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Planning, Public Policy and Management
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Feasibility and Benefits of Deploying Solar Electric Generation Across Public and Commercial Roof Space in Eugene, Oregon

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Abstract

Many commercial and public buildings have large expanses of roof area that are ideally suited for generating electricity with solar photovoltaics (PV). They are often free of obstructions from the sun, like large trees or other natural barriers and are generally taller than most residential structures that may be nearby. By developing a network of interconnected, small to medium-scale solar PV arrays, we may be able to realize economic, environmental and social benefits that steer Eugene toward a more sustainable energy future by reducing our dependence on costly, non-renewable energy sources. While we certainly will not be able to meet all of our electricity needs through distributed solar PV, we could substantially reduce our dependence on the most detrimental non-renewable resources that we currently rely on and increase our overall renewable energy portfolio.

This research investigates the feasibility and potential economic and environmental benefits derived from deploying distributed generation, solar PV systems on public and commercial rooftops in Eugene, Oregon. GIS software and aerial photographs are used to determine the available under-utilized roof area and locally available solar data are used to estimate the amount of energy it is possible to generate.

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Introduction

There is still debate as to the actual reason why global warming is occurring but one thing is clear – the earth's temperature is rising and human choices have a significant impact on the degree to which it will continue. Whether we consider aerosol gas emissions as the primary culprit, as stated by Hansen, et al (2000) or we address greenhouse gas emissions as the main concern, it is apparent that increased CO_2 levels are an important factor in global warming. One way to decrease CO_2 emissions is by decreasing the amount of fossil fuels we burn to produce energy for our modern society, i.e. coal, uranium or petroleum.

The potential economic impacts of global warming are huge. According to a letter signed by fifty economists in the Pacific Northwest, these impacts will affect many sectors of the economy from power generation to agriculture and forestry to tourism. One of their recommendations to mitigate the adverse impacts of global warming includes adopting "business and job development strategies that capture competitive advantage in the manufacture, use, and export of energy efficiency and renewable energy technologies and other technologies that reduce emissions and enhance adaptation," (Barnes, W.F., et al, 2005, 3).

In Eugene, Oregon, as in communities across the country and the world, there is a vast amount of roof-space on large commercial and public buildings that is underutilized. Of course some of this area is used for the building's heating and cooling infrastructure or occasionally even garden or patio space. More often than not though, this is underutilized space that could be used to generate electricity with installation of solar photovoltaic (PV) arrays. Once installed, solar PV is virtually maintenance free and generates power directly from the sun, a limitless resource for as long as there is life on earth.

Eugene is currently in a 2-year business and job development process called the Sustainable Business Initiative (SBI). Mayor Kitty Piercy initiated the SBI after speaking with many constituents to understand their concerns and ideas about Eugene's quality of life. The purpose of the SBI is to promote Eugene as a 'Center of Excellence' in the emerging field of sustainable business practices and products. Solar PV on public buildings can be an important piece of this economic development puzzle. According to the Solar Energy Industries Association (SEIA), "Every megawatt of solar power currently supports 32 jobs, with 8 of these jobs in system design, distribution, installation, and service created where the systems are installed," (SEIA, 2004, 10). The latter means living wage jobs for local people who can be trained locally through Lane Community College's Energy Management Program.

Large installations of solar PV are beginning to occur in Oregon and throughout the Pacific Northwest. In 2003 Kettle Foods of Salem, Oregon installed a 114 kW PV system at their snack food manufacturing plant. At the time it was the largest solar installation in the Northwest (Interstate Renewable Energy Council, 2003). In 2004 Pepsi Cola of Klamath Falls, Oregon installed a 172 kW PV system consisting of three smaller interconnected arrays that will not only generate all of their electricity needs but should also create a surplus that will feed back into the local utility grid (Energy Trust of Oregon, Inc., 2004).

With the city of Eugene's lead and by promoting collaboration between local government, the Eugene Water & Electric Board (EWEB) and private individuals or business owners, we could accomplish a great deal in the move toward increased energy independence. Through sharing funding and technical information resources, experience, and group purchasing that improves economy of scale we could accomplish more than any one entity could on their own. This would go a long way toward further establishing Eugene as a community committed to sustainable energy resource use, responsible economic development and improving the quality of life for all residents.

What is Solar PV?

Simply put, solar PV is a collection of modules that collect light from the sun and transforms it into electricity. The PV module is the building block of a PV array with individual cells "interconnected and encapsulated between a transparent front, usually glass, and a backing material," (IEA, 53). Connected together in a series, the number of modular panels is varied to produce the desired electrical output. Since public and commercial buildings often have large roofs, the array can be designed to accommodate maximum electricity output compared to simply meeting building requirements. When the building consumes less energy than the PV produces, for example an office building on weekends may consume much less power than when it is full during the workweek, the array will continue to operate and the surplus can then provide power for the rest of the community through the traditional grid network.

Why Promote Solar PV on Public and Commercial Buildings?

There is a great deal of research that indicates the positive benefits that can be realized from installing solar PV. Pimental, et al (1994, 8) state that "Photovoltaic technology offers several environmental advantages in producing electricity compared with fossil fuel technologies. For example, using present photovoltaic technology, carbon dioxide emissions and other pollutants are negligible." More recently the International Energy Agency (IEA, 2003, 62) reaffirmed this by stating that, "Replacing fossil fuel-based electricity generation with PV can yield significant environmental benefits." Shifting away from fossil fuels to produce electricity decreases the harmful impacts associated with coal–both mining and burning, uranium mining and storage and production of greenhouse gasses. Even hydropower, considered a renewable energy source, has detrimental effects on endangered fish species and indigenous cultures. Salmon must get past dams to reach spawning habitat and traditional fishing grounds and other important cultural sites of indigenous peoples are often lost as reservoirs backfill rivers and valleys beyond the dams. While there are some negative impacts from producing solar PV equipment - for example PV module production relies on fossil fuel generated electricity, the IEA further addressed the use of toxic materials in the PV manufacturing process by saying that, "current control technologies appear sufficient to manage wastes and emissions in today's production facilities. Recycling technologies are being developed for cell materials," (IEA, 63).

On the economic side of the equation, both utilities and consumers can benefit from the use of solar PV. Utility companies can reduce the need to invest in distant, centralized energy sources that require extensive and expensive transmission infrastructure to deliver electricity to end-users. Consumers can reduce or eliminate their electric utility bill using a renewable energy that consumes no fuel and equipment that has no moving parts. The IEA (2003, 63) states that, "payback time is much shorter than the 20-30 year expected lifetime of a PV system."

Large-scale deployment of solar PV is beneficial for our environment and provides communities with a stable, secure energy source. Economic and environmental benefits can be realized through a collaborative effort between local government, urban planners, the electric utility and private industry through deployment of a network of solar PV installations across large buildings in a community. Throughout the process, stakeholders gain practical, hands-on knowledge about installing such a large-scale, distributed system while promoting the use of a clean, renewable energy source.

Factors Influencing the Adoption of Solar PV

There are many factors that influence the adoption of new or different technologies than we as a society are used to using – cost, environmental concerns, availability, economics and more. It is important for governments to lead by example through responsible choices when alternatives are available and direct policy that sets a standard. “Policy makers must first have the political will to advance the development and use of these technologies and, second, they must enact policies that are both appropriate and consistent to achieve desired results,” (Sawin, 2002, 12). While there is less that a small- to medium-sized community like Eugene can do to influence technology development on a broad scale, establishing policies that incorporate sound, emerging technology use into their operations sets a standard that others in the community can learn from and incorporate as well. Working together the public and private sector can establish a model creating a synergy that in turn can influence national and global resource use trends.

Current Situation in Eugene

One constraint that arises in Eugene is that buildings in the downtown core cannot feed excess power back to the grid due to technical constraints that demand a more consistent supply of electrical power.[1] For these buildings, excess power could be stored in batteries to be used as an uninterruptible power supply. According to Don Spiek from EWEB this issue is being addressed and the Electrical Engineering division at EWEB is pursuing the design and testing of backfeed protection devices that could be applied to point of use PV applications. It is hoped that this work will be complete by the third quarter of 2006 which may open this territory up for more efficient use of grid-tied solar PV (Spiek email, 2006).

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[1] This includes the area bounded by Mill St to the east, Charnelton St. to the west and 5th Ave. to Olive St.

Review of Available Literature on the Application of Solar Photovoltaic Systems on Public and Commercial Buildings

Overview

In *A Realizable Renewable Energy Future*, Turner (1999, 687) asks the question, "is there a sustainable energy system that can supply a growing population with energy without destroying the environment within which it is used, providing energy for the present without compromising the ability of future generations to meet their needs?" Renewable energy, in its many variations provides a positive answer and one component of this renewable energy portfolio is solar PV.

Solar PV for the purposes of this study, is a distributed energy resource (DER) – a small-scale power generation technology (typically in the 3 to 10,000kW range) that can be harnessed where we need it (e.g. a home or business) that is an alternative to or enhancement of the traditional electric power system (CEC, 2005). No government, corporation or utility company controls energy that we obtain from the sun and it shines freely on everyone. As Hammond & Metz state (1977, 241), "Solar energy is democratic."

In the mid 1970's most of the solar research within the Energy Research and Development Administration focused on very large engineering projects that were meant to fit into the existing utility network, mirroring the path of nuclear reactors and coal generation (Hammond & Metz, 1977). In this light, solar PV would be feasible primarily if it remained far from the end-users and controlled by electricity transmission utilities. Since the focus was on projects that provided a large generating capacity, economies of scale prohibited mass deployment of PV equipment to individual residential or small commercial users. Even today the cost of solar PV remains high by comparison to fossil fuel generated electricity that often doesn't account for the associated environmental degradation. Yet the global market for PV shipments increased by 32% in 2003. "In part, market growth was driven by innovations in both technology and manufacturing that continue to increase efficiency, boost product lifetime and reliability, and make installation easier," (SEIA, 2004, 2).

Since the 1970's, much of the research to effectively deploy solar PV on smaller scales has focused on residential buildings. A middle ground that would improve economies of scale for production while maintaining a decentralized structure for electricity generation is to focus on commercial and public buildings. These structures tend to have much more surface area available than residential units, often in the form of large, under-utilized, flat roofs. When either residential or commercial and public buildings use less energy than their PV systems generate, the surplus can be fed back into our existing grid network. This surplus then provides power to users who may wish to pursue Green Pricing – "an optional utility service that enables customers of traditional utilities to support a greater level of utility investment in renewable energy by paying a premium on their electric bill to cover any above-market costs of acquiring renewable energy resources," (U.S. E.P.A., 2005). According to the International Energy Agency (IEA), "Building stock in industrialized [sic] countries offers enough suitable surfaces for PV to generate between 15% and 50% of current electricity consumption" (IEA, 2003, 68).

Barriers to Using Solar PV

Solar PV is a very promising tool in the renewable energy portfolio, but it does not come without its drawbacks. One issue that became apparent in the 1980's was the use of toxic heavy metals used in the production of solar cells, particularly calcium sulfide and gallium arsenide. "Because these chemicals are highly toxic and persist in the environment for centuries, disposal of inoperative cells could become a major environmental problem," (Pimental, D, et al, 1994, 8). Producing PV cells from silicon is one way to mitigate this problem while also reducing the cost of the modules.

Another problem is that solar PV and most other renewable energy technologies provide intermittent sources of power. The 2003 IEA report states that, "When renewables provide too much or not enough power, the reliability of the grid is affected," (IEA, 22). Intermittent fluctuations provided by renewables due to weather changes or the fact that the sun doesn't shine at night can upset the balance between supply and demand that utilities must closely match. Fortunately according to the IEA, solar PV will probably enter the utility market in a smaller distributed form and since "most of the energy will be consumed onsite, the problems for utilities to balance grid energy flows are likely to be manageable until very high levels of penetration are seen," (IEA, 23).

Benefits of Solar PV

While there are barriers that have contributed to solar being a less practical energy source, especially in times of at least perceived, inexpensive fossil fuel costs, in today's changing environmental outlook solar takes on a new importance. Some of the primary benefits of solar PV include:

- it is a Distributed Energy Resource (DER) that mitigates large-scale power outages;
- it has few moving parts, consumes no fuel and is a reliable source of energy;
- reduces our dependence on foreign sources of energy;
- can be deployed in a wide range of applications; and
- conserves billions of gallons of water per year that is diverted from the cleaning and processing of coal as a non-renewable energy resource (EERE, 2004).

Anderson (1996) adds that PV benefits include: modularity – increase capacity by increasing the number of connected arrays; short lead times – installation often takes months compared to years for large fossil fuel based production facilities; and low land requirements, especially important to developing countries whose available non-agricultural land mass is at a premium.

Deploying solar PV across commercial roof space can also be an income producer for a business. In Klamath Falls, Oregon, Pepsi Cola recently installed a 172 kW array that actually spans three locations, separated by as much as 70 miles. The Bocchi family that owns the business "estimates that Pepsi will export about 50,000 kilowatt-hours of electricity per year after satisfying its own internal loads," (Energy Trust of Oregon, Inc., 2004). Not only should they eliminate their electric utility bill, they will receive income from the surplus power they sell to the utility.

The benefits of solar PV can work for both sides of the electric grid, consumers as we've seen above and utility companies. PV as a distributed resource has multiple benefits for utility companies. Kroposki and DeBlasio (2000, 2) state that it can "shave peak demands on the utility grid" – electricity demand is highest when the sun is at its brightest and PV generates the most electricity; and "PV systems can also improve asset utilization by reducing required capital generation spending and delaying some equipment replacement," (2000, 2).

Improving Cost Effectiveness of Solar PV

There are external costs of fossil fuel use that are not accounted for in our current electricity market. Tsur & Zemel (2000, 391) state that optimal energy policy would "offer a precise meaning to the notion of externalities that must be included in the social cost of fossil energy." By including these externalities, the real cost of renewables like solar PV versus continued fossil fuel use become more equalized.

In *Environmental Policy and Sustainable Economic Growth,* Smulders goes on to say that knowledge and human creativity are keys to overcoming the limits of nature. Knowledge consists not only of scientific principles "but also social attitudes regarding how to cope with the environment and how to enjoy it," (1995, 21). He states that knowledge is a public good that must be priced to further accumulate new knowledge, which is part of an economic analysis equation. When we apply this increased knowledge investment to solar PV, we overcome the technical shortfalls and create improved technologies that lower the cost. These in turn can lead to more widespread use of PV. From a long term, sustainable perspective we then realize increased economic as well as environmental benefits for doing so.

Improving the cost/benefit ratio for solar PV is really a multi-faceted approach. According to Hester and Gross (2001, 72), "Future growth [of the PV market] depends on cost reduction, fuel price trends, and government policies such as subsidies." Internationally, Japan and Germany have seen steady growth in their PV markets and improved costs due to aggressive rebates and incentives for both commercial and residential users. In the U.S., California has "proposed ambitious goals for installing solar power on new homes. In response, the solar power industry has increased manufacturing, created jobs, and lowered costs to consumers," "despite facing a record state budget deficit" (ISEA, 2003, 14). In an innovative cost-sharing partnership between the Bonneville Power Administration (BPA), a utility-oriented PV wholesaler and local electric utilities, fifteen Northwest schools received solar PV systems. BPA paid the first $2500 per system and the utility paid the balance. The systems are included in educational curriculum for students and research programs for the BPA that helps them to understand the benefits of developing a standardized PV system (Vignola, 2002).

Methodology

Materials and Methods

A combination of available data from local government resources, aerial photos, ArcGIS software and Google Earth were used to estimate the amount of available roof space on public and commercial buildings in Eugene. Google Earth helped to more accurately visually identify suitable buildings, highlighting roof slope and the presence of HVAC (heating, ventilation and air conditioning) infrastructure or other obstacles. ArcGIS was then used to draw polygons over identical buildings identified in aerial photographs from Lane Council of Governments (LCOG, 2004) data, available through the University of Oregon Knight Library. There were occasional discrepancies between the two data sets because Google Earth's images are more recent - from the last three years (Google Earth, 2006), than LCOG's that were taken in 1995, but for purposes of this research, the differences were minimal. The final determination of course came from the 1995 images since they were what were available to ArcGIS. Tax lot data was also added from LCOG's Metro data set (LCOG GIS Data, 2002). This established a link between buildings identified with ArcGIS and tax lot ID's that could be used later in extending the opportunities of this study; see Appendix A for more details.

Identifying Available Building Stock

Data for this research was obtained looking at commercial and public buildings within the Eugene city limits that are identified as suitable based on the criteria below, including K-12 schools, Mahlon Sweet Airport, the University of Oregon and Lane Community College. Residential and commercial residential buildings (i.e. apartments) are excluded from this study because they have different electricity usage needs than commercial and public structures.

Usable roof space is defined as:

1. Public, city-owned or operated or commercial buildings;
2. Roofs with available solar access, i.e. those not obstructed by taller nearby buildings, trees or other large, shading elements;
3. Roofs that are flat or sloped to the south;
4. Roof area that is free of heating, cooling and other building operations infrastructure;
5. Buildings with total useable roof area of 1000 sq. ft or greater.

Data Collection

The first step in this research was to obtain a GIS data file from the University of Oregon Knight Library that contained some digitized building footprints in the study area. Next, LCOG's aerial photographs along with Google Earth were used to identify more commercial and public buildings. For each of these, the building footprints were then digitized into polygons. When complete, 1561 potentially suitable buildings were identified. Square footage for each of these polygons was then calculated and exported to a spreadsheet to perform further calculations including potential solar array size (measured in kW), tax and other incentives and net system cost.

With data in the spreadsheet all buildings with a roof footprint of under 1000 square feet and a few more that were identified as apartment complexes from the original data set from the Knight Library were removed; this left a population sample of 1462 buildings.
Dr. Frank Vignola from the University of Oregon's Solar Radiation Monitoring Laboratory estimated that about 25 – 50% of available buildings in Eugene would be suitable for solar PV installation (Email, 10/10/05). This takes into account roof orientation, shading, and other factors that would make solar PV impractical on some structures. For this research 35% of this total was selected to create the population sample, which translated to a sample set of 510 buildings. For each building in the sample set, the available roof area was reduced by 20% to account for infrastructure needs for installed solar arrays and another 15% to account for HVAC systems and other potential roof top obstructions (Vignola, personal interview, 5/5/05). This provided the net area available to install a solar PV system on each building.

Kessler, Krumsick and Vignola (2006) reported on tests of eight different solar arrays monitored during 2005 to determine potential annual electrical output in Eugene. Calculations for this research are based on data collected for the Sharp NE-175UI PV panels. This array consisted of three strings of seven panels for a total of twenty-one panels that would occupy approximately 294 square feet; this was rounded up to 300 square feet for a twenty-one-panel array. According to the report, this particular array generated 4032.24 kWh of electricity in 2005. System costs were estimated to be between $5000-$7000 per kW , although with current shortages of PV panels the price has climbed to as much as $8000 per kW (Vignola email, 10/10/05). Aggregate calculations were performed for the network using the current estimated cost of $8000 per kW and a best-case scenario of $6000 per kW that might be achieved when buying panels and other system components in bulk if supplies could be met.

Oregon Business Energy Tax Credits (BETC) and federal tax credits are available to help reduce total system costs. The Oregon BETC can cover up to 35% of eligible costs when spread over 5 years or can cover as much as 28% of system costs when used as a one-time pass through credit. The latter is used for simplicity in these calculations. Federal tax credits can cover up to 30% of qualifying system costs.

Finally, aggregates were calculated for the total distributed generation system for kWh output, kW size of the array, State Tax Credits, Federal Tax Credits, and Net System Cost. Jim Krumsick from the Alternative Energy Consortium in Eugene, indicated that a 10% reduction in net costs could also be included to account for various additional savings that could be utilized over time, depending on the system owner's tax liability (Krumsick, telephone interview, 6/4/06.) The final step was to calculate the cost per kWh of electricity generated, that would need to be credited to system owners that would result in payback periods of 5, 10, 20 or 25 years based on the aggregate figures.

Results and Discussion of Findings

Solar PV is a Viable Option

This research indicates positive prospects for installing solar PV on public and commercial buildings in Eugene. Table 1 illustrates the potential size array available (F), annual electrical output (E), incentives (H-J) and costs (G, K, W) for a representative sample of individual buildings[2]. For example, on a building with approximately 1200 square feet of available roof space a 10kW solar PV system could be installed that could generate as much as 11, 318 kWh of electricity annually; see Building ID108 in Table 1. According to PacificCorp, a Pacific Northwest electricity provider, "The City of Eugene currently boasts four solar projects and two more are in development. The 155.9 kW of electricity produced meet the energy needs of 19 homes each year," (PacificCorp, 2004). By comparison, a 10kW system would meet the needs of approximately 1.2 homes. The net system cost after available state and federal tax credits would be between $19,240 and $25,650. According to an emissions reduction calculator at the Leonardo Academy, this is enough electricity to reduce CO_2 emissions by 7.4 tons annually and

Table 1: Sample of Potential Solar PV Installations on Commercial and Public Buildings in Eugene, Oregon

Building ID	Roof Area (Sq. Ft.)	Roof Area - HVAC (C1)	Roof Area - System Infrastructre (C2)	No. of 21-Panel Arrays (D)	Annual Avg. kWh Output (E)	kW Array (Size) (F)	Initial System Cost (G)	State Tax Credit (H)	Federal Tax Credit (I)	Additional Savings based on Owner's tax liability (J)	Net System Cost at $8000/kW (K)	Net System Cost at $6000/kW
108	**1,238**	**1,053**	**842**	**2.8**	**11,318**	**10**	**$80,169**	**22,447**	**24,051**	**8,017**	**$25,654.00**	**$19,240.50**
607	2,458	2,089	1,671	5.6	22,464	20	$159,122	44,554	47,737	15,912	$50,918.95	$38,189.21
631	3,646	3,099	2,480	8.3	33,326	30	$236,056	66,096	70,817	23,606	$75,537.81	$56,653.36
670	4,909	4,173	3,338	11.1	44,866	40	$317,804	88,985	95,341	31,780	$101,697.38	$76,273.04
614	6,126	5,207	4,166	13.9	55,986	50	$396,570	111,040	118,971	39,657	$126,902.42	$95,176.81
456	9,221	7,838	6,270	20.9	84,269	75	$596,905	167,133	179,071	59,690	$191,009.51	$143,257.14
812	12,321	10,473	8,378	27.9	112,607	100	$797,633	223,337	239,290	79,763	$255,242.46	$191,431.85
294	15,579	13,243	10,594	35.3	142,384	126	$1,008,550	282,394	302,565	100,855	$322,736.04	$242,052.03
166	18,497	15,723	12,578	41.9	169,052	150	$1,197,452	335,287	359,236	119,745	$383,184.64	$287,388.48
1077	**21,566**	**18,331**	**14,665**	**48.9**	**197,096**	**175**	**$1,396,094**	**390,906**	**418,828**	**139,609**	**$446,749.94**	**$335,062.46**
740	24,711	21,005	16,804	56.0	225,841	200	$1,599,708	447,918	479,912	159,971	$511,906.49	$383,929.87
558	31,150	26,477	21,182	70.6	284,684	252	$2,016,512	564,623	604,954	201,651	$645,283.87	$483,962.90
426	36,733	31,223	24,978	83.3	335,707	297	$2,377,922	665,818	713,377	237,792	$760,935.04	$570,701.28
1468	43,301	36,806	29,445	98.1	395,737	350	$2,803,139	784,879	840,942	280,314	$897,004.43	$672,753.32
1407	49,385	41,977	33,582	111.9	451,341	400	$3,196,999	895,160	959,100	319,700	$1,023,039.81	$767,279.86
1066	54,575	46,389	37,111	123.7	498,774	442	$3,532,982	989,235	1,059,895	353,298	$1,130,554.31	$847,915.74
1315	62,043	52,737	42,190	140.6	567,028	502	$4,016,446	1,124,605	1,204,934	401,645	$1,285,262.62	$963,946.97
1206	74,098	62,983	50,386	168.0	677,194	600	$4,796,794	1,343,102	1,439,038	479,679	$1,534,974.07	$1,151,230.55
1410	92,288	78,445	62,756	209.2	843,437	747	$5,974,343	1,672,816	1,792,303	597,434	$1,911,789.64	$1,433,842.23
1146	109,115	92,747	74,198	247.3	997,220	883	$7,063,642	1,977,820	2,119,093	706,364	$2,260,365.41	$1,695,274.05
958	162,857	138,428	110,743	369.1	1,488,381	1,318	$10,542,700	2,951,956	3,162,810	1,054,270	$3,373,663.86	$2,530,247.90
Estimated System cost / kW:		$8,000.00			(Amount used to calculate Initial System Cost)							

Note: See Appendix B for specific formulas represented by figures in ( )

[2] Net system cost is calculated at both $8000/kW and $6000/kW. Currently a shortage of PV panels has driven the price up closer to the $8000 figure, yet purchasing large quantities of PV panels for such a project as this could bring the cost down to the $6000 level,. Only the net cost in Table 1 is adjusted to show both; all others are based on the higher figure.

could save approximately $746 per year in electricity costs[3]. Approximately 75% of the buildings surveyed are 20,000 square feet or less. A 175 kW array that generates close to 200,000 kWh of electricity for a cost between $335,062 and $446,750 after available credits, could be installed on a building with roughly 21,000 square feet of available roof space; see Building ID 1077 above. This would generate approximately $12,989 in yearly electricity savings, reduce carbon emissions by 129 tons annually and generate electricity equivalent to the needs of approximately 21.3 homes.

Tables 2 and 3 below illustrate the aggregate values for a distributed generation solar PV array that consists of 510 buildings with system costs of $8000 and $6000 per kW respectively. This survey includes buildings with available roof space of at least 1100 and ranging as high as 275,000 square feet for individual buildings before installation of a PV system. If this network were installed, it could generate approximately 77,675,000 kWh of electricity annually at a net installed cost between $176 and $132 million, after utilizing available tax incentives. Using the

Table 2: Network Performance and Costs ($8000 per kW system cost)

Total Network kWh Output	Network Array Size, kW	System Cost Before Incentives	Total State Tax Credits	Total Federal Tax Credits	Additional Savings	Total Net System Costs
77,673,289	68,773.2	$550,185,800	$154,052,024	$165,055,740	$55,018,580	$176,059,456
	Network Array Size, MW		Cost per kWh 5 yr Payback	Cost per kWh 10 yr Payback	Cost per kWh 20 yr Payback	Cost per kWh 25 yr Payback
	68.8		$0.45	$0.23	$0.11	$0.09

Table 3: Network Performance and Costs ($6000 per kW system cost)

Total Network kWh Output(L)	Network Array Size, kW (M)	System Cost Before Incentives (N)	Total State Tax Credits (O)	Total Federal Tax Credits(P)	Additional Savings (Q)	Total Net System Costs (R)
77,673,289	68,773.2	$412,639,350	$115,539,018	$123,791,805	$41,263,935	$132,044,592
	Network Array Size, MW		Cost per kWh 5 yr Payback (S)	Cost per kWh 10 yr Payback	Cost per kWh 20 yr Payback	Cost per kWh 25 yr Payback
	68.8		$0.34	$0.17	$0.09	$0.07

[3] The Leonardo Academy website states that estimated annual cost savings are "calculated using fossil fuel-based electric generation and natural gas emission factors and average electricity and fuel rates by customer type for the selected state."

figures from PacificCorp above, this would be the equivalent of meeting the annual energy demand of approximately 8,381 homes.

Currently the Eugene Water and Electric Board does not offer an incentive program to encourage customers to adopt solar PV. According to Steve Still of EWEB's Energy Management Program they do have an active pilot program called *PV Eugene* but it was recently closed to new subscribers because they reached their target of 150 participants (Still telephone interview, 2006). *PV Eugene* pays customers $.25 per kW for electricity generated and all power goes directly into the EWEB grid rather than being used first by the system owner with the surplus going into the grid. The payback figures above in Tables 2 and 3 represent the cost of electricity that could be paid to system owners if a similar program were revised and this level of distributed generation network developed.

Benefits to Eugene's Economy and Environment

Research indicates that for every megawatt (MW) of solar PV generated there are eight local jobs created in system design, installation and service for the systems (Vignola, personal interview 6/2/06.) A 68.8 MW array would therefore result in approximately 550 full time jobs added to the local economy. We are fortunate to have a training facility for solar installers at Lane Community College's Energy Management Program right here in Eugene that could facilitate preparing the labor force necessary to accomplish this goal. Their website estimates that salaries for Renewable Energy Technicians range from $25,000-$30,000 annually. This would be a sizable investment in the local economy, especially considering the other monetary and environmental benefits of installing solar PV throughout the community.

According to the *Cleaner and Greener Emission Reduction Calculator* (Leonardo Academy, 2005) this 68.8 MW array could generate approximately $5,118,670 in annual electricity savings distributed among businesses and investors in the system. It could also reduce our community's carbon emissions by almost 51,000 tons per year. This would all go a long way toward confirming the City of Eugene's commitment to reducing our community's reliance on non-renewable energy resources, reducing our greenhouse gas emissions, creating jobs in the sustainability sector and saving money.

Policy Support for Solar PV

While it is beyond the scope of this research to identify specific policies in which to implement such a program, its important to at least briefly mention several activities that are occurring or have been suggested within our community, or others that could help make it possible.

Mayor Kitty Piercy, with support from the Eugene City Council initiated the Sustainable Business Initiative (SBI) in June 2005. A sixteen-member Task Force, with involvement from over 750 community members through roundtable discussions, town hall meetings, and online surveys, is preparing a set of recommendations to present to the Eugene City Council in the fall of 2006. While their task was primarily focused on job creation and economic development, the concept of sustainability also includes environmental and social well-being. Developing policies that promote broad, extensive use of solar PV on public and commercial buildings in our community is one way to support the goals of sustainable economic development and this research helps confirm the economic and environmental case for doing.

There is also an organization in Eugene called the Alternative Energy Consortium (AEC), several of whose members helped clarify some of the technical aspects of this research. Through a lease agreement with Balzhiser and Hubbard Engineers, they have established a test facility where they are conducting research on the feasibility of various solar PV arrays (one of which was used for these calculations.) The AEC's near term goals are to establish similar lease agreements for solar PV installations on public buildings to expand their testing capability and the use of solar PV in Eugene. Maintaining private ownership of the system allows investors and donors to qualify for the business tax credits that might not otherwise be available to public entities. "The Consortium will design, and monitor the system, and maintain ownership until tax credits have been fully utilized," during which time the system is leased to the public entity at a rate linked to the power production capability of the installed system. "At the end of the lease period the system would be either sold or donated to the public institution," (Krumsick, 2006.) This research could further support their efforts to establish such lease agreements, providing the necessary background data to illustrate the beneficial impact that widespread large-scale use of solar PV can have in Eugene.

Several community members involved in the solar energy industry who also participated in the SBI are considering a proposal to create or promote a solar utility. With financial backing from either the existing electric utility or from new investors, a large-scale centralized or a distributed generation solar PV system could be established. All power would be generated from the sun and fed directly into the existing electrical grid. Investors, whether building owners or not, would realize a return from the purchase price of the power generated.

In 2002 a group of students from Sonoma State University developed an innovative public/private partnership to increase the use of solar PV in Sebastopol, CA. In their feasibility study, they propose that up-front costs could "conceivably be raised through a municipal revenue bond issue," (Aeita, et al, 2002.) This cash would then be used to purchase or help finance installation of the PV systems throughout the community. They considered two basic scenarios for ownership of the systems:

"Plan I The PV system belongs to the building owner. The City pays cash to the vendor and installer for the system and its installation, and the property owner repays the city over time with the money they saved on their utility bill.

"Plan II The PV system belongs to the City. The property owner makes their roof space available and sees a reduction of their utility bill. The property owner shares these utility bill savings with the City. These savings could be shared in different ways:

"II A After some number of years, when the initial cost of the PV system has been recovered by the City, ownership of the PV system is transferred to the property owner, who continues to receive free electricity for the remaining lifetime of the system, or

"II B The property owner continues to make payments to the City throughout the life of the PV system, but at a rate lower than the monthly utility savings. (Once the system has paid for itself, the continuing revenue stream will be used by the City to fund other renewable energy projects.)

"In both Plan I and II, the payments made by the property owner to the City could be specified in different ways, including: (a) a flat monthly or bi-annual payment, (b) a payment based on the *estimated* utility savings each month, or (c) a payment based on the actual utility savings computed with the help of an additional meter that measures only PV output.

"Note that in versions (a) and (b), the property owner assumes the financial risk associated with variable electricity production, whereas in (c) the City assumes this risk. Given standard warranties for PV products and dependable sunshine, this solar production risk is probably very small compared to the risk of utility rate increases (against which the customer is now protected)," (Aeita, et al, 2002.)

Conclusion

The question for solar PV is not so much if it works—it does, even in the cloudy Pacific Northwest. Critical challenges to increasing the use of this available, clean resource include reducing manufacturing waste, improving efficiency ratings for PV modules and mitigating the high initial investment costs. Government policies that lead by example go a long way toward greater deployment of solar PV and eventual cost savings that result from increased economies of scale in manufacturing. Along with increased energy independence, renewable energy including solar PV can help mitigate pollution that has resulted from other forms of energy production in both developed and developing nations. According to Anderson (1996, 13), "What is needed is broader recognition of their immense potential for abating pollution and supportive environmental policies based on economic principles."

There are a wide variety of innovative ways to accomplish the goals of widespread, increased use of solar PV in Eugene. With increasing pressures from global warming and global political instability that results from over-dependence on fossil fuels, primarily petroleum, the time is right for a major shift in direction for local and U.S. energy production. With a collaborative spirit, the political will to try innovative approaches and the financial support of creative individuals and institutions, it is feasible to meet much more of the electricity needs in Eugene from solar PV than we currently do. Through innovative public/private partnerships, increased awareness of financial incentives and market demand for technological improvements, large-scale use of solar PV on commercial and public buildings is one important step in moving our community and nation toward a more sustainable energy future. It is my hope, that this research will provide a stronger foundation to the existing dedicated efforts that are already occurring in our community to achieve this goal.

Acknowledgments

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Appendices

Appendix A: Further Research Opportunities

A) Use local LCOG records and send letters to potential building owners identified in this data set that describes their solar potential. This would be similar to the Marin County, CA project and a sample letter from their program is included in Appendix C. Along with the parcel ID numbers already included in this data set, researchers would need to locate GIS records that also include the taxpayer's name and address, the building address and land use code. Several LCOG data sets from their Regional Land Information Database website (2001) that may be helpful include:

- Detailed Property Search – includes owner name, site address, Lane County assessor account number and assessor map and tax lot number;
- Lane Maps – provides U.S. Geological Survey maps and information on terrain, environment and tax lot plus more;
- Lane Query – allows a user to create custom reports based on user-identified requirements for up to 1,000 properties.

B) Solar Parking Lots: A similar study could be conducted to identify available parking lots to install solar arrays on parking shade structures. At least one business in Eugene, the medical offices at Oak Street Medical, P.C. has already done this and is producing 15% of their total energy needs. By purchasing "green tags" for the remainder of their electricity needs their facility is now "100% climate neutral," (Oak Street Medical, P.C., 2006).

C) Evaluate the feasibility of the Sebastopol Bond Program proposed by students at Sonoma State University or other funding approaches that make installation of solar PV more competitive with current energy generation technologies.

Appendix B: Methodology and Formulas

Methodology and formulas used to estimate the potential solar energy generated on commercial and public buildings in Eugene, Oregon. (Numbers in brackets [] refer to Notes listed at the end of this appendix):

Population Sample Set (S)

A) 1560	Total Population of buildings measured
B) 1560 - 65%	Sample Set, with decent available solar access (Dr. F. Vignola 10/10/05 email; indicates from 25-50% would have decent access)

Calculate for each Building (S_i = building footprint in sq. ft.):

C1) S_i – 15%	Building Footprint minus 15% for building HVAC, etc.
C2) C1 – 20%	C1 Building Footprint minus 20% for infrastructure (paths, mounts, etc.) in square feet
D) C2 ÷ 300	Number of 21 panel strings possible, rounded to 1 decimal **[1]**
E) D * 4032.24	Potential annual kWh generated **[2]**
F) D * 21 * .17	The number of 21-panel arrays times .17; .17 is the number of kW from a 175W panel

Cost Per Array:

G) F * $8000 per kW	System Cost **[3]**
H) G * 28%	State Tax Credit (uses 28% as 35% is taken over many years)
I) G * 30%	Federal Tax Credit
J) G * 10%	Additional cost savings **[4]**
K) G – (H+I+J)	Net System Cost after Rebates and Incentives

Network Aggregates:

L) Sum of all E(S_i)	Network Total kWh produced
M) Sum of all F(S_i)	Network Total size in kW and MW
N) Sum of all G(S_i)	Network Total System Cost before incentives
O) Sum of all H(S_i)	Network Total State Tax Credits available
P) Sum of all I(S_i)	Network Total Federal Tax Credits available
Q) Sum of all J(S_i)	Network Total Additional Savings available
R) Sum of all K(S_i)	Network Total Cost after credits and incentives
S) (N÷L)÷desired payback time	Cost of electricity per kWh to recover full payback of the network system costs in either 5,10, 20 or 25 years

Notes:

1) Each Sharp NT175UI is approximately 14 square feet in size; therefore a 3x7 string of solar panels = 21 *14 = 294 sq. ft; rounded to 300 sq. ft.

2) Number of 7 panel strings * annual output from *Solar 2006: AEC Photovoltaic Test Facility – First Year Test Data*, using the Sharp NT-175UI solar panels.
3) In calculating aggregate values for the entire network this value was also calculated at $6000 per kW.
4) In the report entitled *AEC Photovoltaic Test Facility – A Financing Case Study*, Jim Krumsick includes adjustments for power generation, federal and state tax changes and equipment depreciation spread over six years in his analysis. This was too detailed an analysis to include for each of the buildings in this study. In a phone conversation with him on 6/5/06, he estimated that a figure between 10% & 15% could be used as a lump sum to account for these additional reductions in cost. The conservative 10% is used in calculations for this research.

Appendix C: Marin County, CA Sustainability Team Sample Letter to Businesses

This is a copy of a sample letter sent out by Marin County, CA's Sustainability Team to businesses they identified conducting similar research.

DATE

Facility Manager

Business Name

Address 1

Address 2

City, State. Zip

Dear Facility Manager,

Your facility has been identified as a good candidate for solar electric applications[1]. After preliminary analysis, we have estimated that your site could potentially generate over 50,000 kilowatt-hours every year. The approximate annual cost savings of a solar electric system that would produce this much energy is approximately $10,000[2]. Moreover, a 30kW PV system could earn you as much as $135,000 in incentives from the Pacific Gas and Electric (PG&E) Self-Generation Incentive Program[3]. In addition, there are Interest Tax and Depreciation deductions for which your business could qualify.

As the manager of a facility, you must account for the ongoing operation and maintenance costs of your building(s). The unique aspect of solar is the minimal cost to your organization to maintain the system, while simultaneously reducing your annual payment to PG&E. Solar installations are an investment in which your organization "owns" the electricity it produces, rather than "renting" it all every month from your utility company.

There are many benefits to using solar energy in conjunction with the power already supplied by the utility grid through PG&E, including:

1. Solar energy produces the most power when the cost of electricity is highest.
2. Solar energy hedges against future energy price volatility.
3. Cash and tax incentives available through the state and federal government make

[1] An innovative approach using Geographic Information System (GIS) analysis and mapping was developed to identify areas in Marin that have with [sic] high solar availability and adequate roofing surfaces (at least 3,000 ft^2)

[2] Savings are based on the PG&E Electric Rate Schedule A10, and are estimated based on a 30kW system. Different rate schedules and/or a larger sized system would increase the economics.

[3] The Self-Generation Incentive Program pays incentives on solar at $4.50 per watt or 50% of project costs (whichever is lower).

solar energy economically attractive.

4. Producing clean, renewable power can boost a business' image within the community.

If you would like to learn more about installing a solar electric system at your facility, we invite you to register to attend a free workshop, hosted by Pacific Gas & Electric and the County of Marin, on October 10, 2003 from 9am – 5pm.

At this workshop, information will be provided on basic PV concepts, current rebates, low-interest financing and system sizing. We also encourage you to go to our website for more information—www.marinsolar.org.

If your organization is interested in solar, please fill out the postcard included with this letter to receive additional information and/or to sign up for the PG&E workshop*. The County is providing free site visits prior to the upcoming workshop to the first 10 organizations that respond. If someone other than the facility manager plays a role in your organization's energy management, please forward this invitation to him/her.

In closing, the Marin County Community Development Agency is interested in supporting the installation of clean, reliable electricity in Marin County. Please feel free to call Gwen Johnson at the County of Marin at 415-499-3292 or by email at gjohnson@co.marin.ca.us with questions.

Yours very truly,

Gwen Johnson
County of Marin
Marin Solar Program Coordinator

The full case study, of which this letter comes from, is available at: http://www.co.marin.ca.us/depts/CD/main/pdf/BEST_pdf/solar/VoteSolar_MapCaseStudy.pdf

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