Utility Scale Solar PV Cost

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GRAC

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Outline

1. Summarize solar portion of the previous GRAC meeting - June 20, 2013
2. New Capital Cost information and analysis
3. Proposed Capital Cost & O&M Forecast
4. Revised Performance Capacity Factors

GRAC Meeting 1

Solar in the news

- Rapid growth in solar development fueled by solar initiatives like DOE SunShot, Federal Tax Credits, State Renewable Portfolio
- Decline in installation costs along with gains in solar cell efficiency
- Solar PV manufacturer bankruptcies and layoffs
- Utility rate making and net metering controversies

GRAC Meeting 1

Recent Cost Report Summaries

- Energy Environment Economics (E3) Cost and Performance Review of Generation Technologies for WECC (Oct 2012)
- US Energy Information Administration (EIA) Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants AEO2013 (April 2013)
- Lawrence Berkeley National Laboratory (LBNL) Tracking the Sun V – An Historical Summary of the Installed Price of PV in the US 1998-2011
- Solar Electric Power Assoc (SEPA) Centralized Solar Projects Update Bulletin – Q1 2013

GRAC Meeting 1

Defined a Utility Scale PV Reference Plant with cost estimates and projections

- 20 MW_{ac} plant using crystalline modules mounted on single-axis trackers
- 3 year development cycle
- Cost estimates using recent cost reports and projects
- Overnight Capital Cost Estimate for 2012 construction \$4,270/kW_{ac} declining to \$2,888/kW_{ac} by 2020 and \$2525/kW_{ac} by 2025
- Finalize numbers at next GRAC – here we are

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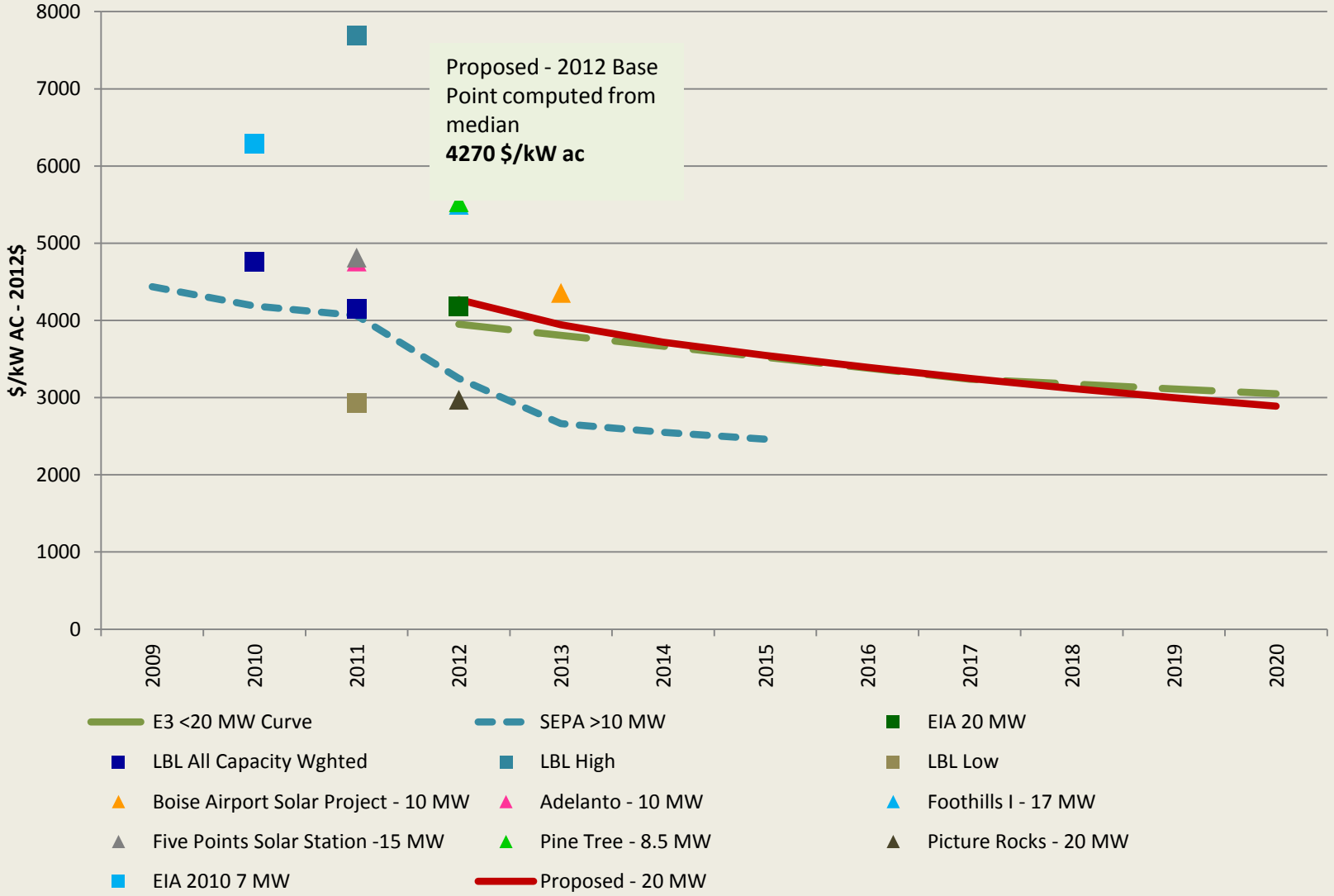
Preliminary
Solar PV Utility Scale Capital Costs ($/ kW AC) for 20 MW Plant



New Solar Information

A number of very low priced power purchase agreements have recently been announced – mostly California municipals

Is there an emerging sweet spot for project sizes around 20MW – due to land costs, environmental siting, transmission and integration?

- City of Palo Alto
  - 3 projects starting in 2017 - $69/MWh
  - Central Valley and S. California locations, on distressed ag land, 20 to 40MW sizes
- City of Roseville
  - 32 MW Lost Hills Project at 75 $/MWh
- Riverside Public Utilities
  - 2 solar pv projects at 70 $/MWh
  - Projects 14 to 26 MW in size

New Solar Information

Lawrence Berkeley National Lab and National Renewable Energy Laboratory have new reports on Solar PV Costs http://emp.lbl.gov/reports

A few interesting tidbits:

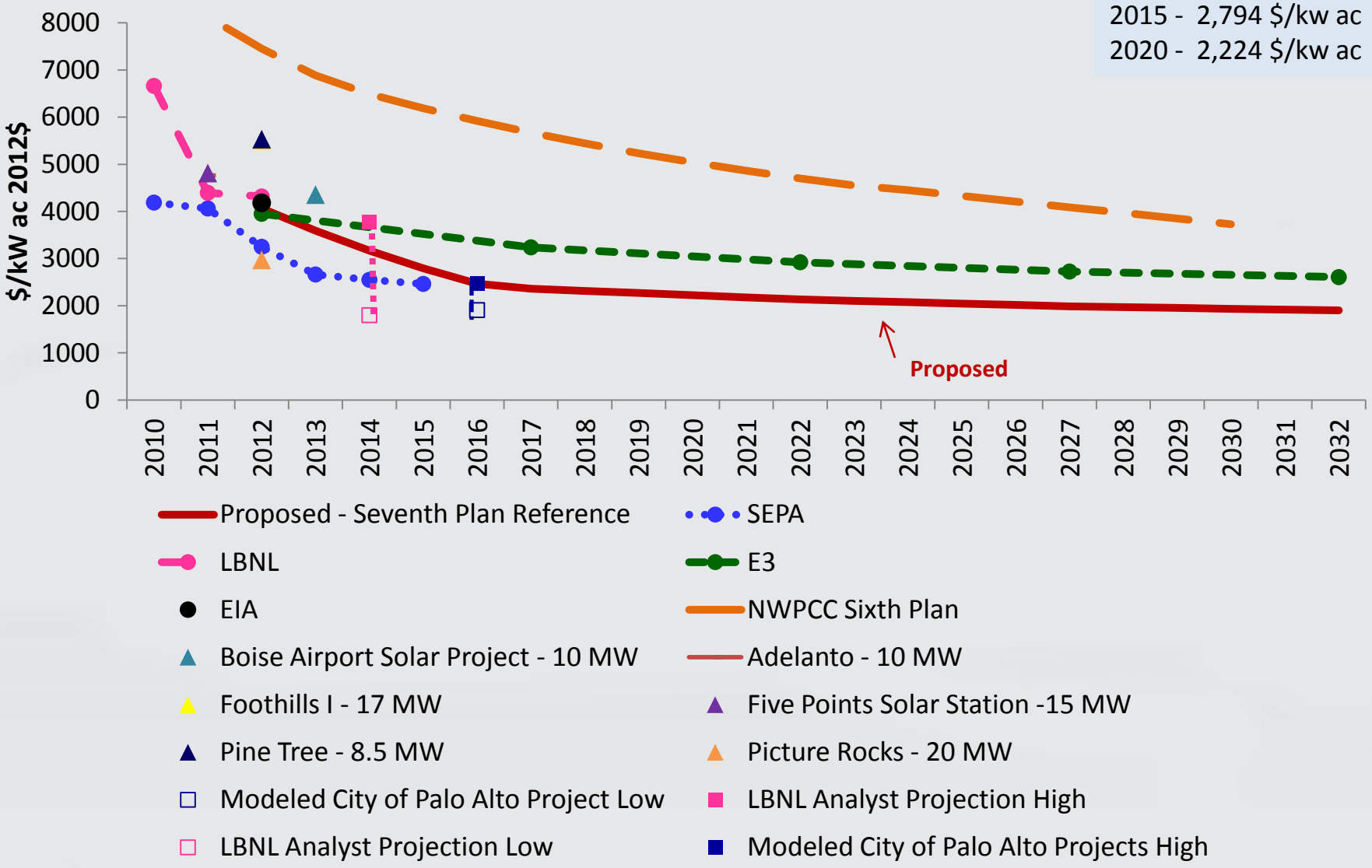
- Crystalline Silicon systems converging with Thin Film Systems in terms of cost
- Large variation in project costs related to system configuration, size, geographic location
- O&M is estimated to be between $20/kW year and $40/kW year

New Capital Cost Estimate for Solar PV Reference Plant

- Same reference plant as before
  - 20 MW Crystalline Single Axis Tracker
- For 2012 starting point – used data from reports EIA, E3, LBNL and SEPA
- Calculated a capital cost estimate for the Palo Alto PPA projects for 2016 – ranged from 1,908 to 2,460 in $/kWac ($2012)
- Ran a forward curve through the high case and followed E3 learning curve estimate
- Land size of a typical 20MW installation?

Solar PV Utility Scale
Capital Cost Estimates & Projections ($/kW ac - 2012 $)

Estimates & Projections
2012 - 4,066 $/kw ac
2015 - 2,794 $/kw ac
2020 - 2,224 $/kw ac



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Cost Estimate for Solar PV Reference Plant

- 20 MW Crystalline Single Axis Tracker – with overnight capital costs ($/kW ac) of
  - 4066 $/kW in 2012
  - 2794 $/kW in 2015
  - 2224 $/kW in 2020
  - 1936 $/kW in 2030
- O&M from EIA – 27.75 $/kW-year and de-escalating following capital cost curve
- Integration cost 1.15 $/MW-hr based on BPA 2012/13 rate case
- Land size of a typical 20MW installation?

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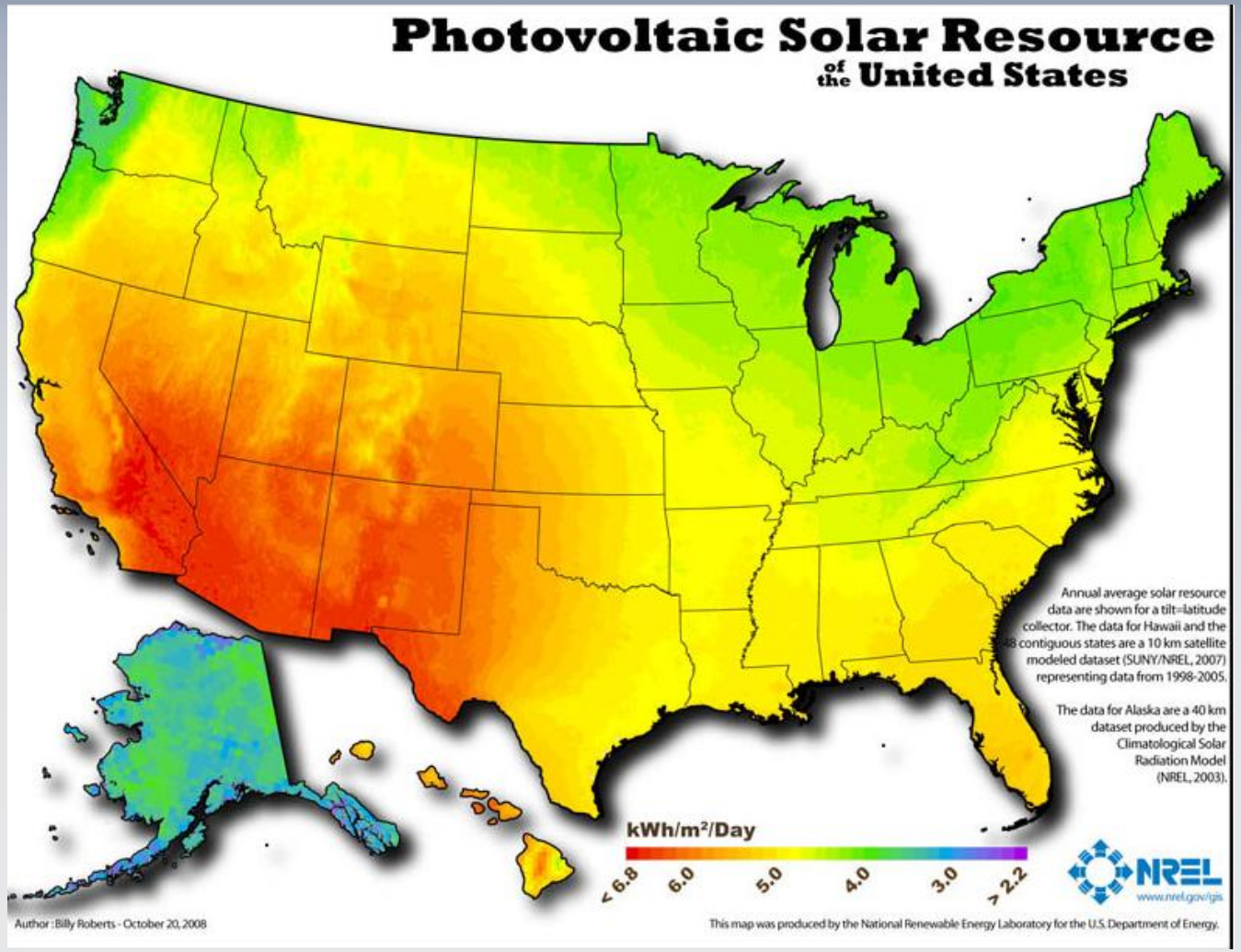
Performance Updates



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Since the last GRAC meeting…

- Defined Council's approach to solar capacity factor
- Updated capacity factors for single-axis tracker 20MW AC project for 16 sites
- Added capacity factors for fixed-axis 20MW AC project for 16 sites

Configuration Trends

LBNL released a report* on cost, performance, and price trends of utility scale solar (Sept 2013)

- Trackers generally yield a higher capacity factor than fixed-tilt (20% increase typical)
- Majority of trackers are single axis vs. dual axis
  - ~10% increase in generation in a dual-axis system is often outweighed by the incremental cost

* Utility-Scale Solar 2012: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States (LBNL)

Capacity Factor - Council

There are different ways to define a capacity factor for a solar plant – here is the Council's approach:

Capacity Factor = Annual generation (kWh AC) ÷ System Rating (kw AC) ÷ 8,760 (hrs/yr)

- AC – AC (Easier to compare against other resources)
- Average over lifetime of plant (includes 0.5% annual degradation and 25-yr life)

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Modeling Assumptions - 1

NREL System Advisor Model (SAM), version 2013.1.15	
Technology:	Solar PV (PVWatts system model)
Location:	WECC Load Resource Areas (16)
Nameplate Capacity:	20 MWac (25,974 kWdc)
DC to AC Derate Factor*:	0.77
Configuration:	**Single-axis tracking**, forced tilt at latitude
Cells:	Crystalline silicon
Performance Adjustment:	100% of annual output (no shading); 0.5% year-to-year decline
Plant life:	25 years
Weather data:	Typical/representative of long-term averages; not one full historical year, but a year comprised of 12 typical historical months (non-cumulative)

* Includes all component derate factors, i.e. inverter, transformer, system availability, etc.

Utility-Scale Solar PV Performance **(Single-Axis Tracking System)**

Location	Load Resource Area	Capacity Factor (AC-AC rating basis)
Burns, OR	**E. WA/OR (1)**	**24.24%**
Fresno, CA	N. CA (2)	26.80%
Daggett, CA	S. CA (3)	32.18%
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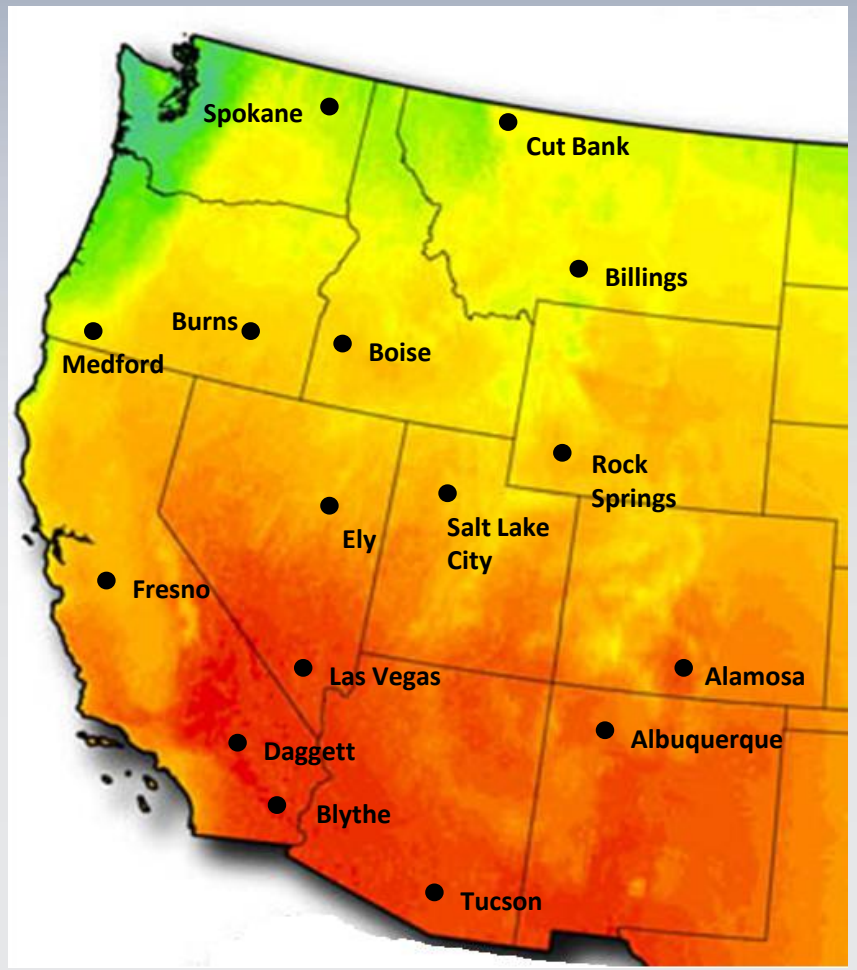
Medford, OR	**W. WA/OR**	**22.86%**



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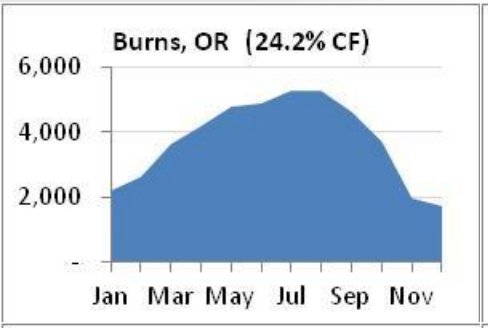
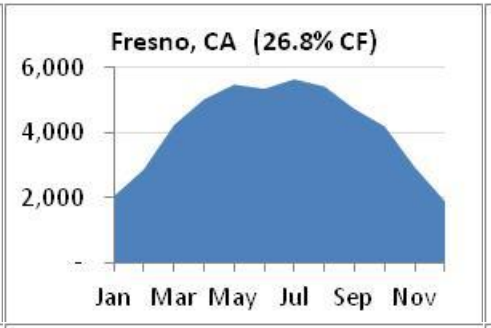
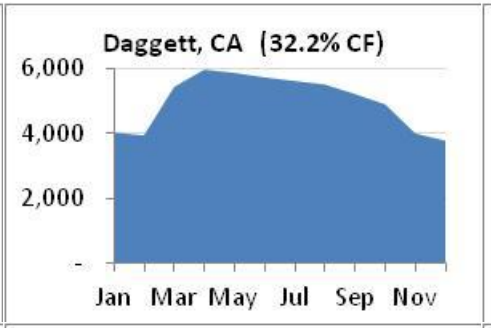
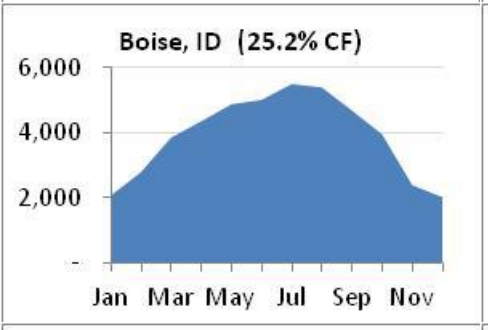
Single-Axis Tracker: Monthly Annual Energy (MWh)

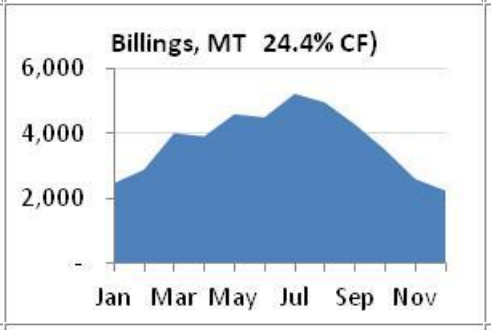
(First year output, each year thereafter degrades 0.5%)

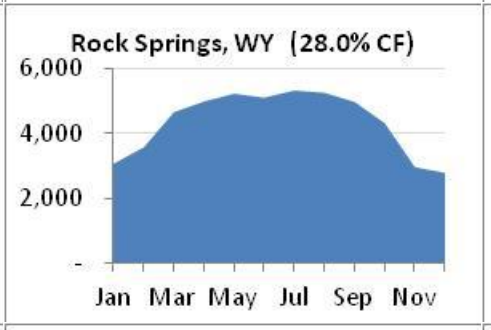


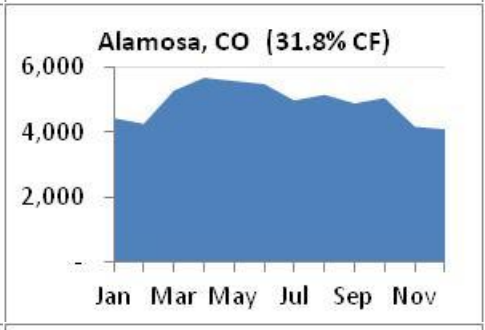


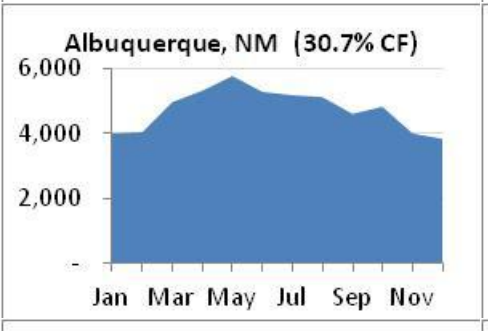


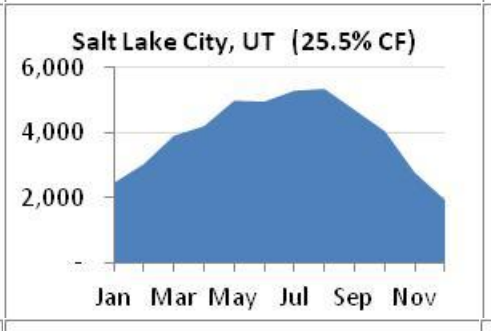


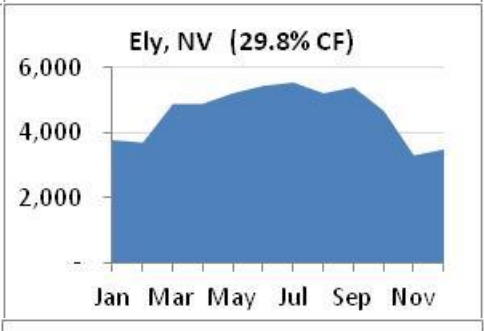


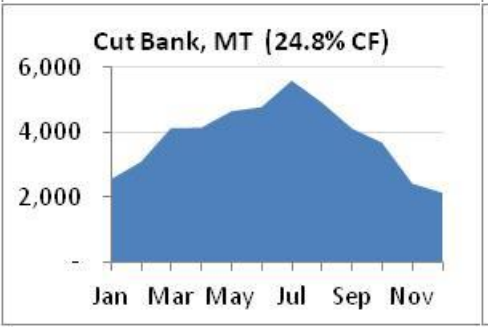


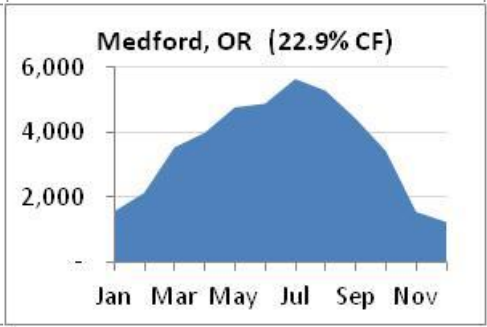












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Utility-Scale Solar PV Performance **(Fixed-Axis System)**

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Daggett, CA	S. CA (3)	23.8%
Spokane, WA	**BC (4)**	**16.5%**
Boise, ID	**S. ID (5)**	**19.1%**
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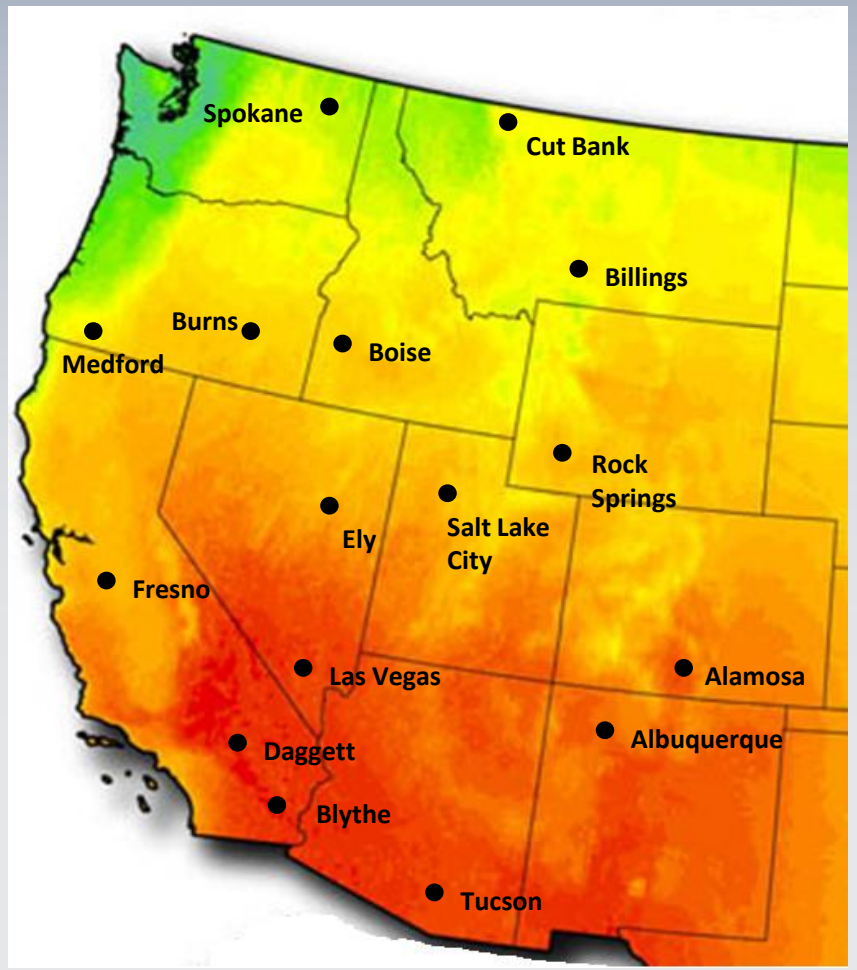
Medford, OR	**W. WA/OR**	**17.5%**



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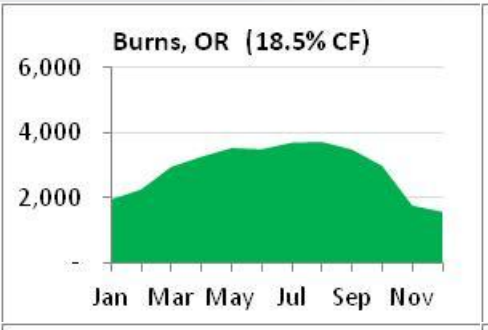
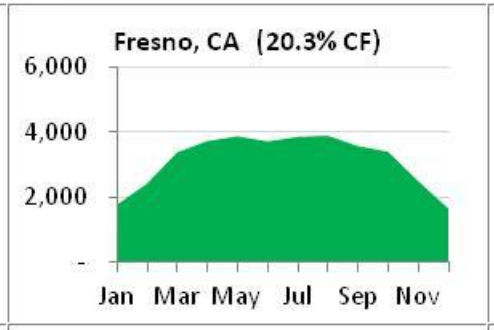
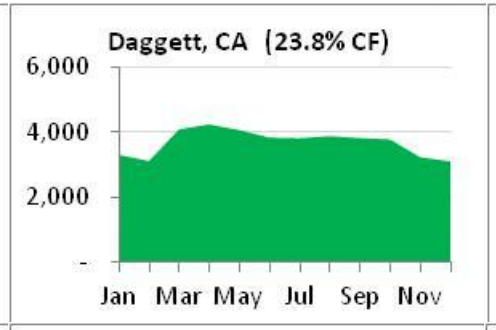
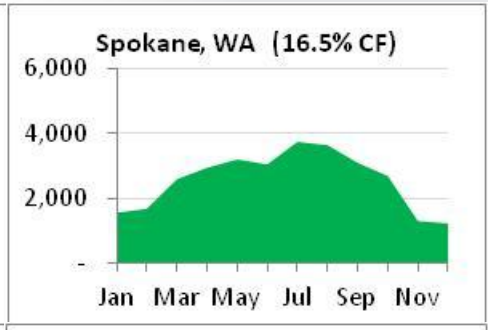
Fixed-Axis: Monthly Annual Energy (MWh)

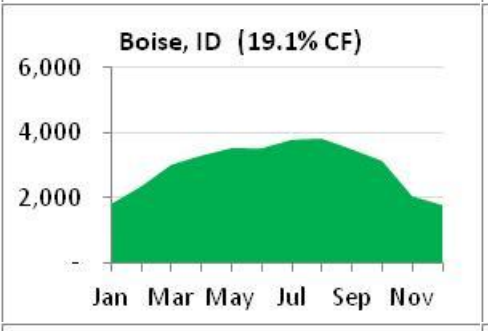
(First year output, each year thereafter degrades 0.5%)

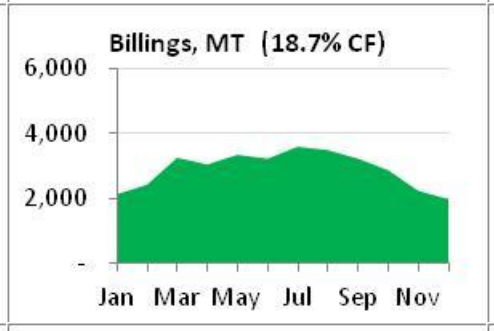


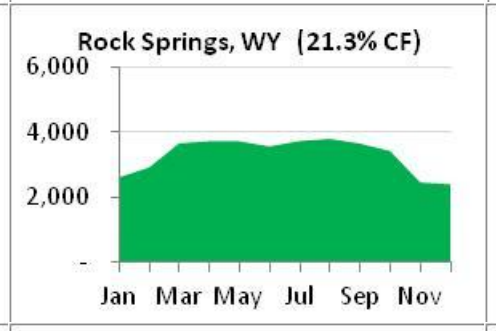


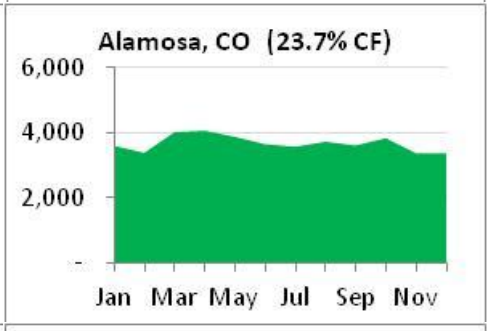


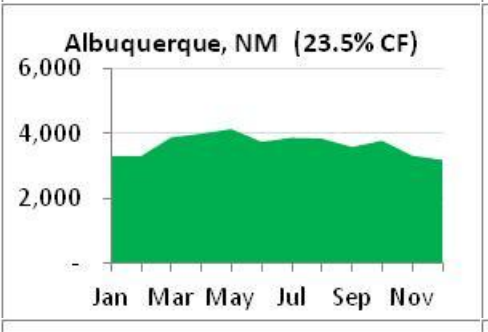


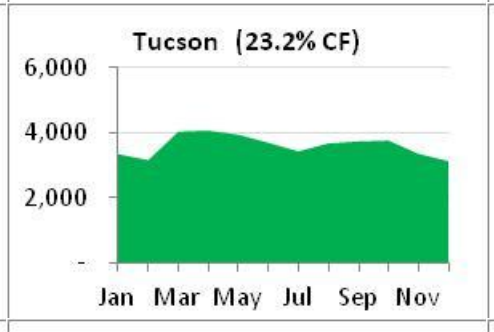


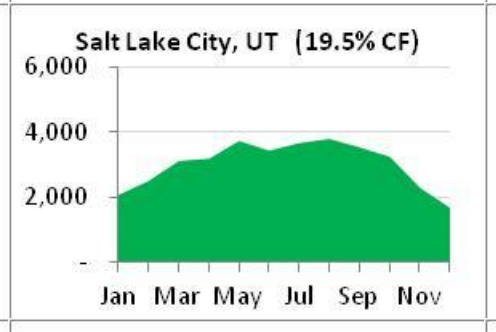


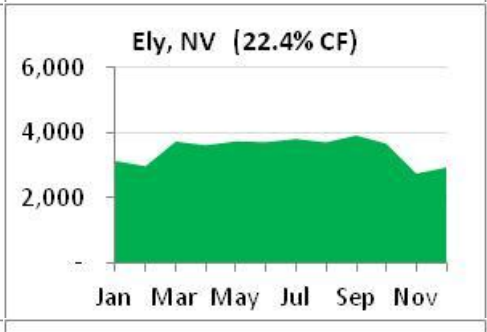


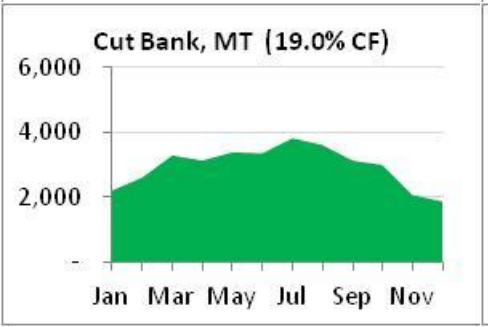


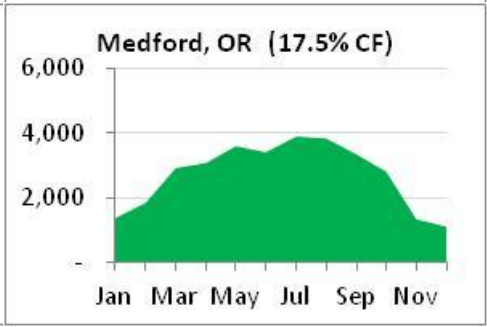












Single-Axis Tracker vs. Fixed-Axis

Location	Load Resource Area	Single-Axis Tracker CF	Fixed-Axis CF
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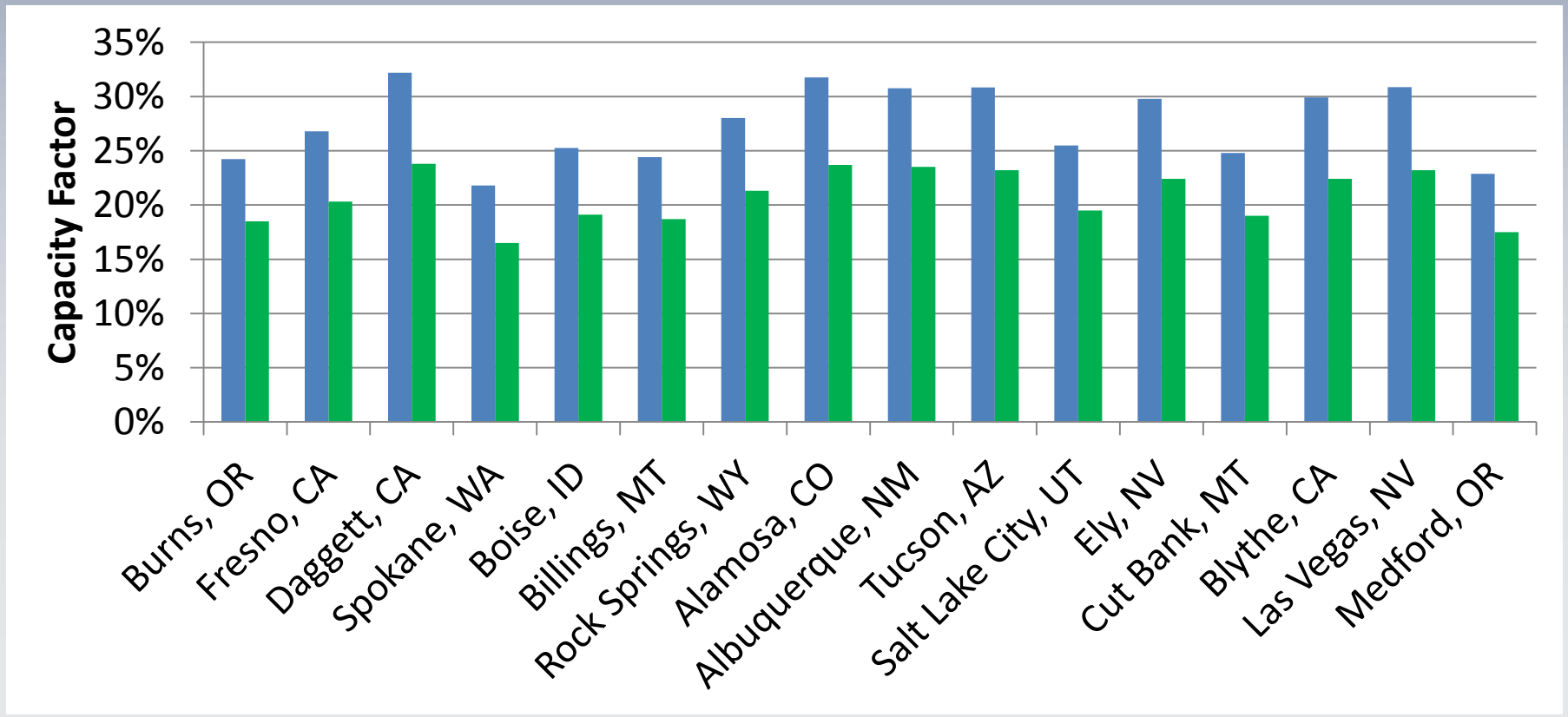
Single-Axis Tracker vs. Fixed-Axis



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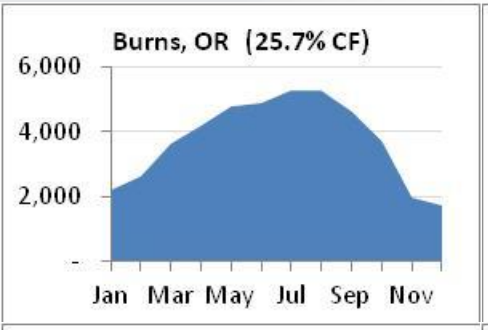

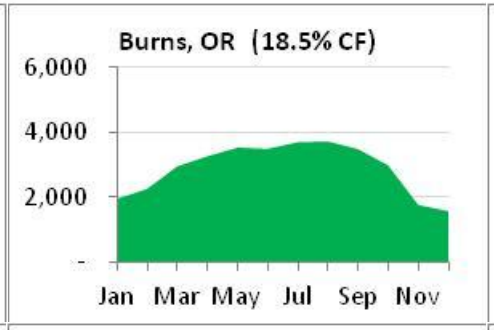

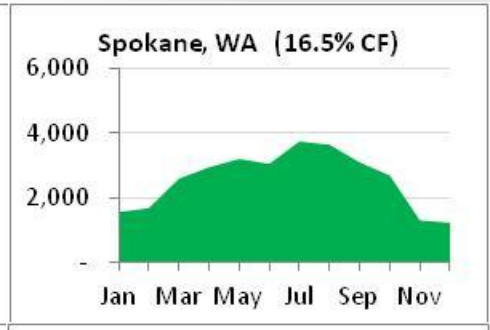

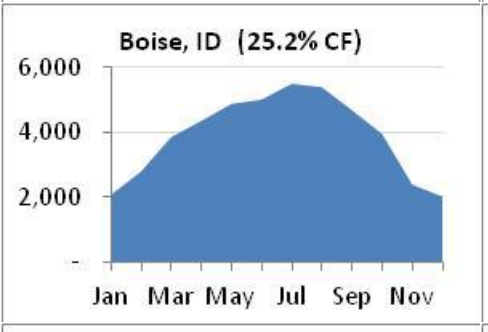

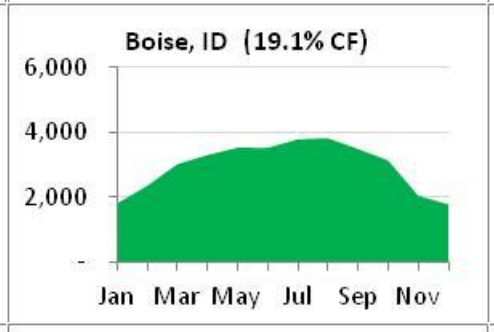

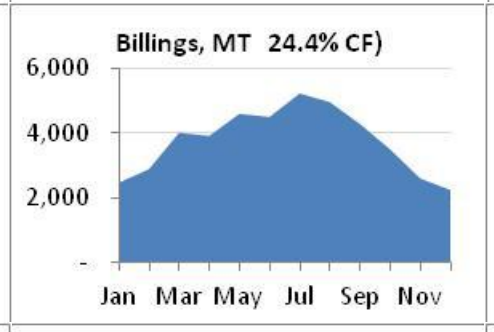

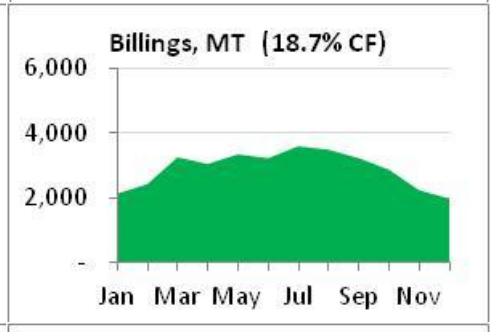

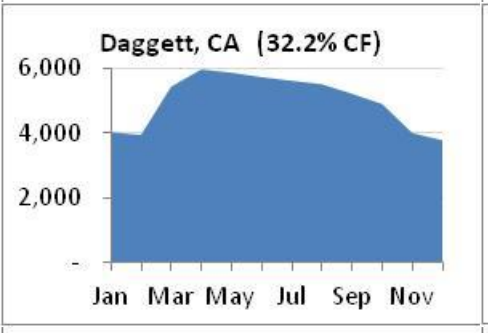

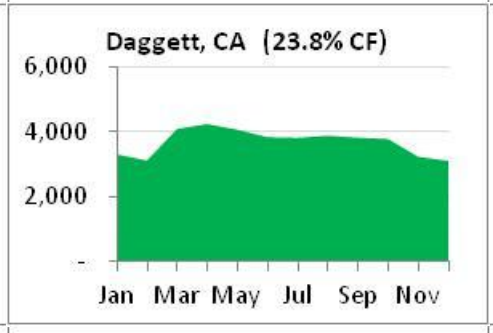

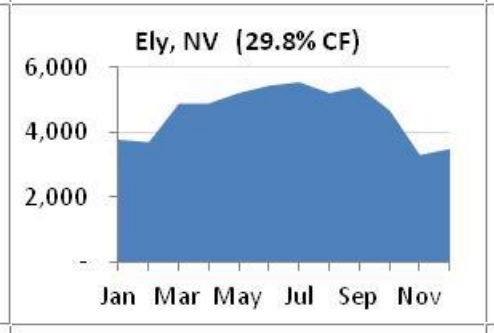

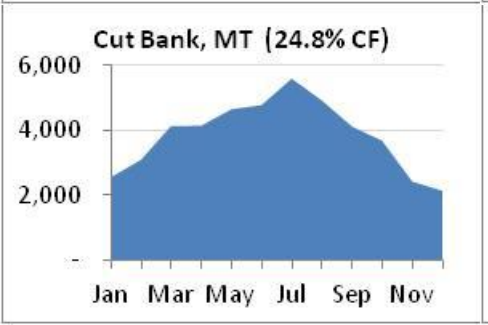

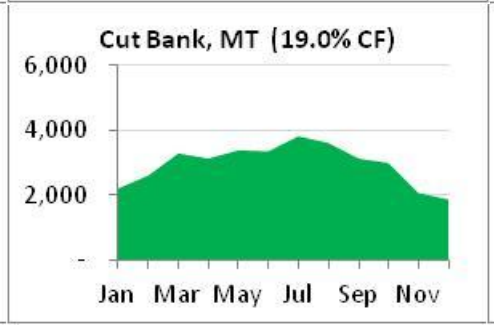

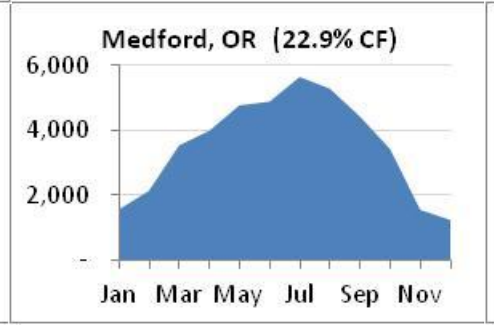

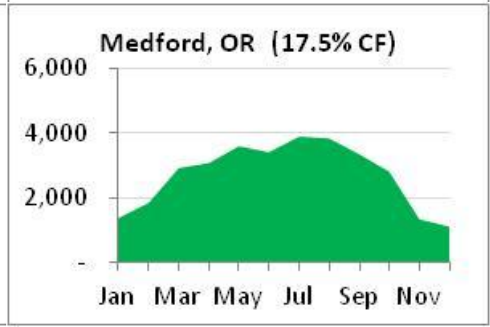

Solar Energy Industries Association (SEIA)