



## IEA PVPS Task 14

## High Penetration of PV into Electricity Grids

# High Penetration Projects in the US

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# Current Status in United States

- **Distribution Level** : High Penetration examples are now being installed and monitored – new requirements for high penetration are starting to formulate
- **Transmission Level** : Large systems are starting to be installed – with plans for the largest systems in the world
- DOE has developed a comprehensive approach to address high penetration issues through
  - development of advanced inverter technologies
  - updating power system simulation and planning practices
  - updating interconnection standards and codes
  - and documenting successful case studies on high penetration PV projects





# Distribution Grid Integration





# Distribution Case Studies

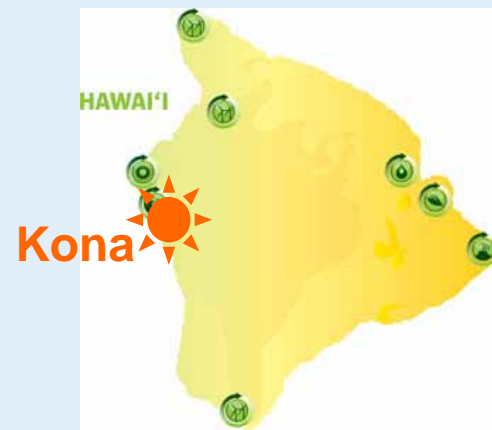
- Big Island, Hawaii
- Oahu, Hawaii
- Kauai, Hawaii
- San Antonio, Texas
- Fort Collins, Colorado
- Fontana, California
- Porterville, California





# Big Island, Hawaii

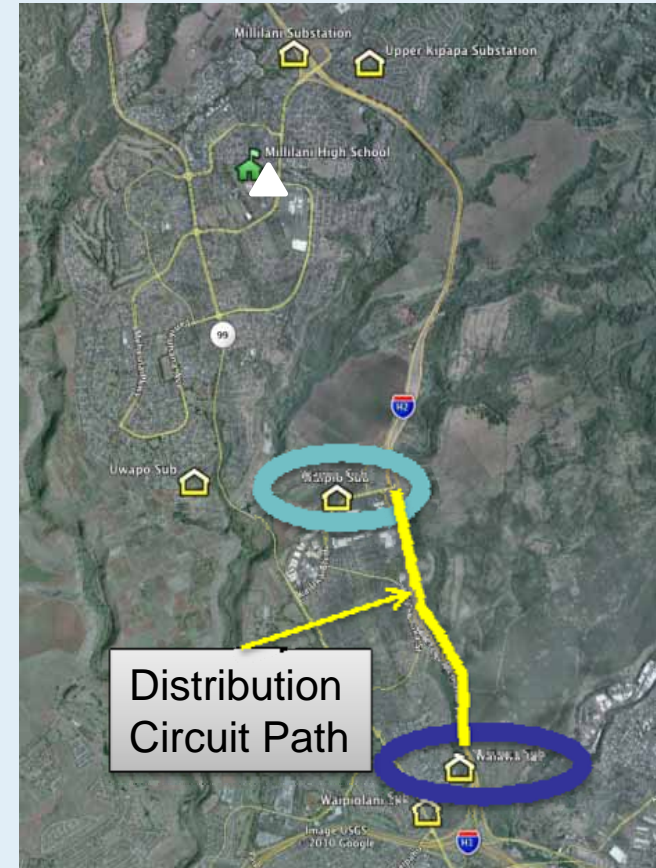
- HELCO estimates that the island of Hawai'i has the most rooftop photovoltaic (PV) installations per capita in the United States
- Kona area of Big Island has circuits with high penetration of solar (over 60%)
- Entire island has over 10MW of distributed solar (load is 175MW peak)
- Big Island also has a large percentage of Wind (31MW), Geothermal (30 MW), and Hydroelectricity (16 MW)





# Oahu, Hawaii

- Examining distribution circuit with 26% penetration
- Completing study of impacts





# Kauai, Hawaii

- 1.2MW PV system installed
- System represents 100% penetration on clear days





# San Antonio, Texas

- CPS Energy recently interconnected a 14MW PV plant (Blue Wing)
- Split as two 7MW connections to distribution circuits ~5miles (8km) from substations
- Represents a penetration level of 80%
- Includes 500kW technology demonstration site that has CIGS, CdTe, Crystalline, amorphous SI

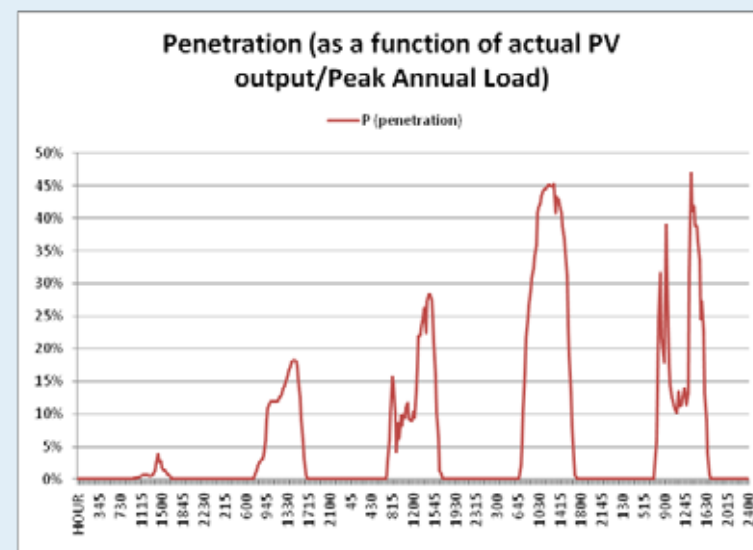






# Fort Collins, Colorado

- 5.2MW PV system
- System represents 47% penetration on circuit





# Fontana, California

- 2.3MW PV System installed in SCE services territory
- Represents 23% penetration currently
- Plans are to install more PV on this circuit





# Porterville, California

- 5MW PV System installed in SCE service territory
- Represents 100% penetration on a long rural circuit





# Distribution Case Studies

| Country | State              | City         | System Name | System Aggregate Size | Penetration |
|---------|--------------------|--------------|-------------|-----------------------|-------------|
| USA     | Hawaii, Big Island | Kona         |             |                       | 62%         |
| USA     | Hawaii, Oahu       |              |             | 0.8MW                 | 26%         |
| USA     | Hawaii, Kauai      |              |             | 1.2MW                 | 100%        |
| USA     | Texas              | San Antonio  | Blue Wing   | 14MW                  | 80%         |
| USA     | Colorado           | Fort Collins | CSU         | 5.2MW                 | 47%         |
| USA     | California         | Fontana      |             | 2.3MW                 | 23%         |
| USA     | California         | Porterville  |             | 5MW                   | 100%        |





# High Penetration Survey

| Parameter                                    | Value | Notes |
|--|-------|-------|
| Feeder Name                                  |       |       |
| Feeder Number                                |       |       |
| Substation Transformer Size (MVA)            |       |       |
| Transmission Voltage (Primary) (kV)          |       |       |
| Feeder Voltage (Secondary) (kV)              |       |       |
| Peak Load (MW)                               |       |       |
| Minimum Daytime Load (MW) if available       |       |       |
| System Fault Current at Substation           |       |       |
| Feeder conductor rating (A) – main size      |       |       |
| Voltage regulation type                      |       |       |
| Voltage regulation location                  |       |       |
| Reclosers on feeder, setting if available    |       |       |
| Any other DG on Feeder? Size?                |       |       |
| Reverse power flow capability of transformer |       |       |
| Number of other circuits on substation       |       |       |





# High Penetration Survey

| Parameter                                   | Value | Notes |
|---|-------|-------|
| Installed PV Capacity (MWac)                |       |       |
| Fault Current from PV (kA)                  |       |       |
| Zero sequence impedance of DG ground source |       |       |
| Distance from Substation (miles)            |       |       |
| Available Fault Current at PV location      |       |       |
| Impedance of circuit at PV location         |       |       |
| Utility ground source impedance             |       |       |
| Transfer trip on PV?                        |       |       |





# IEA Task 14

## High Penetration PV

### Case Studies

- Please contribute information for Case Studies
- Contact Ben Kroposki at
- [benjamin.kroposki@nrel.gov](mailto:benjamin.kroposki@nrel.gov)





# Transmission Grid Integration

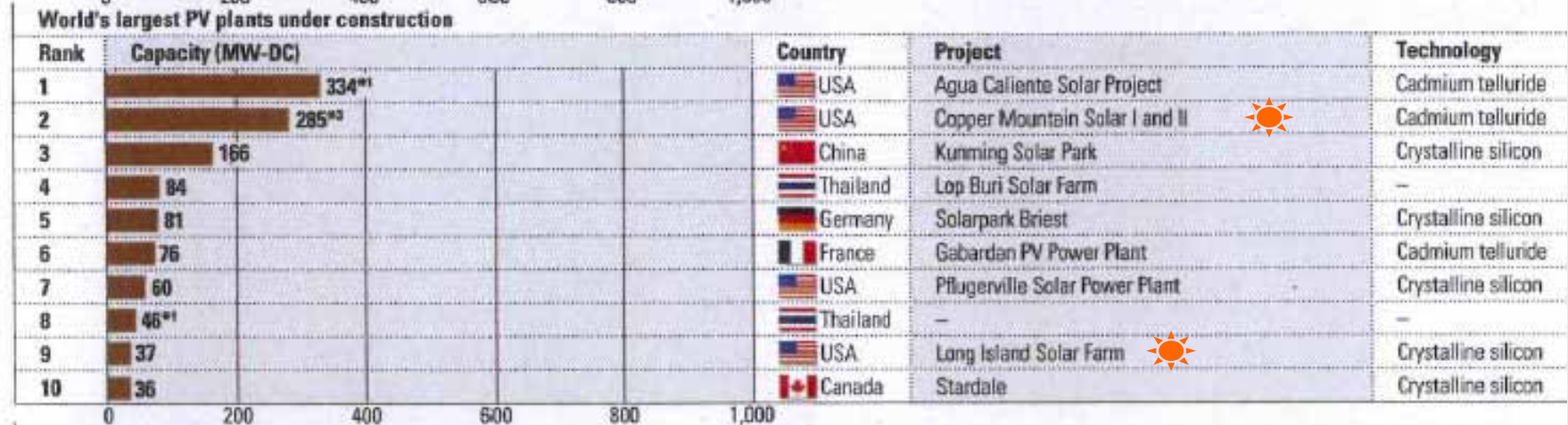
PVPS







# Largest PV plants operating, under construction, in development



PVPS





# Copper Mountain, Nevada





# DeSoto, Florida

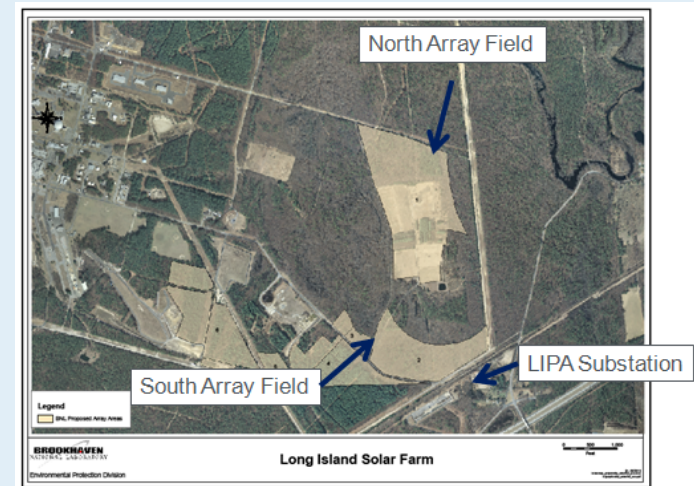
- 25MW currently (may expand to 300MW)
- Connects to transmission system
- Installing a high density irradiance grid inside 25MW and inside 300MW footprint





# Brookhaven, New York

- 34MW current being installed
- Installing a detailed irradiance sensor and power sensor network in system





# Largest PV Plants Under Development

| Rank | Capacity (MW <sub>dc</sub> ) | Country | Project               | Technology          |
|------|------------------------------|---------|-----------------------|---------------------|
| 1    | 805                          | USA     | Mesquite Solar        | Crystalline, others |
| 2    | 690                          | USA     | Desert Quartzite      | CdTe                |
| 3    | 633                          | USA     | Topaz Solar Farm      | CdTe                |
| 4    | 633                          | USA     | Desert Sunlight       | CdTe                |
| 5    | 374                          | USA     | -                     | Crystalline Silicon |
| 6    | 345                          | USA     | Desert Stateline      | CdTe                |
| 7    | 317                          | USA     |                       | Crystalline Silicon |
| 8    | 288                          | USA     | CA Valley Solar Ranch | Crystalline Silicon |
| 9    | 288                          | USA     | Silver State South    | CdTe                |
| 10   | 264                          | USA     | AV Solar Ranch One    | CdTe                |





# High Penetration Solar Forum

In March 1-2 2011  
DOE/CPUC held a  
workshop on high  
penetration PV in San  
Diego.

Reviewed projects being  
funded by DOE and CPUC



**Workshop information available at:**

[https://solarhighpen.energy.gov/high\\_penetration\\_solar\\_forum](https://solarhighpen.energy.gov/high_penetration_solar_forum)





# High Penetration Solar Portal

**High Penetration Solar Portal:**  
<https://solarhighpen.energy.gov/>

