

BUILDING THE FOUNDATION FOR A TERAWATT WORLD

Why a Global Database Matters



Laurie Burnham
Sandia National Laboratories

PV DAYS 2019, Halle Germany
22-24 October 2019

This work is funded in part or whole by the U.S. Department of Energy
Solar Energy Technologies Office, under Award Number 34363



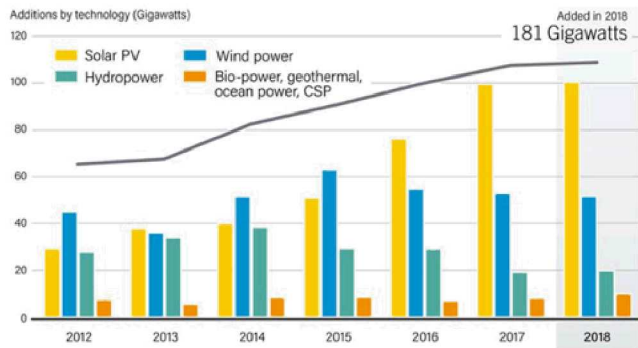
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

CLOSING-IN ON A TERAWATT WORLD

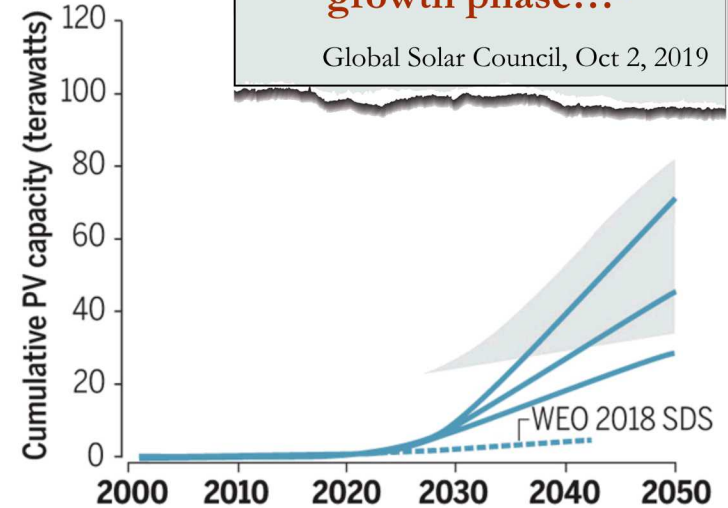
German government wants 98 GW of solar by 2030

Major Solar PV Markets
Are Emerging Worldwide

Annual Additions of Renewable Power Capacity, by Technology and Total, 2012-2018



Solar Dominates



2018 World Energy Outlook New Policies Scenario

Germany added 2.72 GW of PV in eight months

In August alone, around 327 MW of new solar generation capacity was registered in the country. This month the FIT for solar systems up to 750 kW in size will fall another 1.4%

OCTOBER 1, 2019 PETRA HANNEN

US utility solar pipeline soars to 37.9 GW, a new record

-- U.S. Solar Market Insight Report, Q3, 2019

Solar investments by Fortune 100 cos.

The solar wave rises

September 17, 2019 Christian Roselund

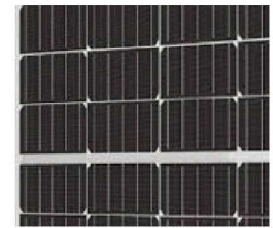
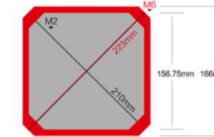
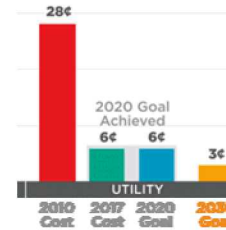
Solar Industry Plots Path to 20% of U.S. Power Mix

TRENDS THAT MAKE A TERAWATT FUTURE POSSIBLE

I. Precipitous Drop in Costs

II. Technological innovation (increased active area/module power output)

- High-cell-efficiency-c-Si (e.g. mono PERC)
- Larger cell size (166mm)
- Advanced module technologies: half-cut; shingled cells; multi-busbar
- Bifacial modules



III. Aggressive policies (decarbonization)

Utility-level

GMP Announces Divestment Of Pension Funds from Fossil Fuels

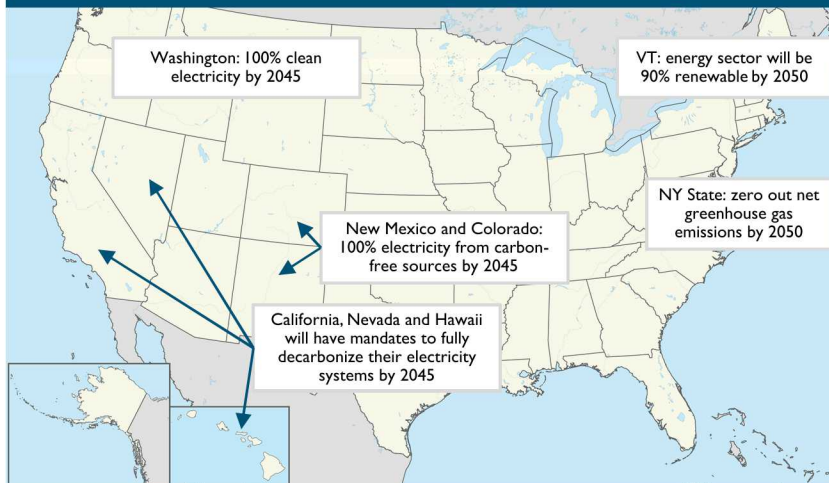
Divestment Adds to GMP's Work with Customers Across Vermont Cutting More Than 1 Million Pounds of Carbon This Week
27 September 2019

COLCHESTER, VT. – Green Mountain Power (GMP) announced it is divesting its pension fund from fossil fuel companies. With the reinvestment of about \$13.5 million finalized this week, the company's \$180 million pension fund is 99.2% divested, and positive impacts are expected on financial returns. The final .8% of investments will be divested by the end of 2020. Company President and CEO Mary Powell made the announcement alongside renowned environmentalist Bill McKibben during a Climate Week divestment event in New York City Thursday evening.

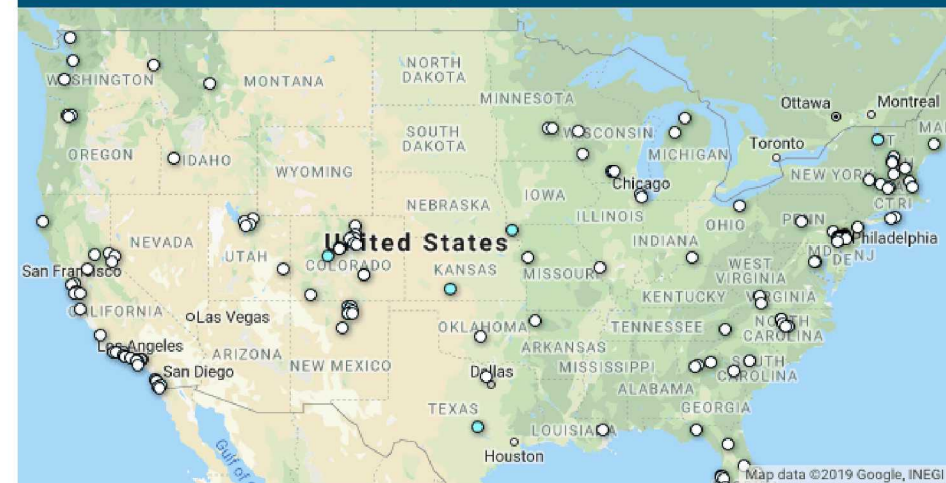


Figure 1. Timeline for the clean energy transition 2019 and 2050.

State-level



City-level



Cities powered by 100% renewable energy (2019).
Cities committed to 100% renewable energy (2050).

AS A CONSEQUENCE, SOLAR IS INCREASINGLY DISTRIBUTED

4

Northern Latitudes

- 4 of Top 10 US States for PV Growth are Above 40°
- Alaska has 2 MW of solar: 563 kW in Fairbanks (lat 64.83 °)



Norway saw 23.5 MW of solar come online in 2018

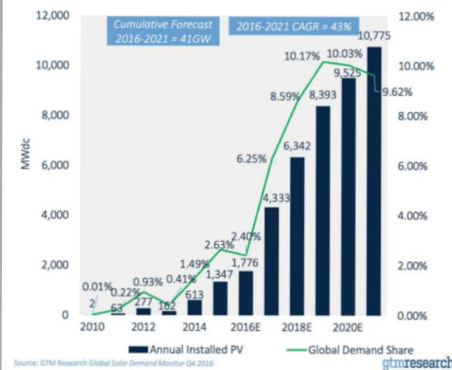


Gambia plans 150 MW solar project with 20 MWh storage option



Growth in Latin America

Latin America PV Demand 2010-2021E



Deal signed for 40 MW solar park in DR Congo

By Emiliano Bellini on Oct 4 2019, 2:27pm

Floating PV



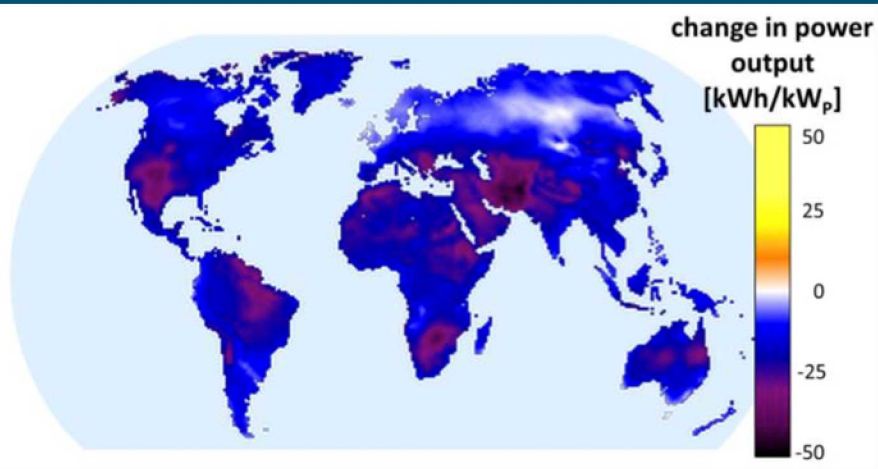
Also increasingly fragmented...

BUT NOT SO-WELL KNOWN TRENDS

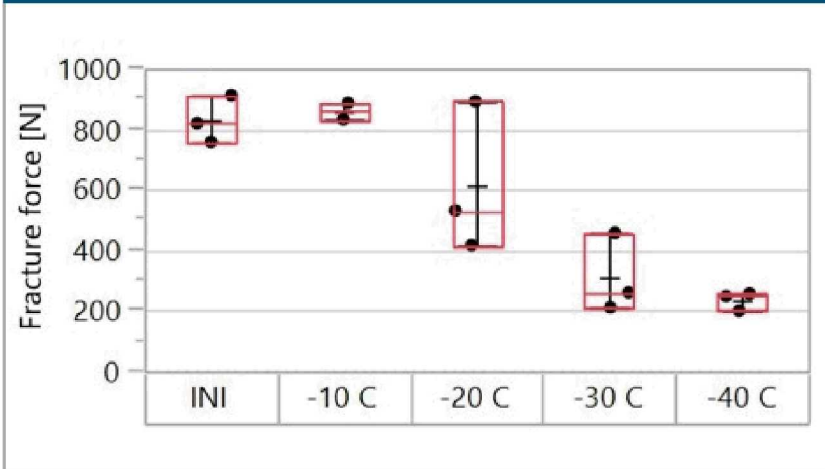
- Reliability of emerging low-cost technologies
- Lifetime performance (degradation)
- Winter storms more extreme (Oct 2019 storm deposits 30" in N. Dakota)
- Summer heat waves hotter and longer
- Accuracy of performance models in view of global climate change
- Early system failures (impact on growth)



Projected global change in energy output for Si PV, 2000-2100 based on IPCC projections. Peters and Buonassisi, 2019.

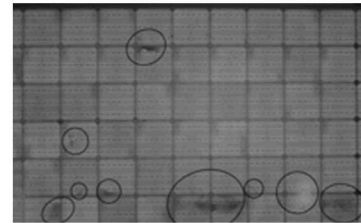


Study by Schneller et al shows less force is needed to induce cell cracking as temperatures drop*



BIFACIAL MODULES AS AN EXAMPLE

- ~ 30% increase in productivity; minimal cost; production doubled in 2019
- But long-term challenges not well understood:
 1. Diurnal and seasonal shifts in albedo
 2. Backside mismatch
 3. Back-of-module soiling
 4. Mechanical stress
 5. Substrate O&M
- Need to identify performance inputs; quantify uncertainty
- Need more data on bifacial gain and bifacial reliability across environments and installation designs



THE IMPORTANCE OF A GLOBAL DATA REPOSITORY

Meteorological and Climatic Factors that Affect PV Performance are Variable and Complex

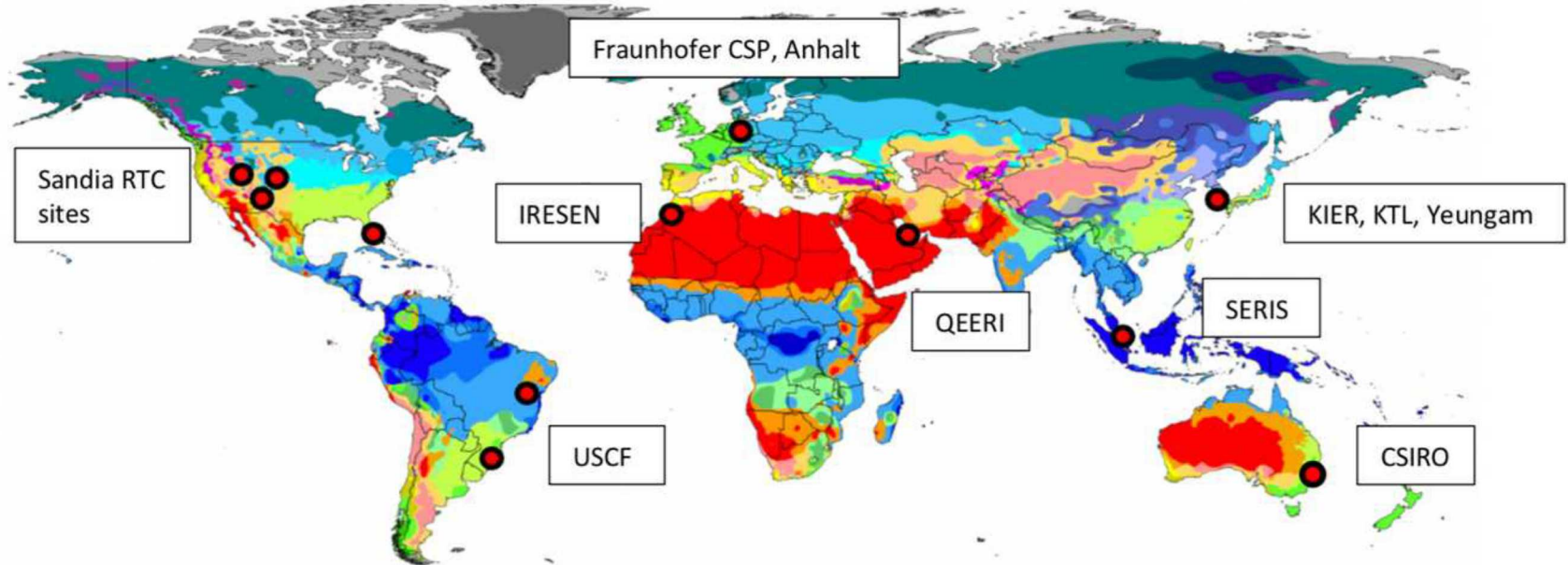
- Irradiance (intensity, uniformity, spectrum, variability, reflection, soiling, albedo)
- Temperature (uniformity, effects of air temp, irradiance, wind, RH, etc.)
- IV Behavior (LID, linearity, metastability, mismatch)
- System Performance over time (degradation, variability)

Long-term PV Performance and Reliability Across Diversity of Climates Not Well Understood

PV Is Not One-Size-Fits-All

- Data will enable greater efficiency through design optimization

PHOTOVOLTAIC COLLABORATIVE TO ADVANCE MULTI-CLIMATE PERFORMANCE AND ENERGY RESEARCH (PV CAMPER)



Mission

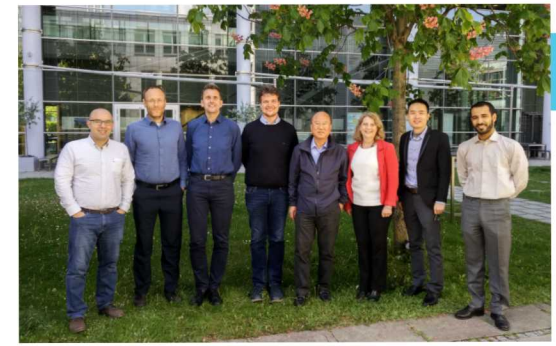
To create a global technical platform that enables pioneering photovoltaic research, validates the performance of emerging technologies in specific climates and helps accelerate the world's transition to a solar-intensive economy

Organization

Currently has 11 member institutions, representing a network of 13 field sites that span both hemispheres and most major climate zones.

ORGANIZATIONAL OBJECTIVES

- Create a global technical platform with common infrastructure and protocols
- Foster collaborative R&D in the areas of PV performance and reliability
- Identify and quantify the factors that contribute to climate-specific efficiencies and create a repository of data to support design optimization
- Generate set of best-practices for data monitoring and collection



PV CAMPER RESEARCH PROJECTS

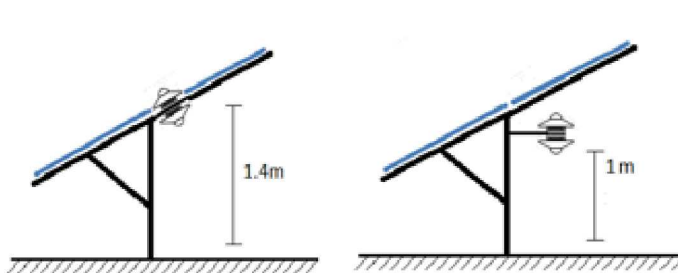
PYRANOMETER UNCERTAINTY

Measurement of pyranometer drift across multiple climates



GLOBAL ALBEDO ANALYSIS

Ground-based albedo measurements (diurnal and seasonal variation) compared with satellite measurements*



* Dittmann, et al. Comparative Analysis of Albedo Measurements (Plane-of-Array, Horizontal, Satellite) at Multiple Sites Worldwide. EU PVSEC 2019, oral presentation 12.09.2019

GLOBAL SOILING ANALYSIS

Impact of condensation on soiling losses



BACK-OF-MODULE TEMPERATURE STUDY

Intent is to quantify the accuracy and reliability of different temperature sensors and build a global database

BUILDING A GLOBAL DATABASE



- 13 field sites in both hemispheres and representing major climate zones
- Each site has equivalent technical capabilities:
 - Grid-tied crystalline-silicon PV reference system
 - High-accuracy meteorological and irradiance instrumentation (DNI, GHI, DHI, POA and albedo)
 - High-resolution DC data-monitoring instrumentation
 - High-frequency data acquisition systems
 - Module characterization capabilities that meet IEC standards
- Each site has agreed to common O&M protocols
- Data will be uploaded via API to PVCAMPER database hosted on DuraMAT.org
 - Manual or automated data upload
 - Standardized format (allows for machine learning)
 - Supported by Python toolkit
 - Data password protected; read-only
 - Access by permission



CONCLUSIONS

- Repository of large-scale (global) high-quality data:
 1. Supports complex challenges (e.g., impact of climate change on PV performance)
 2. Enables more accurate and complex performance modeling
 3. Increases system efficiencies by enabling cross-climate performance comparisons
 4. Encourages international research
- The PV CAMPER database is a unique resource
- The PV CAMPER database is a high-impact tool: standardized, accessible and expandable.

- Hosted by DuraMAT
- Data password protected; read-only
- Multiple upload options:
 - Manual: upload csv files
 - Automated:
 - CKAN API
 - Python ckanapi module
 - API via a URL via Python requests
 - Bash script using cURL or a scripting utility like httpie.

THANK YOU!

lburnha@sandia.gov