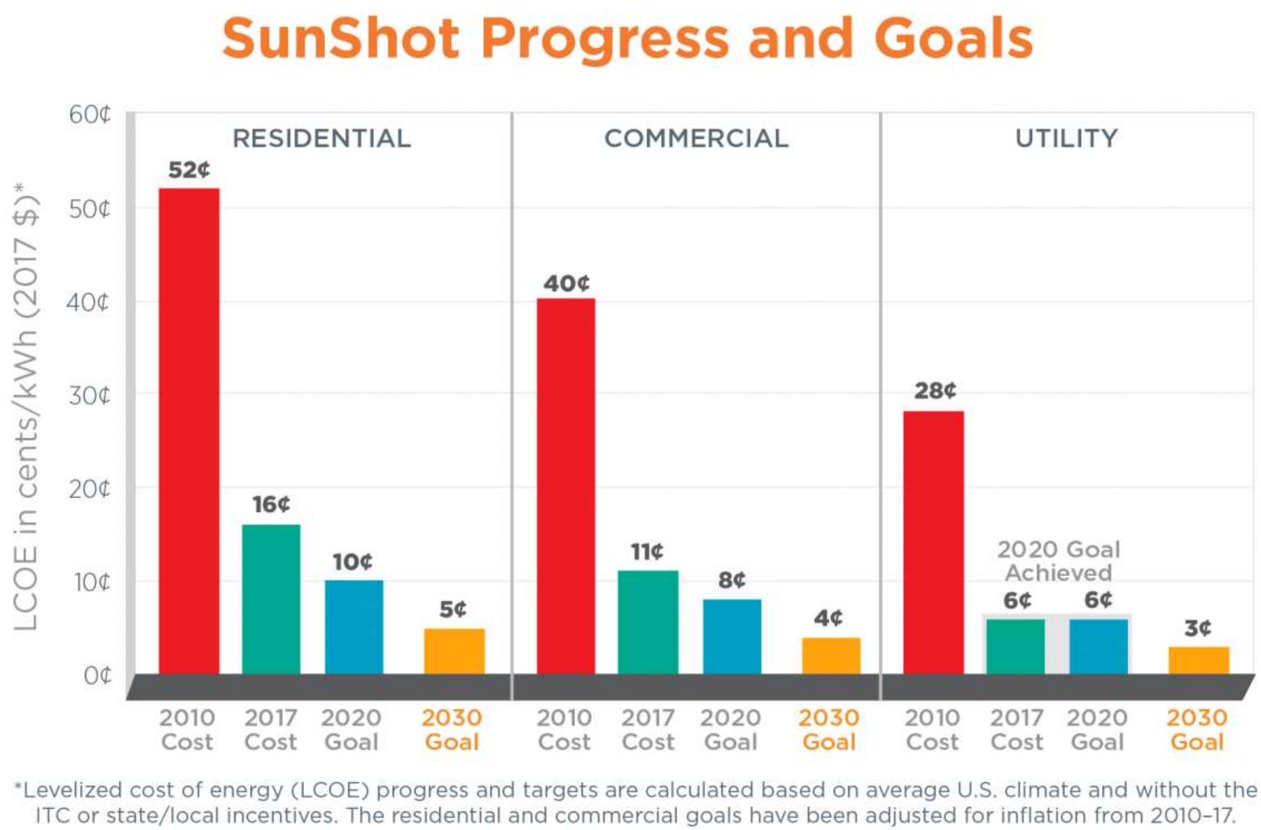
Sun Shot Initiative – Status 2019

"Sun Shot Initiative" (2011) under B. Obama & S. Chu (ESec) to significantly reduce costs of solar energy (→reduce the total costs of solar energy by 75 percent by the end of the decade, Goal: solar PV cost of $1/W, or $0.06/kWh)

We did it! -- 2020 (utility scale) goals achieved in 2017!!



U.S. Department of Energy, SunShot 2030, https://www.energy.gov/eere/solar/sunshot-2030 , accessed June 2019

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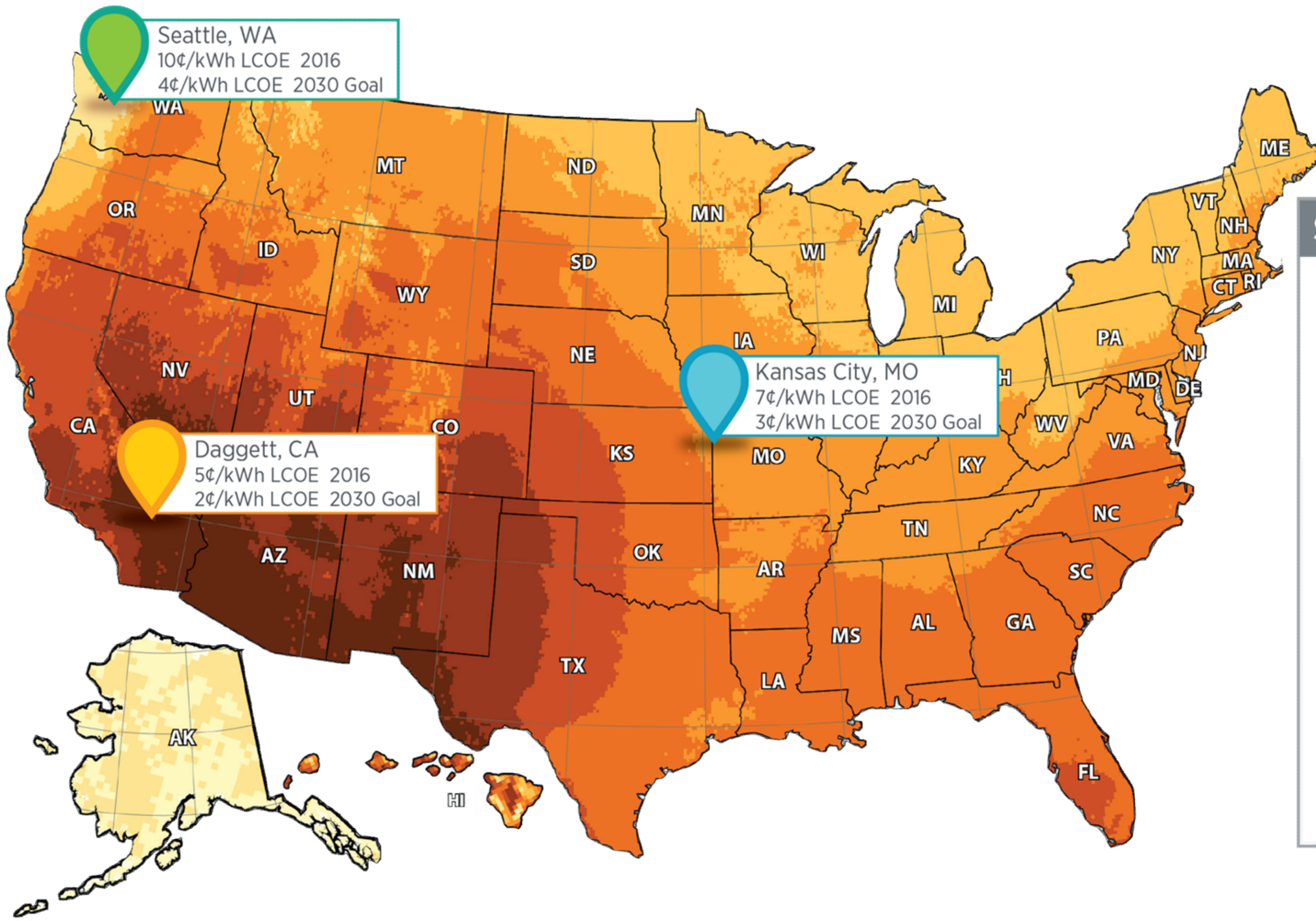
Average Solar Resource Calculation



Solar Resource Across America

kWh/m²/Day

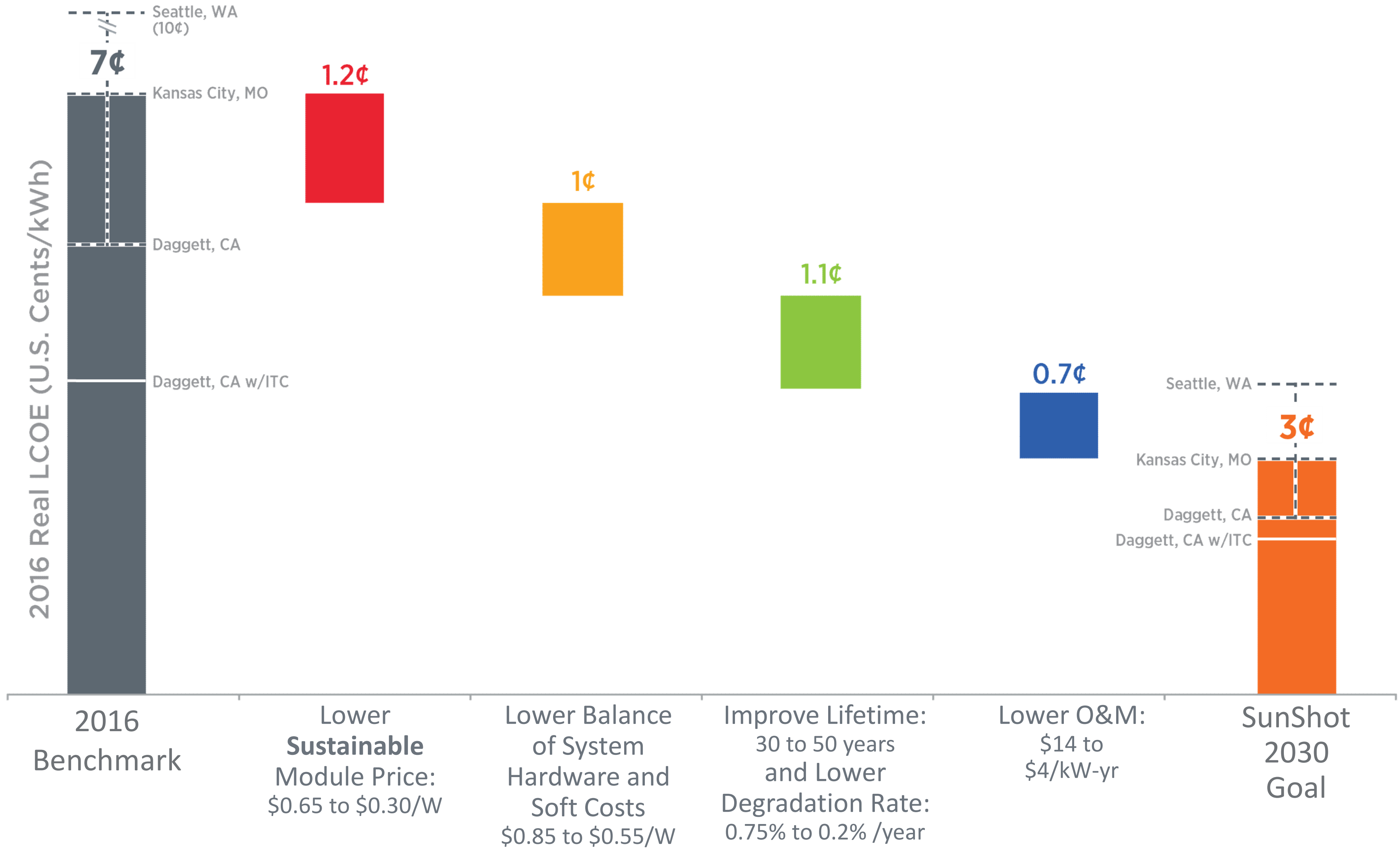
- > 6.5
- 6.0 to 6.5
- 5.5 to 6.0
- 5.0 to 5.5
- 4.5 to 5.0
- 4.0 to 4.5
- 3.5 to 4.0
- 3.0 to 3.5
- < 3.0

Daggett, CA - **High**
Kansas City, MO - **Average**
Seattle, WA - **Low**

The amount of power that is produced by a PV system depends upon the solar resource availability (in addition to other factors like temperature and snowfall), which is location dependent. The median solar resource for the United States is represented by Kansas City, MO, while the highest solar resource is represented by Daggett, CA, and the lowest solar resource is represented by Seattle, WA.

https://www.energy.gov/sites/prod/files/2018/05/f51/SunShot%202030%20Fact%20Sheet.pdf

A Pathway To 3 Cents per kWh for Utility-Scale PV

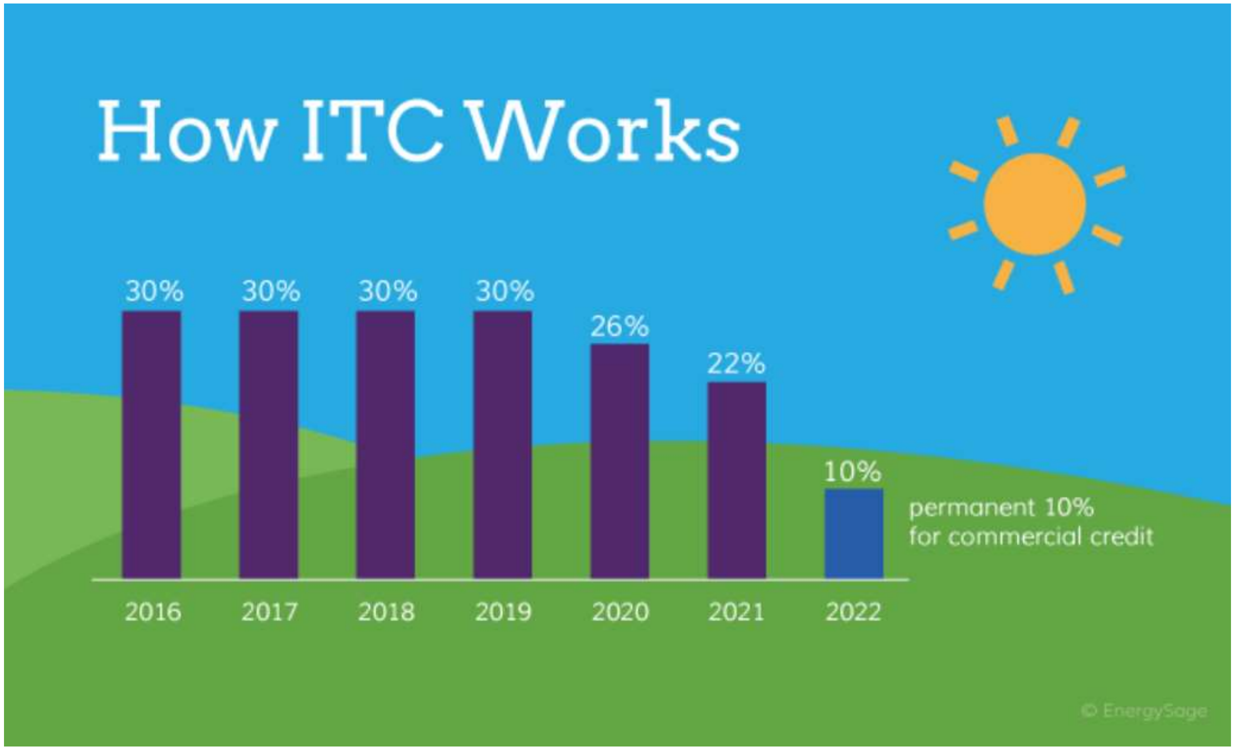


100 $MW_{(DC)}$ One-Axis Tracking Systems With 1,860 $kWh_{(AC)}/kW_{(DC)}$ First-Year Performance. Includes 5 Year MACRS. Cost of capital is 7% and inflation is 2.5%.

SunShot U.S. Department of Energy

Solar Investment Tax Credit

- established by the Energy Policy Act of 2005, set to expire in 2007
- Continued due to popularity, will sunset for residential installations in 2021
- 10% for commercial installations, 2022 onward



U.S. Department of Energy, SunShot 2030, https://www.energy.gov/eere/solar/sunshot-2030 , accessed June 2019

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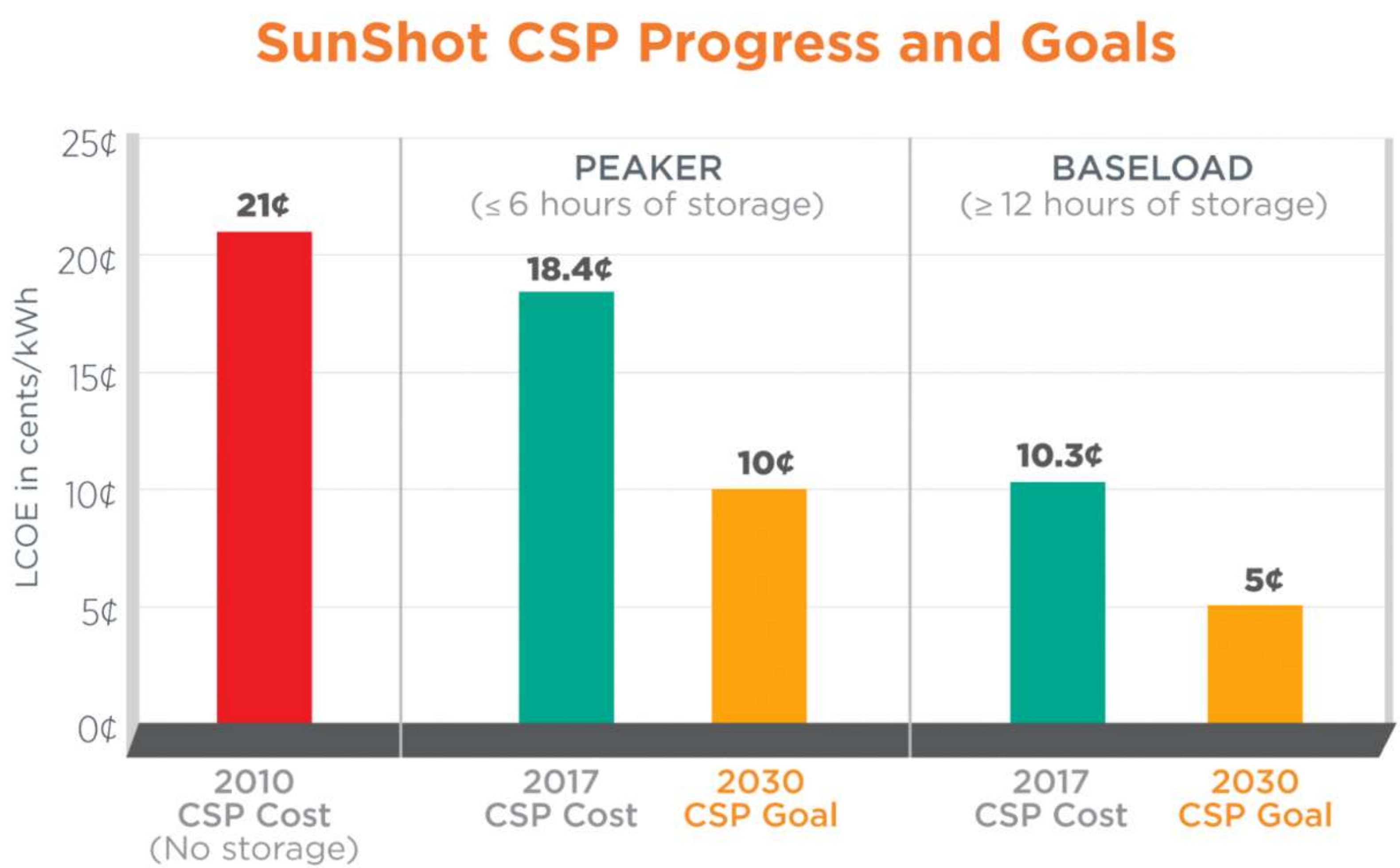
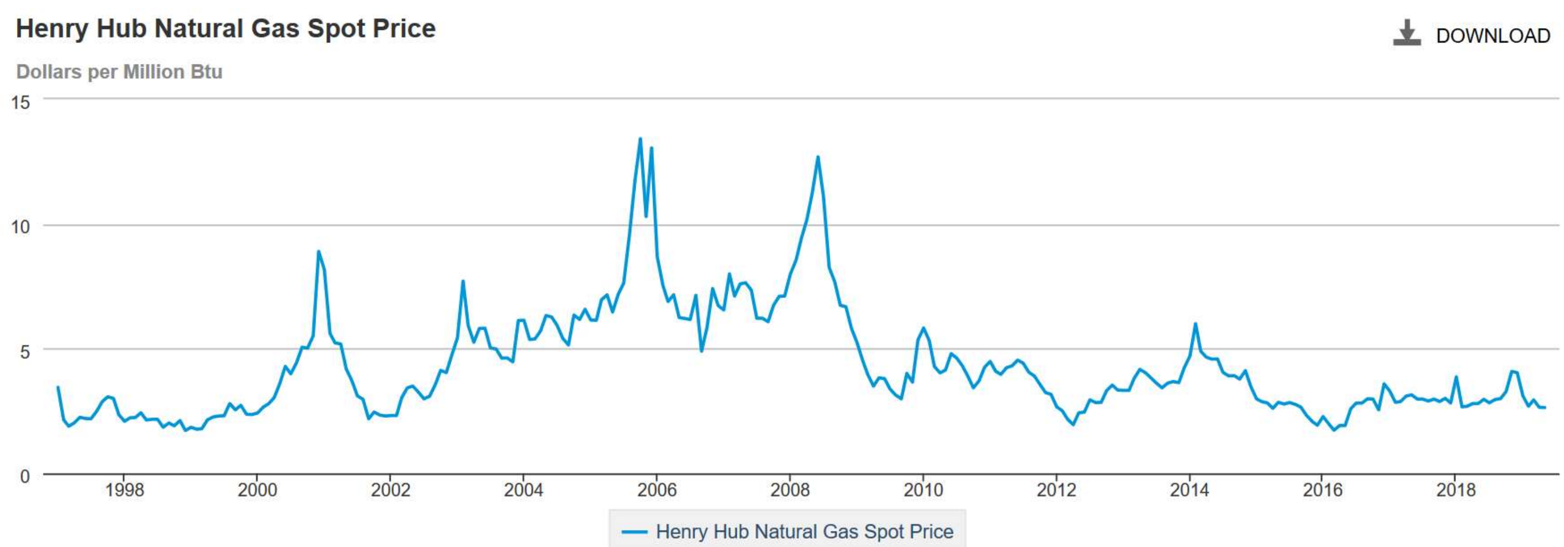
For comparison: Concentrating Solar Power (CSP)



(Note: The specific plant CSP-TES plant configuration for which the 2030 cost target was developed includes 14 hours of thermal energy storage and a solar multiple of 2.7)

Competing Fossil Fuels

- Natural gas is currently cheapest electrical energy source
- We've had 10 years of low gas prices due to shale gas – and low prices will likely likely continue for some time (decades?)
- But: the fuel is not free, which will help solar PV/CSP as its cost is reduced further



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Basic PV calculation for white paper

USA-Mexico border, basic PV solar energy calculations				
Wosnik	input in yellow boxes			
	This is the calculation I used for the white paper.			
https://maps.nrel.gov/nsrdb-viewer/				
solar resource (GHI, average, conservative)	5.5	5.5	5.5	[kWh/day*m^2]
PV conversion efficiency	**0.15**	**0.18**	**0.228**	[-]
	(polycrystalline)	(polycrystalline)	(monocrystalline)	
			(eg. SunPower)	
border length	**3,201**	**3,201**	**3,201**	[km]
	3,201,000	3,201,000	3,201,000	[m]
width of "panel curtain"	**5.0**	**5.0**	**5.0**	[m]
(note: stand-in value to help visualize size)				
solar panel area	**16,005,000**	**16,005,000**	**16,005,000**	[m^2]
number of 72 cell PV panels (~1.0m x 2.0m)	8,002,500	8,002,500	8,002,500	[-]
electric energy/day (mentioned in white paper)	**13.2**	**15.8**	**20.1**	[GWh/day]
	13,204,125	15,844,950	20,070,270	[kWh/day]
average power	**550,172**	**660,206**	**836,261**	**[kW]**
	550	**660**	**836**	**[MW]**
(for comparison, the single-reactor PWR at Seabrook, NH is rated at **1,244 MW**, and has been operating at a capacitor factor >0.9)				

installed capacity	2,400,750,000	2,880,900,000	3,649,140,000	[W]
	2,401	**2,881**	**3,649**	[MW]
capacity factor (approx.)	0.229	0.229	0.229	[-]
panel cost, per Watt	$ 0.30	$ 0.30	$ 0.30	[$/W]
total panel cost	$ 720,225,000	$ 864,270,000	$ 1,094,742,000	[$]
total system cost, per Watt installed	**$ 1.00**	**$ 1.00**	**$ 1.00**	[$/W]
toytal system cost	$ 2,400,750,000	$ 2,880,900,000	$ 3,649,140,000	[$]

Typical PV panels	(res.)	(comm.)	
no. of cells	60	72	cells
approximate width	1.0	1.0	m
approximate length	1.6	2.0	m
approximate area	1.6	2.0	m^2
panel efficiency	0.150	0.150	
panel rating	240	300	W
panel efficiency	0.180	0.180	
panel rating	288	360	W
panel efficiency	0.228	0.228	
panel rating	364.8	456	W

- Note: these are rough estimates, based on a few simple inputs (yellow)
- PV panels are rated at 1,000 W/m^2
- Power vs energy, installed capacity [kW] vs electricity [kWh]

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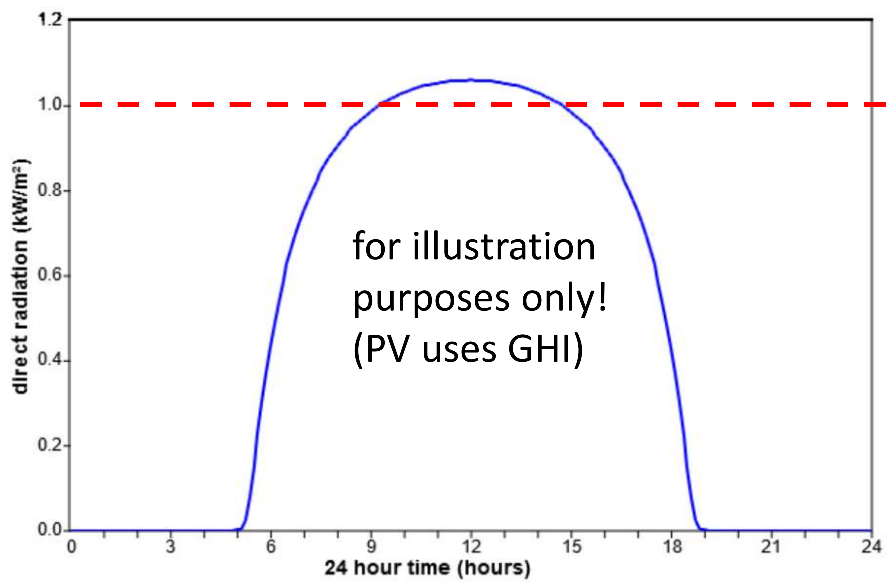
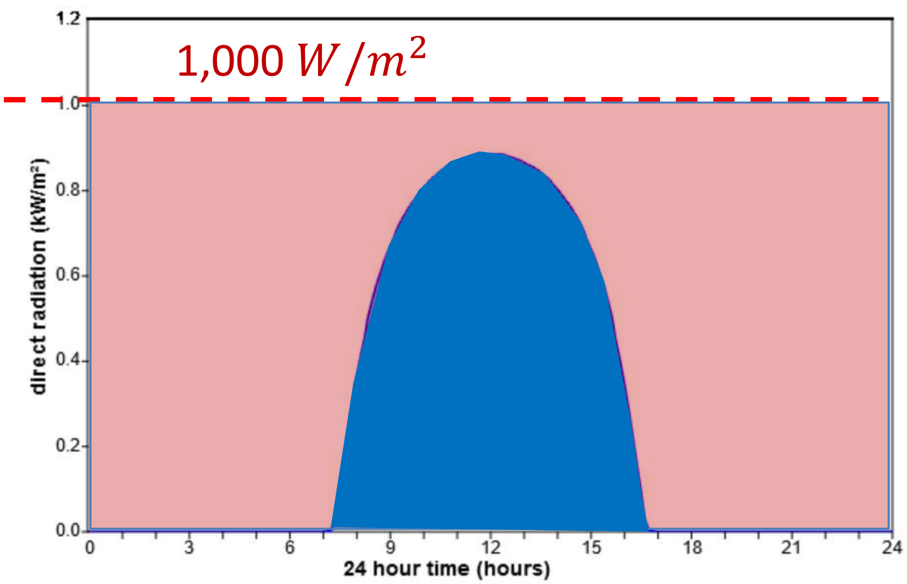
capacity [kW] *vs* electric energy [kWh]

- PV has low capacity factor (avg. C.F. ~0.23-0.25 at border)
- Good match for cooling needs, poor match for heating needs

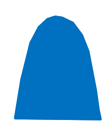




Lat 32 deg N
(Yuma, AZ)

June

December

Capacity factor ~  / 

Also: DC vs AC
"capacity factor gaming"

(energy is the area under the curve)

Solar PV – Project Installations

- This will all get sorted out by project design / engineering
- Not to worry about details now, but need to provide reasonable/defensible numbers to potential sponsors and press

- Careful when comparing "installed capacity" vs "electrical energy produced"
(the pie charts will look different)

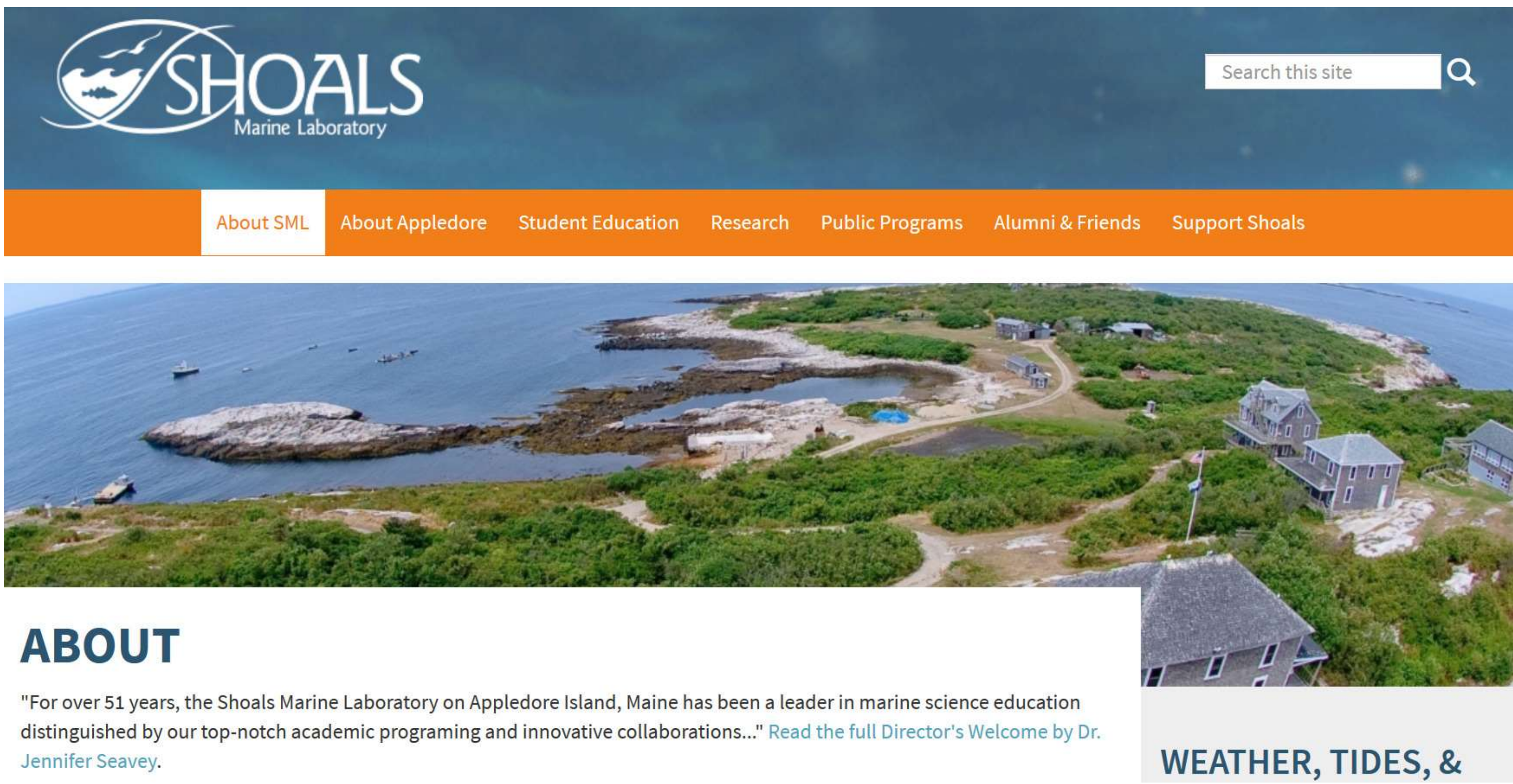
Solar energy (PV) as part of an energy system

Examples:

- Shoals Marine Laboratory (UNH/Cornell U.)
- Sustainable Housing using PV as energy source

Shoals Marine Laboratory

- Appledore Island (Isles of Shoals), 6 miles offshore
- University of New Hampshire and Cornell University
- **Reduced diesel usage by over 90%** over the past 10 years via addition of wind, solar PV, energy storage, water conservation



Shoals Marine Lab on Appledore Island, ME

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Shoals Marine Lab on Appledore Island, ME

(play video)

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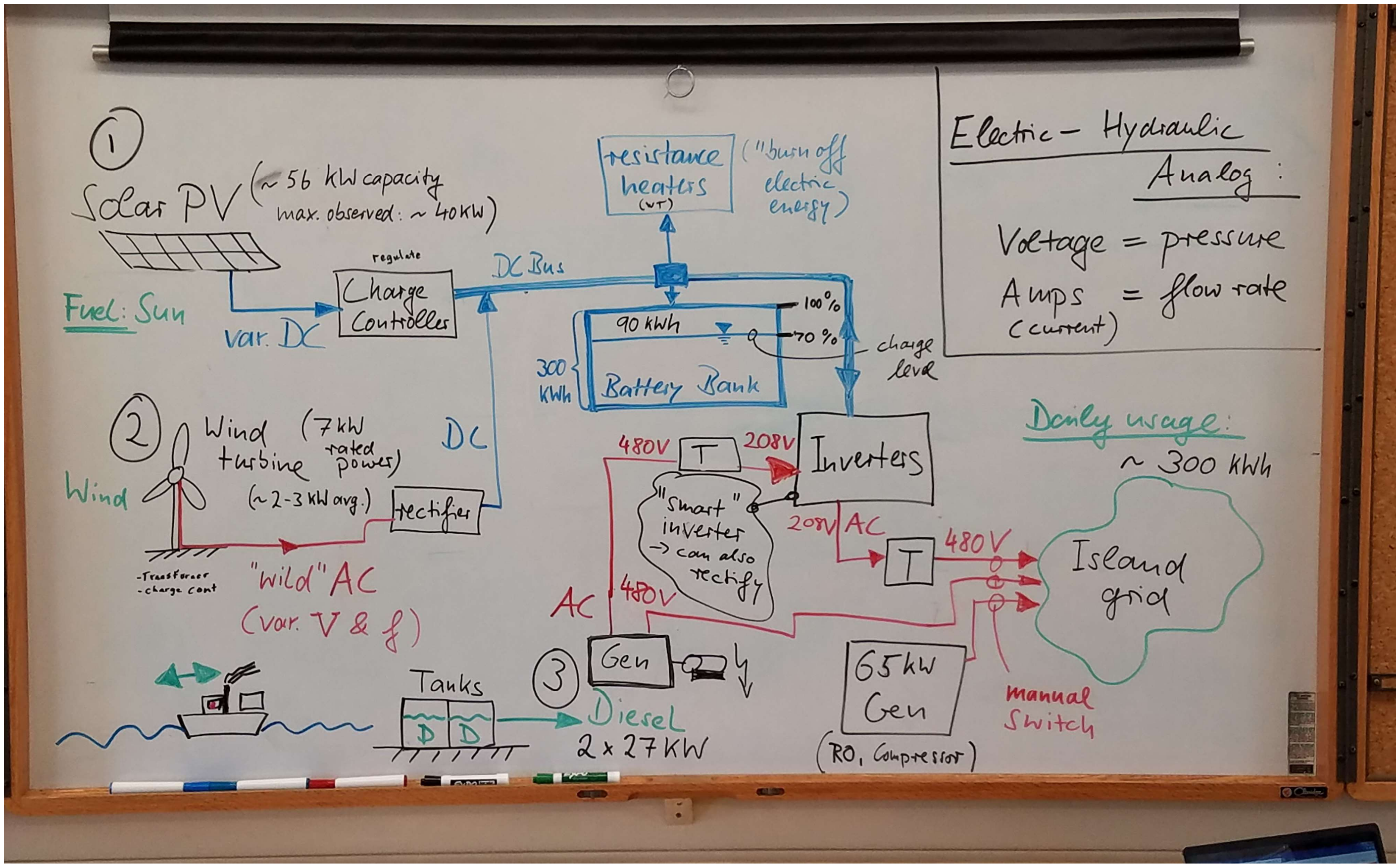
Sketch of island energy system



M. Wosnik, 2015

(…kind of like the early FEWIEP sketches)

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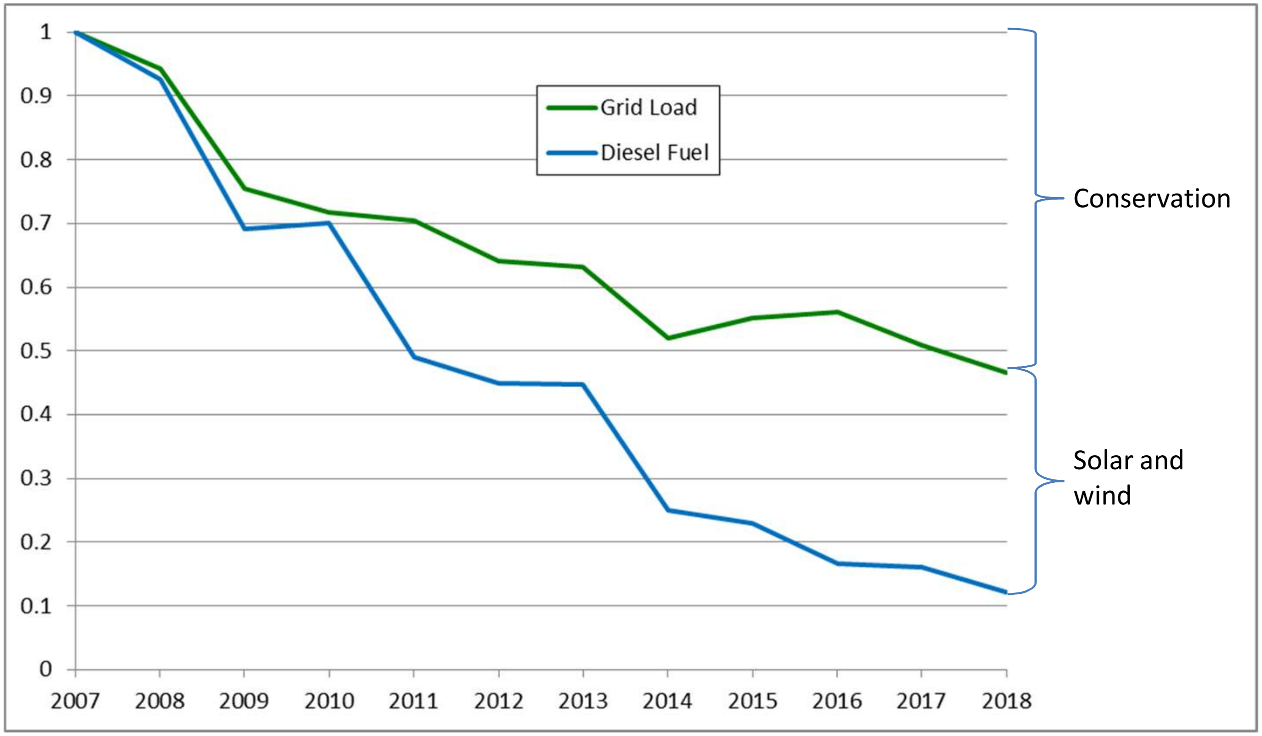
Electric Grid Load & Diesel Fuel Usage

(normalized with 2007 electric energy & diesel fuel consumption)



Tom Johnson, SEI Mentor, 2019

→ Reduced Diesel consumption by almost 90%

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Sustainable housing community project in Freiburg, Germany

→ Transferable to Mexico-U.S. border area

Solar Settlement at Schlierberg

- Built between 2000-05, 59 homes
- Produce more energy than they use
- Example of "PlusEnergy" houses

The solar resource in Germany is equivalent to Northwest U.S.

Stakeholder Engagement

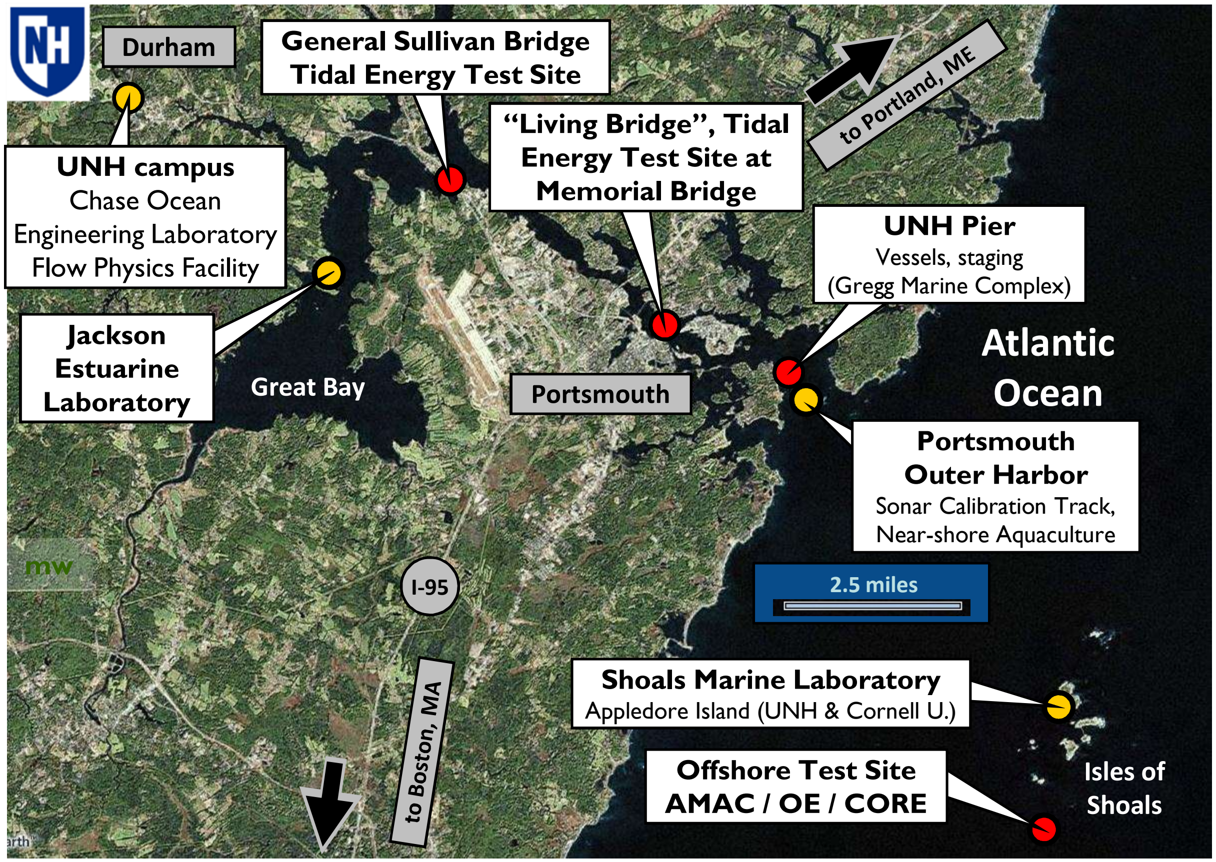
- None of us live in the area where we are proposing an "anchor project"…
- Need to **engage stakeholders** early and often!!
- Note to engineers: The social and community aspects are often the most important parts of the project ("social engineering")

Additional Slides

Stakeholder engagement - example

- UNH-CORE Test Sites
  - Offshore test site
  - Tidal energy test sites

Ocean/Marine Renewable Energy Related Facilities and Test Sites at UNH



Tidal Energy Test Sites, Offshore Test Site and UNH Pier (staging)

- Ocean Engineering Laboratory

- **2x Tidal Energy Test Sites**
- **Offshore Test Site**
- **UNH Pier**

- Other Marine Laboratories/Sites:
  - Jackson Estuarine Lab
  - Shoals Marine Lab
  - Portsmouth Outer Harbor

- Located 1 hour north of Boston, MA

Contact: martin.wosnik@unh.edu

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UNH Offshore/Wave Energy Test Site

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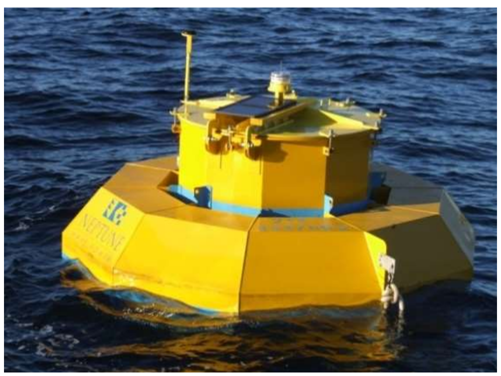
Ocean Renewable Energy
Research & Technology Development at UNH









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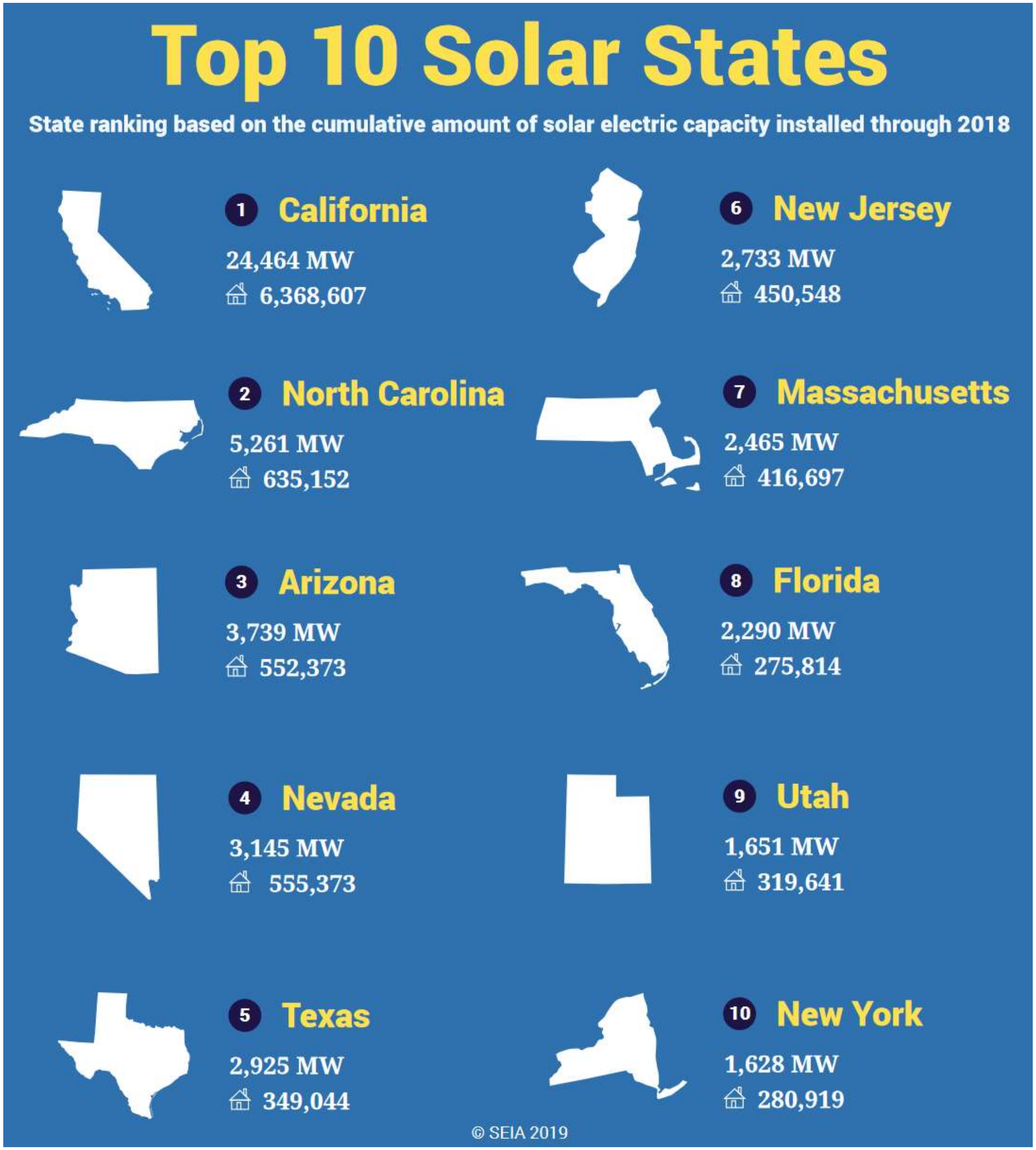
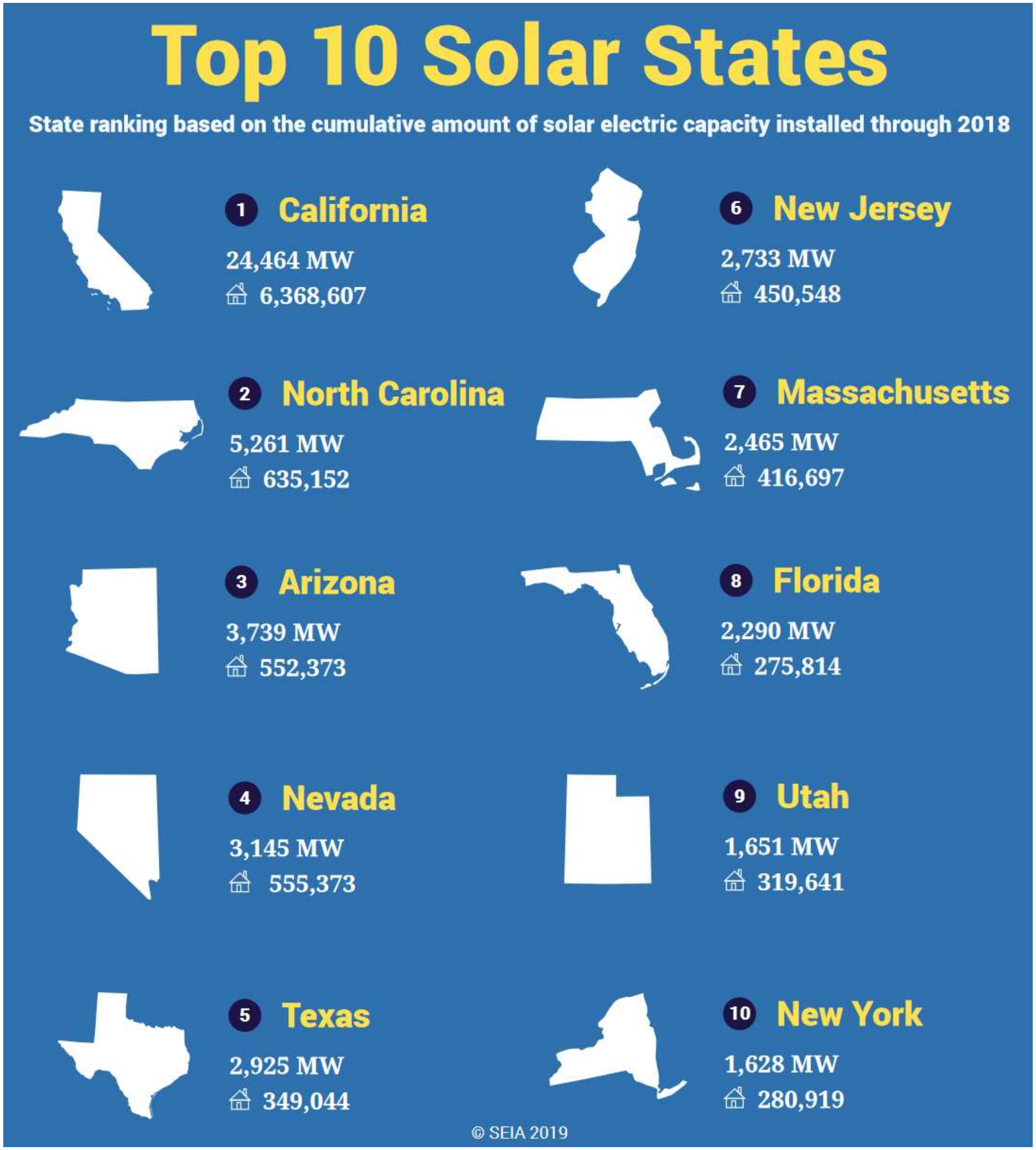
University of New Hampshire

Contact: Martin Wosnik martin.wosnik@unh.edu

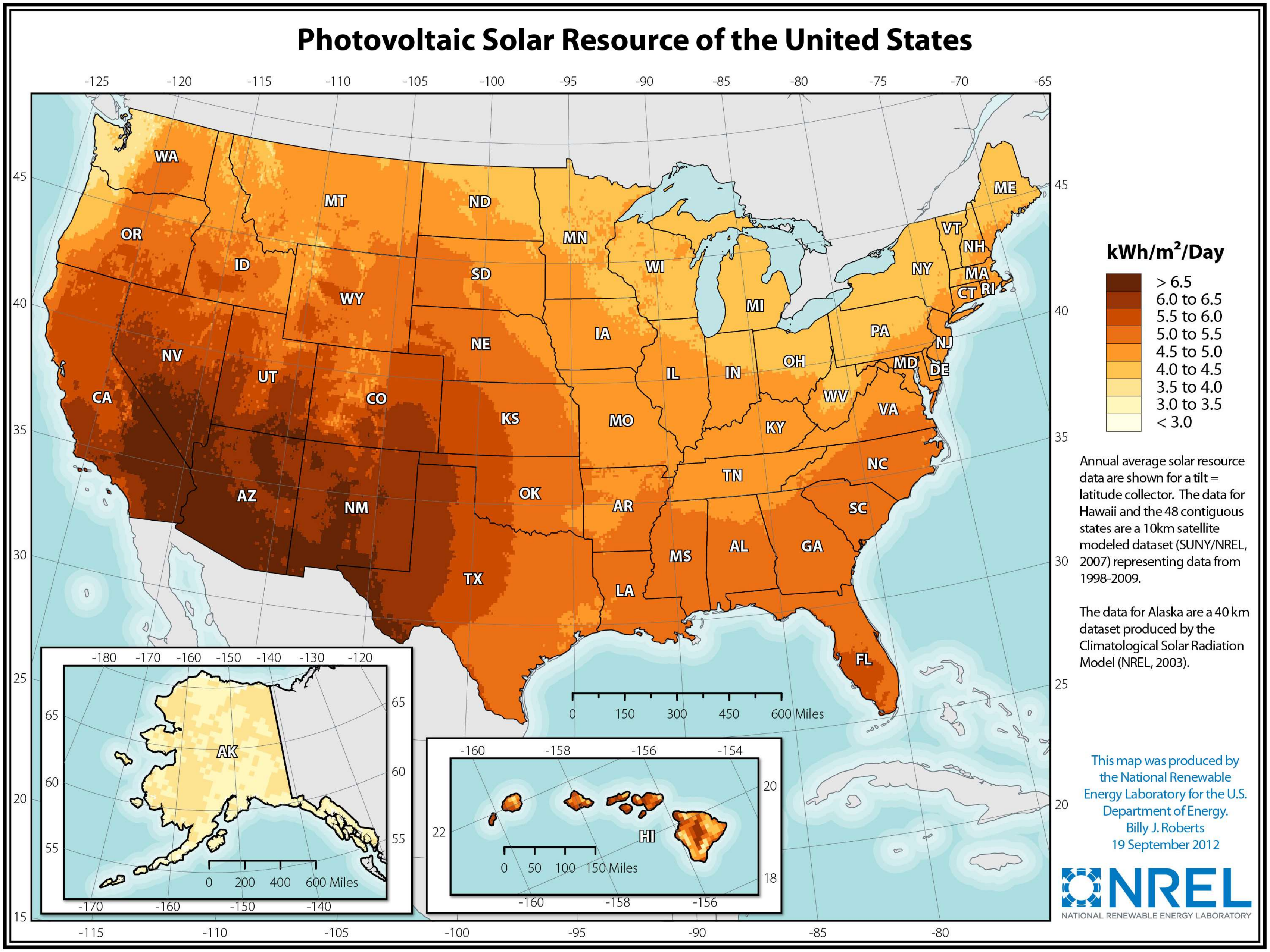


Which states strike you as "odd" in this list?

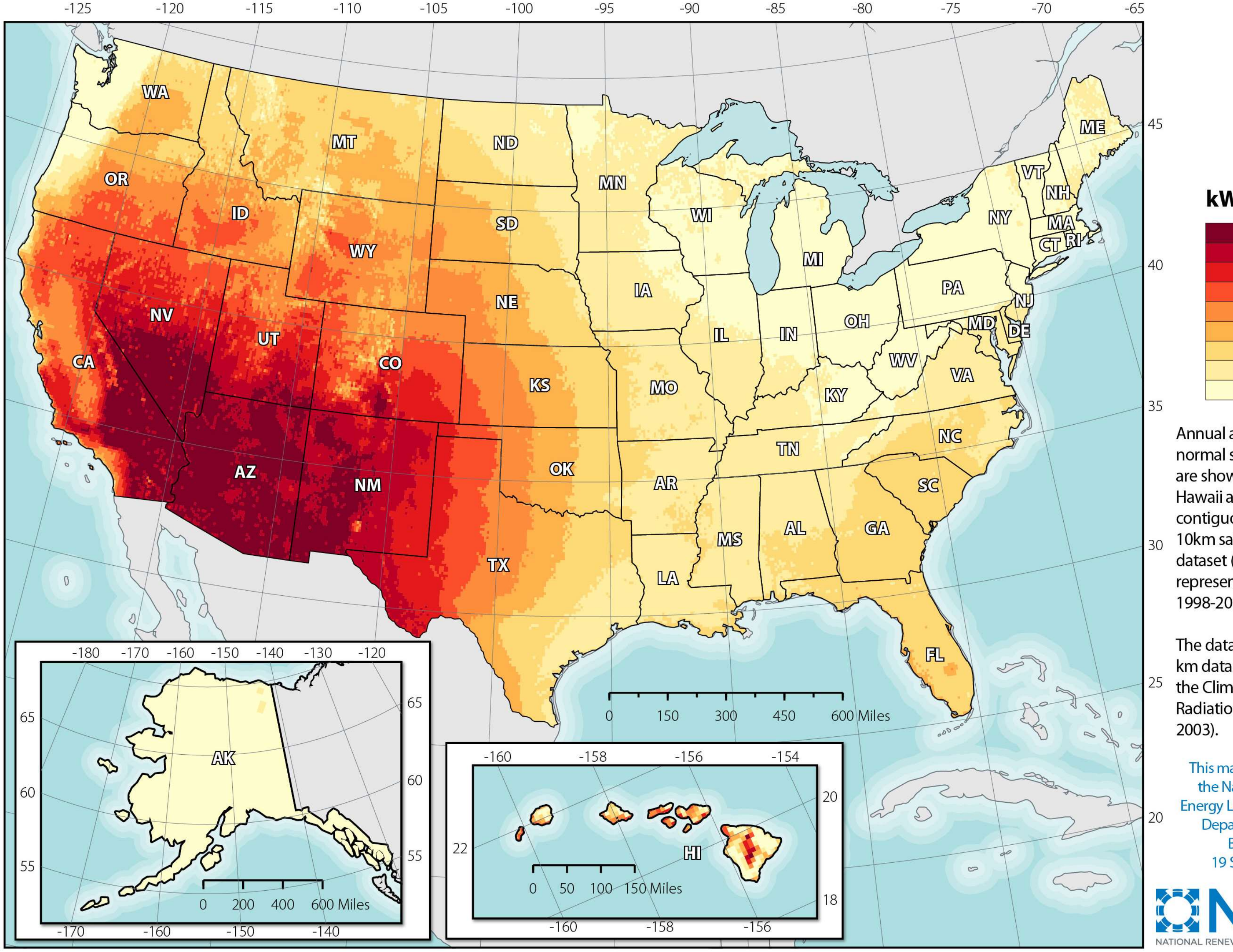


State incentives promote solar PV installation

(e.g., MA, NY, NJ)


Photovoltaic Solar Resource of the United States
kWh/m²/Day
> 6.5
6.0 to 6.5
5.5 to 6.0
5.0 to 5.5
4.5 to 5.0
4.0 to 4.5
3.5 to 4.0
3.0 to 3.5
< 3.0
Annual average solar resource data are shown for a tilt = latitude collector. The data for Hawaii and the 48 contiguous states are a 10km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2009.
The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Billy J. Roberts
19 September 2012
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
WA OR CA NV ID MT WY UT AZ NM CO ND SD NE KS OK TX MN IA MO AR LA WI IL MI IN OH KY TN MS AL GA FL SC NC VA WV PA NY MD DE NJ CT RI MA NH VT ME
AK
HI
0 150 300 450 600 Miles

Concentrating Solar Resource of the United States



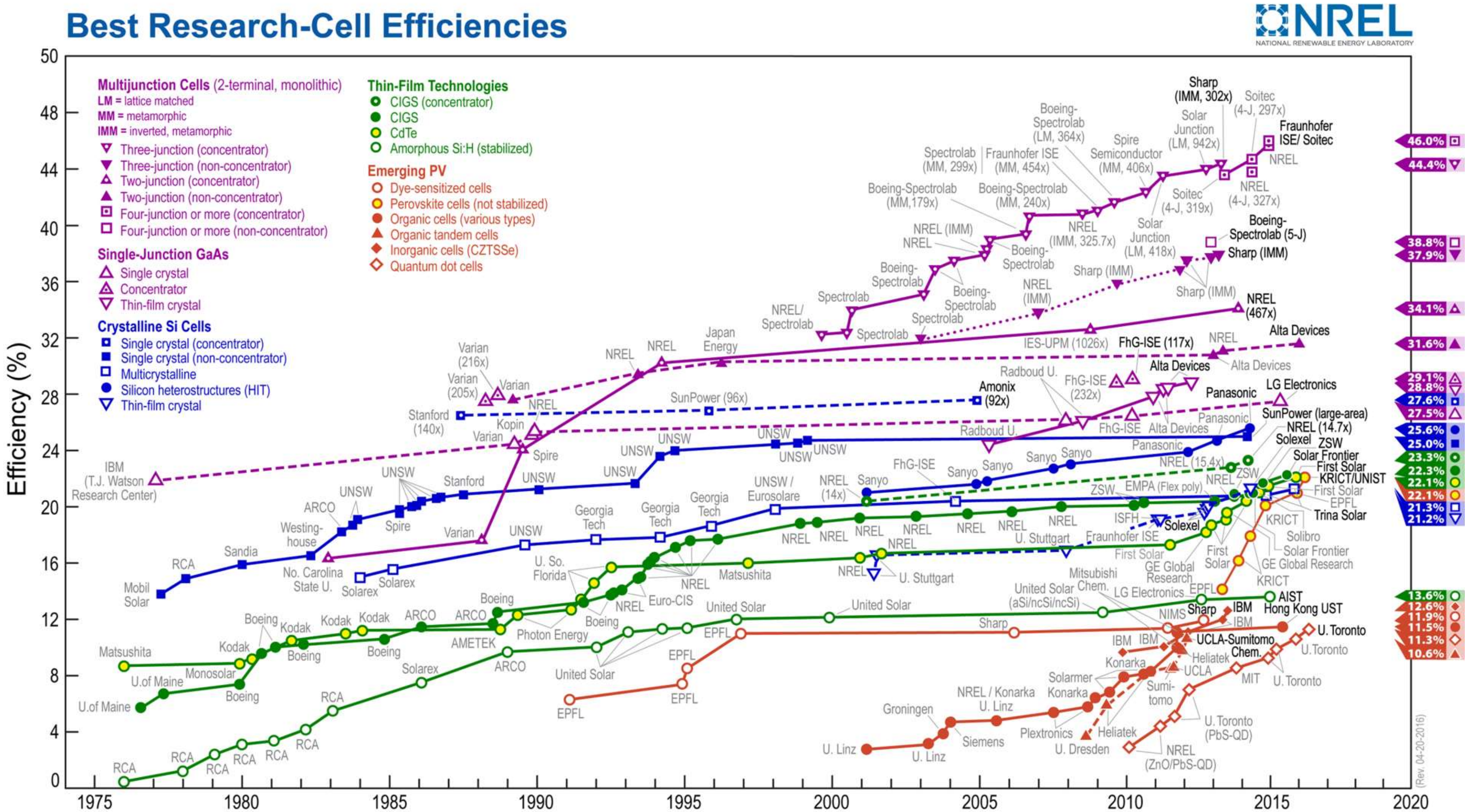
Annual average direct normal solar resource data are shown. The data for Hawaii and the 48 contiguous states are a 10km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2009.

The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Billy J. Roberts
19 September 2012

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

History of PV Research Cell Efficiencies



NREL: http://www.nrel.gov/ncpv/

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