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Solar Plan for Oregon

A Planning Scenario

How to Build a Large, Low-Cost Solar Resource,
Reduce Greenhouse Gas Pollution, and
Cut the Cost of Oregon's Electric Utility System

Produced by
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Introduction Solar energy can be used to substantially reduce greenhouse gas (GHG) emissions, while also reducing the cost of Oregon's electric utility system and producing other benefits.

To meet Oregon's commitments to reduce GHG emissions we need to burn less coal and natural gas to produce electricity. The state's electric utility system needs to be about 80% based on renewable energy. This electric utility "de-carbonization" will require substantial investments in new zero-carbon energy technology.

This *Solar Plan for Oregon* is a *scenario*[1] in which 20 percent of Oregon electricity would eventually be produced by solar energy. We would invest about $10 billion in solar photovoltaic (PV) generation capacity over the period 2015-2030. Half would be built on buildings as distributed PV (DPV) and half on land as utility-scale power plants (UPV). The economic results of this scenario are summarized here.

Table 1: Summary Costs and Benefits of a 20 Percent Solar Scenario in Oregon.
Benefits based on Portland General Electric (PGE) and PacifiCorp (PAC) Avoided Cost Rates.

Cost and Benefit Results in 2012 $ (Billions)		
Life Cycle Costs		
Distributed PV on Buildings		$3.87
Willamette Valley Utility Scale		$1.74
Sunny Oregon Utility Scale		$1.41
	Total Cost	$7.02
Benefits (Based on 2013 PGE & PAC Avoided Cost Rates)		
Distributed PV on Buildings		$4.21
Willamette Valley Utility Scale		$2.58
Sunny Oregon Utility Scale		$2.07
	Total Benefit	$8.86
Net Present Value in 2012 $ (Billions)		$1.84

Greenhouse gas pollution reduction The *Solar Plan for Oregon* would reduce greenhouse gas emissions by 108 million tons over the life of the solar installations. Other pollution caused by fossil fuel power plants would also be reduced. The cost of this carbon and other pollution reduction is negative – it is better than free.

Share the benefits A large-scale solar program can produce these and other net economic benefits for Oregon. The role of regulators and policy makers can then become that of allocating benefits among utility customers and shareholders, rather than allocating costs.

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[1] The term "scenario" describes a planning model used to evaluate a possible future state of the electric system. It is driven by many assumptions, is not a hard and fast proposal, nor is it optimized for many variables. If you, or your organization, have an interest in helping to frame, evaluate and potentially support the continuing development of this scenario, please contact Chris Robertson.

Solar energy is now low cost

> *"…[A]wareness of the current economics of solar power lags among many commentators, policy makers, energy users and even utilities… The challenge is to elegantly transition PV from a highly promising and previously expensive option, to a highly competitive player in electricity industries around the world."*[2]

Over the past three years the solar energy market has fundamentally changed. Costs of solar technology have fallen faster than nearly anyone expected. Low cost solar electricity is now realistic. It provides important opportunities for innovation in public policy and in business models about how to reduce GHG emissions.

Many questions will arise as policy makers, companies, consumers and interest groups understand the new solar cost picture. One thing is certain though; low cost solar energy will disrupt our thinking about what is possible.

Disruptive challenge and opportunity Low cost solar energy will be a highly disruptive technology for the electric utility industry. Experience in many other industries shows that companies can be fatally damaged if their leaders fail to innovate and manage an appropriate strategy in the face of such disruption in their business models. Oregon cannot afford to have disruption on that scale in the electric utility industry. It is incumbent on leaders in the state to recognize the danger and opportunity, and help chart a course that can produce winning outcomes for all.

Table 1, above, summarized some of the economic costs and the benefits of a large-scale solar program in Oregon, which on balance would reduce the net present value of the electric utility system by about $2 billion and improve the economic welfare of consumers. This scenario can also produce opportunities for utilities to increase their capital investments and shareholder earnings. Shareholder and consumer interests will need to be balanced. Stakeholder collaboration and effective policy-making will be required.

Other benefits and costs A long boom in solar power plant construction can produce lots of other benefits for Oregon's economy, all at a profit. Low cost solar energy would help to reduce carbon emissions, bridge political divides, reduce imports of purchased fuels from other regions, stabilize energy prices for consumers, hedge the effects of low hydro flows, and provide the opportunity, if needed, for increased returns to electric utility shareholders.

Growth in solar construction would stimulate manufacturing and construction employment, and advance economic development in both urban and rural Oregon. State income tax revenue would increase. A new tax base for Oregon's rural counties would grow as solar power plant construction grows.

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[2] Morgan Bazilian, Ijeoma Onyeji, Michael Liebreich, Ian MacGill, Jennifer Chase, Jigar Shah, Dolf Gielen, Doug Arent, Doug Landfear, and Shi Zhengrong. *Re-considering the Economics of Photovoltaic Power*, Bloomberg New Energy Finance, 2012

A big Oregon solar market can help to grow Oregon businesses. Oregon companies can make all of the technology parts and pieces necessary to build out large-scale solar resources. Competition from China and other factors have driven down solar manufacturing costs. The result is that companies like Solarworld are now competitive in world markets, and could easily sell into a growing Oregon market.

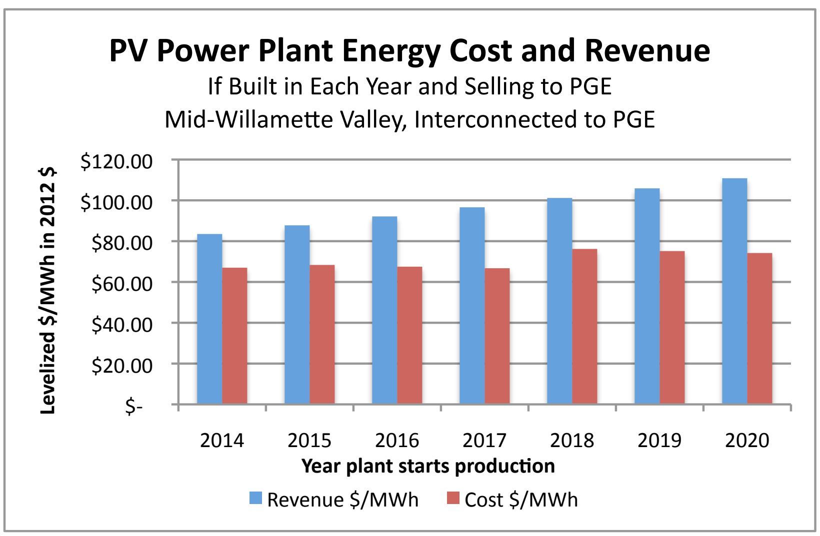
Twenty percent solar by 2030 This *Solar Plan for Oregon* is a *scenario* in which eventually 20 percent of Oregon electricity could be produced from solar power over the period 2015-2030. The solar resource would be built on buildings and in the built environment (distributed photovoltaic, or DPV) and on land as large utility-scale PV solar power plants (UPV).

The primary design goals in this *scenario* were:

- To eventually produce 20% of Oregon's annual electricity – about 9 million MWh per year – from solar resources built over the period 2015-2030
- Half the energy production from DPV systems on buildings
- Half from UPV power plants
- Net cost reduction for the electric utility system

Here is an example of how energy delivered by new utility-scale solar power plants can be cost-effective. Figure 1 illustrates the economics of utility scale solar power plants built in each of the years 2014 – 2020, interconnected to PGE and located in the mid-Willamette valley. The revenue from energy sales to the utility, based on PGE's Avoided Cost Rate Schedule, exceeds the cost of production. Other potential revenue streams are not included, though they could make a material difference in this example.[3]

Figure 1: Economics of Utility Scale PV Power Plants in Mid-Willamette Valley



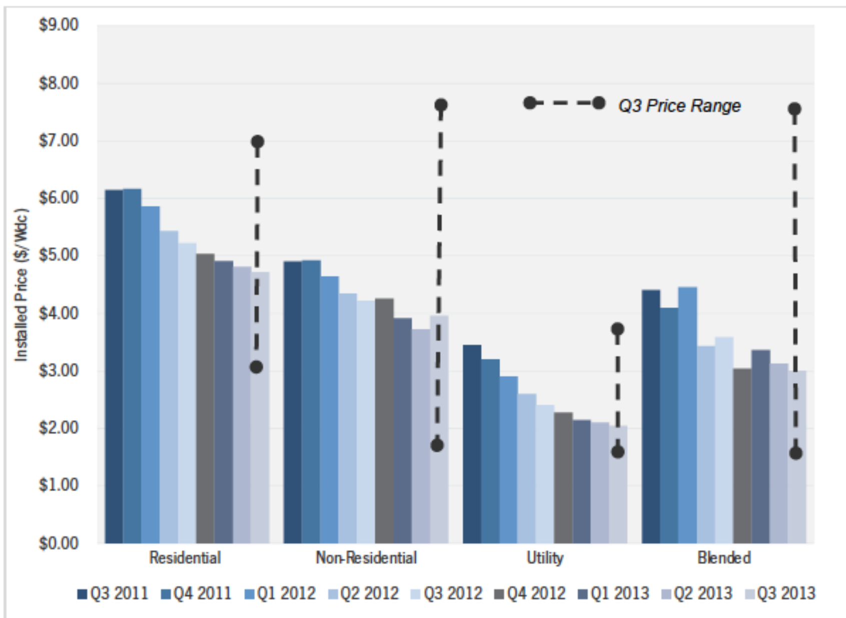
[3] Figure 1 is from the Oregon Solar Energy Industries Association's April 2013 *Vision to Integrate Solar in Oregon* (VISOR), authored by Chris Robertson. This *Solar Plan for Oregon* builds on the VISOR market research and economic analysis. The VISOR Appendix contains details of the economic analysis used to produce this figure. Access VISOR at chrisrobertsonassociates.com

System prices Future installed prices in the solar market are a major input to this scenario. Year-by-year installed prices have been falling, and are expected to continue to fall, driven by both government and industry R&D. This section explains the data and reasoning used to build an Oregon installed price vector for each market segment for the period 2015-2030.

The following figure[4] presents a two-year history of the quarter-by-quarter installed prices for PV systems in the residential, non-residential and utility-scale markets. Also presented is the price range for each sector in Q3-2013. These prices are all-in, prior to any incentive payments. Notice the very large range in prices in each sector.

Figure 2: Average Installed Price by Market Segment, $/Watt Q3-2011 through Q3-2013

Figure 2.8 Average Installed Price by Market Segment. Q3 2011-Q3 2013



In Q3-2013 the average and low prices ($/Watt) for PV systems installed in each sector were as follows. (Average price reported in the GTM/SEIA text; low prices estimated from the chart.)

Table 2: US Installed Prices Q3-2013 $/Watt

	Average	Low
Residential	$4.72	$3.00
Non-Residential	$3.96	$1.85
Utility-scale	$2.04	$1.80

[4] *US Solar Market Insight,* Q3-2013, published by the Solar Energy Industries Association and Greentech Media

The US Department of Energy's SunShot Initiative has established price targets for each market sector for the year 2020. Many industry observers believe that these goals will not be achieved by 2020. Nevertheless, DOE and the industry are working on a long list of cost reducing methods in design, engineering, materials, manufacturing, supply chain management, finance, installation, permitting, interconnection, asset management, operations, maintenance, and others.

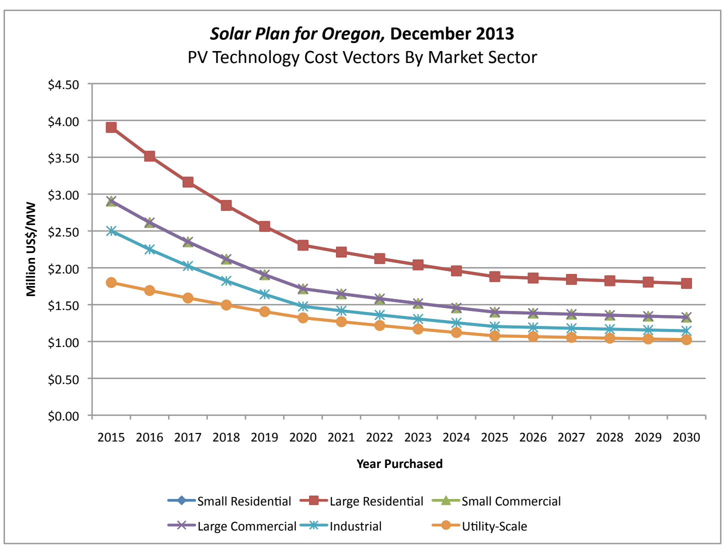
For the purpose of this scenario we assume that the DOE SunShot price targets will not be achieved. We use a factor of 1.4 to adjust the DOE goals for the year 2020, as follows. Table 3 also presents the 2020 prices used in this scenario.

Table 3: US DOE SunShot Initiative's 2020 Price Goals and Adjusted Goals ($/Watt)

	DOE Goal	Miss DOE Goal by Factor 1.4	Oregon Solar Scenario 2020
Residential	$1.50	$2.10	$2.31
Non-Residential	$1.25	$1.75	$1.72
Industrial	--	--	$1.48
Utility-scale	$1.00	$1.40	$1.32

Figure three presents the installed PV system price vectors developed for this scenario, for the residential, commercial, industrial and utility-scale segments (Small and large residential and small and large commercial segments happen to use the same numbers, which can be adjusted, so the small residential and small commercial price curves are masked by the large residential and commercial curves.)

Figure 3: PV Technology Cost Vectors by Market Segment



Prices are assumed to start in 2015 at the mid-point between the average and low prices in the US market in Q3-2013. Prices decline in the utility-scale segment by 6% per year through 2020, and in the other segments prices decline by 10% per year. These price decline rates are broadly in line with recent national market experience. Prices decline in the period 2021-2025 by 4% per year in all segments. From 2026-2030 prices decline 1% per year.

These PV price vectors are assuredly not “correct” and can be expected to vary up or down. The assumptions used to produce these vectors are broadly consistent with national market experience, and may be conservative.

In Oregon, these prices are controversial in some segments of the solar industry. The prices depend to a great extent on how fast and effectively we reduce market barriers and how fast we scale the market up so contractors can reduce unit costs. If we do not do that well, then the pricing in this scenario, particularly for the DPV resources, could be too aggressive.

Construction program schedule The design goal for this construction schedule is eventually to produce 20 percent of Oregon electricity annually from solar resources, half each from UPV and DPV resources. Table 4 presents the MWh per MW per year for distributed and utility-scale solar resources. The DPV resource is a population weighted average using fixed tilt arrays on buildings. Utility-scale power plants would use horizontal single axis tracking technology. Their production numbers reflect the difference in sunshine the Willamette Valley and sunny Oregon.

Table 4: Energy Production from various systems, MWh/MW-yr

Distributed PV, population weighted average	1184
Utility-Scale, sunny Oregon	1691
Utility-Scale, Willamette Valley	1392

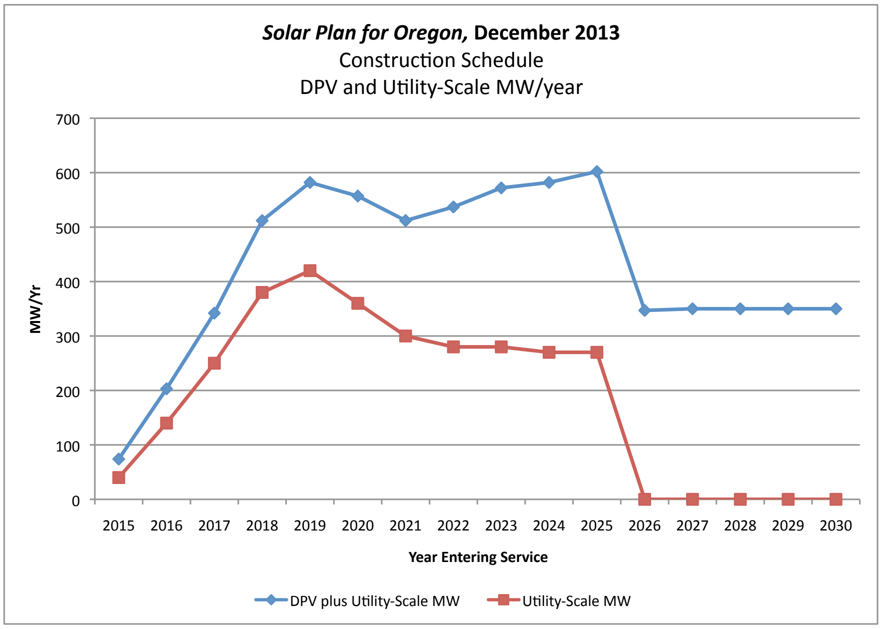
Based on these production numbers, to achieve the 20 percent energy goal would require the following MW for each segment:

Table 5: MW required for each market segment to meet 20% energy by 2030 goal.

Market Segment	MW
Utility-Scale, sunny Oregon	1341
Utility Scale, Willamette Valley	1641
Distributed PV	3857
Total	6848

Figure 4 models the annual solar construction for both utility-scale and DPV resources. The utility scale resource is shown in red and the DPV resource in blue. Note that the utility scale resource is front-loaded in this scenario. This enables the average installed cost to be reduced in the near term, while giving the DPV segment contractors time to get to economies of scale.

Figure 4: Integrated Construction Schedule for DPV and UPV MW/year



With the cost vectors from Figure 3 and the construction schedule from Figure 4, the average solar resource capital cost $/MW can be computed.

Figure 5: Year-by-Year Installed Costs $/MW for DPV, UPV and Average

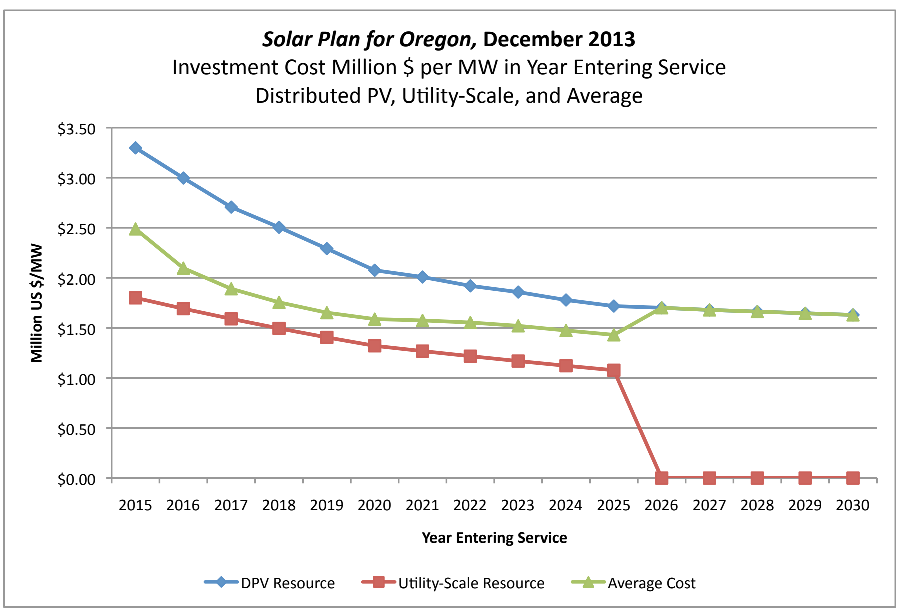
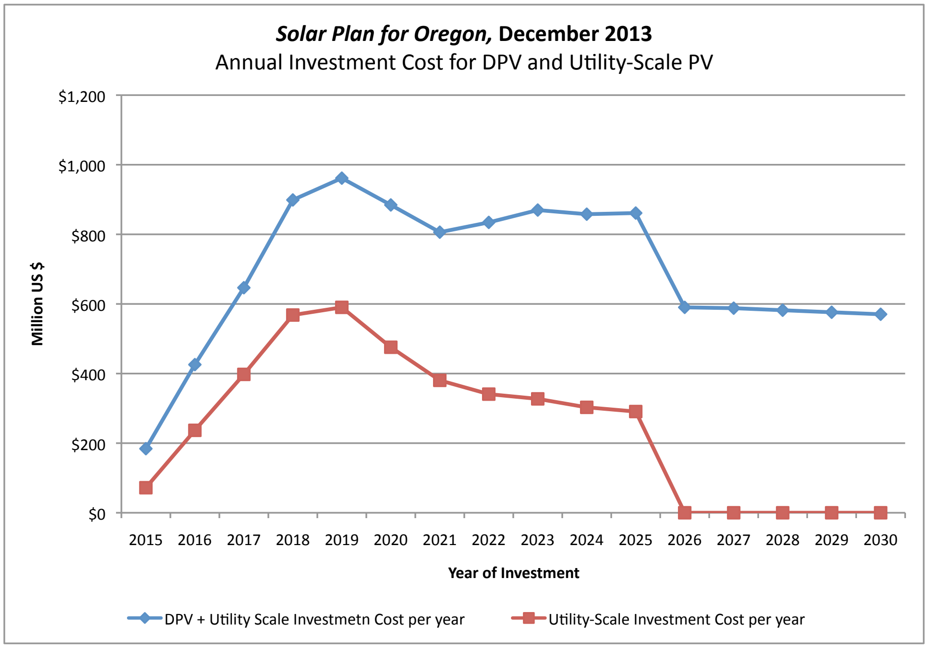


Figure six presents the annual investments necessary to build the resource construction schedule. These are obviously very large numbers. How to mobilize the investment flows will be a significant design issue.

Figure 6: Annual Investments Required for the Construction Schedule in Figure Three.



Principles on which to build the *Solar Plan for Oregon*

1. Set a long-term solar resource acquisition goal, and a schedule that has defined annual production commitments. Include both UPV power plants and DPV on buildings.

2. Seek to produce economic savings in net present value for the electric utility system and its customers. The aggregated solar resource should be able to produce energy at lower net present value than the 2013 electric utility avoided cost rates. Recognize that future utility avoided cost rates will fluctuate up and down due to energy market interactions. Define the solar resources as least cost and least risk as long as they are meeting their price and performance objectives against 2013 avoided cost rates.

3. Establish a Feed-In-Tariff mechanism to pay for the energy (MWh) produced by solar systems. Price to be paid for solar energy production covers debt service, operating expenses and a bond-like return on investment. Capital cost of systems must enable efficient contractors to profit and grow. Pay enough, but don't overpay. Follow the proven principles from the German Feed-In-Tariff regime – transparency, longevity and certainty.

4. The solar energy MWh will be bought by the utility as energy resources for the grid. Each solar system has a revenue meter that accounts for the energy flowing into the grid. Utility customers will retain their existing electric meter and their energy usage will be billed

separately from the solar energy they produce. "Net metering" is not used for these transactions.

5. The electric utilities will be permitted to own and operate some fraction of the solar energy systems, in addition to the customer and investor owned systems built under the Feed-In-Tariff regime.

6. The utility is responsible for grid investments and improvements that are necessary to enable the solar resource expansion. Similarly, the utility is responsible for identifying and prioritizing circuits and locations where both DPV and utility-scale projects are more or less useful and desirable from a grid perspective. The objective is to seek a balance between minimizing the need for grid investments, and optimizing the solar resource expansion. This information will be frequently updated.

7. Smart inverters and energy storage will be inherent in the solar resource investments. The utility, regulators, industry and interest groups will work to establish the necessary contracting and market mechanisms needed to facilitate the added value these technologies can bring to the grid and to the solar installations.

8. Account for all benefits and costs. Electric utility system costs will change as the solar resource is brought on line. Some costs may increase, for example integration, distribution circuit and substation upgrades, metering and billing systems. Other costs may decline, for example, deferral of distribution circuit upgrades (e.g. for circuits nearing thermal limits on peak that are dominated by gas space heating and air conditioning loads), voltage and frequency control, and others.

9. Utility shareholders could earn a premium return on equity if the utility does an excellent job facilitating the interconnection and growth of the solar resource, and documenting the net savings that are produced. The utilities can also increase their rate base and shareholder earnings through prudent investments in plant and equipment needed to facilitate the solar resource build-out.

10. The cost of solar installations goes down as the amount of solar capacity grows, and as concerted action is taken to reduce market barriers and other "soft" costs associates with solar installation. State and local governments, utilities (public and private), regulators, industry and interest groups must address and solve the market barriers to PV growth in Oregon that have the effect of increasing costs. Absent effective and systematic barrier reduction the solar resource will cost more than necessary, and produce fewer net benefits.

11. The State Treasurer's office should create a debt facility to provide long-term debt financing for PV systems with loans to be serviced by the FIT contracts. Create an incentive interest rate for PV systems made, built, financed and energized in Oregon. Oregon Investment Funds will earn competitive, risk-adjusted interest rates.

12. State government and business leaders should ask the Congressional delegation to press for legislation to enable efficient use of the Investment Tax Credit (ITC) and depreciation (MACRS) tax advantages. Design a business model with the utilities, banks and Treasurer's office to utilize the federal tax benefits as efficiently as possible.

13. Create inverter design standards for Distributed PV to enable systems to "island" in the event of earthquakes or other natural disasters. Distributed energy resources can assist in recovery activities, but only if, in the absence of the grid, they can power critical circuits in the buildings on which they are built.

14. Land devoted to solar farms can *simultaneously* produce energy and grid services, food products, and carbon sequestration in the soil. This should be a design goal for solar systems built on arable lands. For utility scale PV power plants, especially in the Willamette Valley, produce a regulatory regime that can enable agricultural production on lands that are also used for energy production. This work has already been done in Europe, where solar farms and food production occur on the same land.

Conclusion This *Solar Plan for Oregon* describes a *scenario* to produce deep reductions in Oregon's greenhouse emissions by using solar technology on buildings throughout the state, and utility-scale solar power plants on land in rural Oregon.

The term "scenario" describes a planning model with its inputs and assumptions used to evaluate a possible future state of the electric system. The scenario appears to cost-effective and to enable significant benefits for Oregon. However, many potentially contentious details need to be vetted and worked out before this solar scenario can be confidently assumed to be feasible, practical and implementable.

If something like is to be implemented in Oregon, the business model design to accomplish these goals must be carefully crafted. Numerous organizations with interests in the outcome would have to participate in the communication, collaboration, creative problem solving and consensus building process. Leadership at the highest levels in government, business, the solar and electric utility industries, and the advocacy community will be required in order to marshal the resources and process necessary to get to an effective outcome.

Next steps If you, or your organization, have an interest in discussing next steps, or in helping to frame, evaluate and potentially support the continuing development of this scenario, please contact Chris Robertson.

Technical Appendix

In April 2013 the Oregon Solar Energy Industries Association (OSEIA) published its *Vision to Integrate Solar in Oregon* (VISOR), authored by Chris Robertson. The VISOR study may be accessed at chrisrobertsonassociates.com

The VISOR study's economic analysis dealt exclusively with utility-scale PV power plants (UPV). The VISOR report contains a technical appendix that describes in detail the Excel workbook inputs, assumptions and methodology used in the analysis. This appendix supplements the VISOR appendix and the text of this study with the additional assumptions and methodology necessary for others to replicate the analysis.

In brief, the VISOR study defined the parameters required for a UPV PURPA power plant at one MW scale, and explored the economics of building PURPA power plants in Oregon over the period 2014 – 2020. The VISOR workbook calculates a separate analysis for each plant at one MW scale per construction year, for UPV in the Willamette Valley and sunny Oregon.

This study, the *Draft Solar Plan for Oregon*, extends the base VISOR economic analysis to:

- Include Distributed PV systems (DPV) on buildings and in the built environment
- Define a multi-MW, multi-year construction program for both DPV and UPV
- Evaluate the construction program costs against the 2013 PURPA avoided cost rate schedules for Portland General Electric (PGE) and Pacificorp (PAC)

For this study the construction period was extended to 2030. Separate analyses of one MW scale UPV in two locations and DPV (averaged across Oregon counties, see Table A-5 below) were calculated for each year on the 2015-2030 period.

Avoided Costs Avoided cost vectors were developed for the VISOR study for both PGE and PAC. The PGE vector is revised here, based on their proposed revision to PURPA rates contained in their OPUC filing in UM-1610 in 2013. The PAC avoided costs were the rates then in effect in late November 2012. For each, the vector uses 6/7 of the on-peak rate and 1/7 of the off-peak rate, to accommodate the fact that Sunday energy production in any season is considered off-peak. The rates are inflated beyond their cut-off years by 1.7%/y for the PAC rates and 2.6%/y for the PGE rates. PURPA avoided costs rates have been quite volatile, particularly in the near term, though the longer term shapes and magnitudes of the rates are similar.

Figure A-1: PGE Avoided Cost Rate Volatility

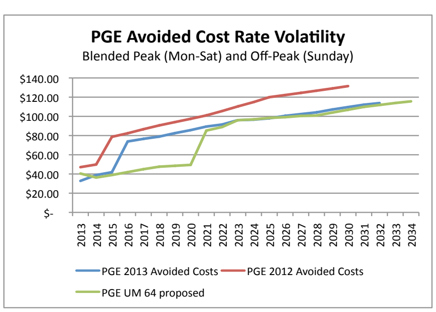


Table A-1 defines the DPV market segments, their fraction of the total market and their unit scale. These are estimates that could be improved with detailed market research.

Table A-1: Market share and unit scale

Distribution of project scale	% of total	Unit scale kW
Smalll Residential 5 kW	15%	5
Large Residential 10 kW	50%	10
Small Commercial 20 kW	22%	20
Large Commercial 500 kW	8%	500
Industrial 1000 kW	5%	1,000
Utility Scale 10000 kW	100%	10,000

Project costs for the period 2015-2030 The market research base for the starting project costs is defined in the text. That discussion is not replicated here.

Learning Rates Once the starting 2015 costs were established then a learning rate was applied to reduce the costs in each subsequent year. The period 2015-2020 learning rate was 90% for DPV and 94% for the UPV projects. In 2021-2025 for each segment the learning rate was 96% and post 2026 the rate was 99%. The cost vectors that result are presented in Table A-2.

Table A-2: Cost vectors 2015-2020

Cost Vectors, $/W	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Smalll Residential 5 kW	$3.91	$3.51	$3.16	$2.85	$2.56	$2.31	$2.21	$2.13	$2.04	$1.96	$1.88	$1.86	$1.84	$1.82	$1.81	$1.79
Large Residential 10 kW	$3.91	$3.51	$3.16	$2.85	$2.56	$2.31	$2.21	$2.13	$2.04	$1.96	$1.88	$1.86	$1.84	$1.82	$1.81	$1.79
Small Commercial 20 kW	$2.91	$2.61	$2.35	$2.12	$1.91	$1.72	$1.65	$1.58	$1.52	$1.46	$1.40	$1.38	$1.37	$1.36	$1.34	$1.33
Large Commercial 500 kW	$2.91	$2.61	$2.35	$2.12	$1.91	$1.72	$1.65	$1.58	$1.52	$1.46	$1.40	$1.38	$1.37	$1.36	$1.34	$1.33
Industrial 1000 kW	$2.50	$2.25	$2.03	$1.82	$1.64	$1.48	$1.42	$1.36	$1.31	$1.25	$1.20	$1.19	$1.18	$1.17	$1.16	$1.14
Utility Scale 10000 kW	$1.80	$1.69	$1.59	$1.50	$1.41	$1.32	$1.27	$1.22	$1.17	$1.12	$1.08	$1.07	$1.06	$1.05	$1.03	$1.02

Asset management, operations and maintenance The DPV analysis directly parallels the VISOR utility scale analysis on these terms. Inverters are replaced at year 15. Asset management costs are included. Property taxes are excluded for DPV systems.

Economic terms Similarly the economic terms used in the VISOR study for UPV are replicated for the DPV resource. These include interest rate, discount rate, capital structure, efficient use of ITC and MACRS. Financing was assumed to last for 20 years as in the VISOR. Whether a business model can be designed to efficiently use the ITC and MACRS is an open question.

PV system lifetime The lifetime assumed for the PV systems is 30 years. While potentially controversially, it is a fact that Solarworld panels are in the field still producing energy more 30 years after being installed. With effective O&M and asset management it is reasonable to consider a 30-year life.

Construction schedule The construction schedule was built up to achieve the design goal of annual solar MWh eventually equaling 20% of Oregon's 2012 electricity sales. The annual construction per market segment is somewhat arbitrary and can be adjusted as parties comment on the scenario. Of special interest is the rate of growth of the DPV segment; does it grow at a rate suitable for contractors to get to economies of scale?

Table A-3: Construction Schedule

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
DPV MW	Annual MW >>>															
Smalll Residential	5	10	15	20	35	45	40	45	45	45	45	45	45	45	45	45
Large Residential	10	20	30	55	65	80	100	120	150	160	180	190	190	190	190	190
Small Commercial	10	15	20	25	30	40	40	60	65	75	75	75	75	75	75	75
Large Commercial	5	10	15	20	20	20	20	20	20	20	20	25	25	25	25	25
Industrial	4	8	12	12	12	12	12	12	12	12	12	12	15	15	15	15
Total Fixed Tilt = 3857 MW Goal	34	63	92	132	162	197	212	257	292	312	332	347	350	350	350	350
Utility Scale MW																
Willammette Valley	20	80	160	220	240	200	160	140	140	140	140	0	0	0	0	0
East side and South	20	60	90	160	180	160	140	140	140	130	130					
Total Utility Scale	40	140	250	380	420	360	300	280	280	270	270	0	0	0	0	0
Total MW DPV + Utility Scale	74	203	342	512	582	557	512	537	572	582	602	347	350	350	350	350

Annual investments The annual investments per segment are the product of the cost vectors times the annual MW in the construction schedule.

Table A-4: Annual investment per segment ($ milllion)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Investment per Market Segment ($ Million)																
Smalll Residential	$20	$35	$47	$57	$90	$104	$89	$96	$92	$88	$85	$84	$83	$82	$81	$80
Large Residential	$39	$70	$95	$157	$167	$184	$221	$255	$306	$313	$338	$354	$350	$347	$343	$340
Small Commercial	$29	$39	$47	$53	$57	$69	$66	$95	$99	$109	$105	$104	$103	$102	$101	$100
Large Commercial	$15	$26	$35	$42	$38	$34	$33	$32	$30	$29	$28	$35	$34	$34	$34	$33
Industrial	$10	$18	$24	$22	$20	$18	$17	$16	$16	$15	$14	$14	$18	$18	$17	$17
Total DPV	$112	$189	$249	$331	$371	$409	$426	$493	$542	$555	$570	$590	$588	$582	$576	$570
Utility Scale projects																
Willammette Valley	$36	$135	$254	$329	$337	$264	$203	$170	$164	$157	$151	$0	$0	$0	$0	$0
East side and South	$36	$102	$143	$239	$253	$211	$178	$170	$164	$146	$140	$0	$0	$0	$0	$0
Total Utility Scale	$72	$237	$398	$568	$590	$476	$380	$341	$327	$303	$291	$0	$0	$0	$0	$0
Total Cost DPV + Utility Scale	$184	$426	$647	$899	$961	$884	$806	$834	$870	$858	$861	$590	$588	$582	$576	$570

DPV energy production PV Watts was used to calculate the energy production form fixed tilt PV arrays that would be typical of DPV installations in 8 Oregon counties. A weighted average energy production was calculated based on the county populations.

Table A-5: DPV Energy Production in Oregon Counties

Fixed Tilt PV Energy Production in Oregon			Weighted
	Population	Oregon County	Average
Oregon Locations in PV Watts	Weight %	MWh/MW-yr	MWh/MW-yr
Jackson	6.79%	1374	93
Marion	10.52%	1187	125
Portland Metro	58.89%	1123	661
Deschutes	5.34%	1474	79
Umatilla	2.53%	1352	34
Lane	11.66%	1178	137
Malheur	1.01%	1477	15
Clatsop	1.23%	1062	13
Coos	2.06%	1302	27
Weighted Average	100.00%	1184	1184

UPV energy production and market share PV energy production depends on sunlight, which varies considerably across Oregon. Using horizontal single axis tracking the energy production numbers are reported in Table A-6. Also included in that table are the total MW assumed to be installed in each area. The share split was designed to get half the UPV energy from each area.

Table A-6 UPV energy production and market share

	MWh/MW	Total MW Assumed
Willamette Valley	1392	1640
Sunny Oregon	1691	1350

Costs and benefits For each plant (DPV, UPV Willamette and UPV Sunny Oregon) in each construction year the total costs and revenues based on PURPA rates were discounted to 2012 dollars. They were then totaled and the results presented in Table 1 of this paper.

Table A-7 (and Table 1 from the text): Costs and benefits in 2012 $ (Billion)

Cost and Benefit Results in 2012 $ (Billions)		
Life Cycle Costs		
Distributed PV on Buildings		$3.87
Willamette Valley Utility Scale		$1.74
Sunny Oregon Utility Scale		$1.41
	Total Cost	$7.02
Benefits (Based on 2013 PGE & PAC Avoided Cost Rates)		
Distributed PV on Buildings		$4.21
Willamette Valley Utility Scale		$2.58
Sunny Oregon Utility Scale		$2.07
	Total Benefit	$8.86
Net Present Value in 2012 $ (Billions)		$1.84