CHAPTER ONE – INTRODUCTION

Environmental Context

Fossil fuel-based electricity production has many deleterious environmental effects. The largest in scale and potential for catastrophic consequences is the production of carbon dioxide (CO_2), the most abundant greenhouse gas. Fossil fuel use and production accounts for about seventy-five percent of total anthropogenic CO_2 emissions[1]; because of the large role electricity plays in CO_2 production, the industry will have to effect its mitigation on a corresponding scale. The use of photovoltaic power for electricity production is one method for securing CO_2 emission reductions.

The Kyoto Protocol

International efforts are underway to stabilize the production of CO_2 and other greenhouse gasses. The main global body pursuing greenhouse gas mitigation is the United Nations Framework Convention on Climate Change (UNFCCC). According to the provisions of the agreement reached during the Third Session of the Conference of the Parties (COP-3) of the UNFCCC in Kyoto, Japan, the industrialized world is committed to reducing the emissions, accounted for in terms of equivalent CO_2 production, of six greenhouse gases not controlled by the Montreal Protocol by about 2010. These six gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexaflouride (SF_6). The Kyoto Protocol opened for signature on March 16, 1998 and will become legally binding ninety days after it is ratified by fifty-five percent of the parties, which must include a sufficient number of Annex I (developed) countries to account for fifty-five percent of their emissions. Congressional approval is needed before the United States can ratify the treaty, and approval appears to hinge on the participation of the less developed countries.[2]

According to the protocol, the United States must reduce equivalent CO_2 emissions to seven percent below 1990 levels during a "commitment period" between 2008-2012. The United States' real reduction is estimated to be closer to 2-3% of 1990 levels because of other provisions in the agreement; such as the way that “sinks”, such as forests, that remove these gases from the atmosphere are counted.[3] Because the U.S.’ emissions have continued to grow since 1990, stabilizing U.S. emissions at 1990 levels by 2008 would require a 28 percent reduction off business as usual.[4] Joint implementation, or emissions trading, is allowed between countries with some conditions. One of these conditions is that trading must be supplemental to domestic actions; a nation cannot completely fulfill its target reductions by joint implementation.

An emerging global consciousness?

Articles at the time of the conference predicted that drastic reductions in fossil fuel consumption and the restructuring of the economy's energy usage patterns would emerge as nations strove to meet the goals of the Kyoto Protocol.[5,6] The accord was also seen as a windfall for the emerging renewables energy market which seemed likely to benefit from the federal research and commercialization incentives to follow.

However, a recent article in Science[7] predicts no real change in the United States’ energy consumption patterns and that emission reductions will only occur on paper. The author perceives no real political will on the part of world governments to make lasting changes in energy usage. For example, because of the closures of a large number of highly polluting factories in the former East Germany, Germany would have already reached its target reductions. Russia also has a potential gold mine which will result from the sales of emissions reductions from highly polluting factories that have been closed or will be closed shortly. It is likely that the United States and other countries will primarily meet their goals by purchasing such reductions. This doesn't translate into a paradigm shift in energy consumption, merely improved global accounting. How can this pessimistic view be reconciled with the plethora of recent articles heralding the arrival of a new global climate conscience?

Contribution due to electricity production

"Electricity satisfies almost 15 percent of the nation's end-use energy demand, consumes about one-third of the primary energy resources used, and accounts for about 1.7 percent of gross domestic product….the generation of electricity results in about 40 percent of the carbon dioxide, 70 percent of the sulfur dioxide, 30 percent of the oxides of nitrogen and 40 percent of the fine particulates emitted annually in this country."[8] Electricity production contributes a large and ever growing fraction of the world's releases of potentially climate changing gasses. The U.S. electric sector alone contributes eight percent of global carbon dioxide emissions.[9] The less developed countries are only beginning to whet their appetites for cheap power; as pre-industrial countries gain more and more of a share of the world's marketplace, global greenhouse gas emissions will skyrocket. These emissions could be reduced through the use of renewable energy sources, such as photovoltaics.

In some sense the Congress is justified in demanding greenhouse gas emission reductions from less developed countries or in demanding that they at least agree to consider reductions. For example, China is currently the second largest producer of greenhouse gasses in the world, second only to the United States in emissions (U.S. per capita emissions are much higher than China's per capita emissions); however, despite their volume of emissions, nearly half of the Chinese population is still without electricity. As China electrifies, it will burn more and more coal, by 2020 coal consumption in China will increase to somewhere between two and three times what it is today bringing with it a corresponding increase in CO_2 emissions.[10] The Chinese government has to weigh the environmental considerations of development with the demands by the Chinese people for an increased standard of living.

Energy and development

Energy fuels development. Our economic system is based on the assumption of unlimited, low-cost energy sources and inexhaustible pollution sinks. However, unlimited fossil-fuel consumption has deleterious local and global effects on the environment and human health that could ultimately cause catastrophic economic failure and social collapse. This poses a troubling dilemma for policy makers and politicians: how can policy be formulated to avoid short-term economic upheaval while simultaneously providing for a prosperous future? While this thesis will not endeavor to answer these questions on a global scale, they are as crucial locally as globally.

At the present time Rhode Island derives less than one percent of its electricity from renewable sources, but the state is currently pursuing policy options that would increase the generation of renewable resource electricity. It makes environmental sense to employ renewable energy in Rhode Island, but with conventional economics systems which do not internalize the social costs due to electricity productions, it doesn't make economic sense. In the past utilities could undertake projects and programs that were not cost-effective but that provided other benefits such as environmental protection or programs for the underprivileged because in the protected regulatory atmosphere the utilities were ensured of recouping their invested monies. This atmosphere ended on January 1, 1998 when The Rhode Island Utility Restructuring Act of 1996, which opened electricity generation to retail competition, took effect. Rhode Island's legislation, like that of most states, [i] provided protections for sectors that might be made more vulnerable such as low-income customers and the environment.

The federal government has introduced programs and tax incentives for renewable technologies aimed at reducing carbon emissions and protecting the environment. Time will reveal whether these programs will receive funding from the Congress. It will take more time to discover whether these federal programs and state programs really signify a national commitment to renewable energy technology or if they will end up as lip service and the reshuffling of already existing commitments as the implementation of the Kyoto Protocol seems fated to be.

[i] See Appendix II for a listing of environment protection measures in state restructuring legislation.

Why Photovoltaic Power?

Photovoltaics are neither the only nor the most cost effective renewable energy source currently available. Wind turbines are generating electricity at a cost of about five cents per kilowatt-hour, which is in the same order of magnitude as the two to three cents per kilowatt hour for electricity produced by conventional coal-fired plants. Why am I considering photovoltaic power and not some other renewable source? I believe that PV has advantages over other renewables and will be the most feasible power supply of the renewables in the long term. The contributions of each renewable energy source as a percentage of the domestic electricity supply are summarized in Table 1.

Table 1. Renewable electricity as percentage of total domestic electricity supply.(1993).[11]

GENERATION TYPE	PERCENTAGE
Hydropower	10%
Biomass and Municipal Solid Waste	2.4%
Geothermal	0.6%
Wind	0.1%
Direct Solar	Negligible

Impacts of Photovoltaic Power

PV power generates no emissions during operation. Fossil fuel plants produce carbon dioxide which contributes to global climate change, sulfur dioxide which contributes to acid rain and nitrogen oxides which are precursors of ground level ozone (smog). The Manchester Street Plant (fueled by natural gas and fuel oil number 2)[12] produced 79 tons of NO_x, 5 tons of SO2 and 266,458 tons of CO_2 in 1995.[13] Emissions for several New England Electric System plants are listed in Table 2. It is interesting to note that for each of these plants, except the Manchester Street Plant, approximately one ton of CO_2 is emitted for each megawatt-hour of electricity produced.

Table 2. Emissions for NEES owned plants (1995).[14]

	EMISSIONS (TONS)			
Plant	**NOx**	**SO2**	**CO2**	**Generation (MWH)**
Brayton Point	11,285	52,348	8,996,830	8,357,421
Manchester Street	79	5	266,458	640,349
Salem Harbor	6,347	21,909	3,186224	2,580,845
William F. Wyman	1,381	4,139	848,139	802,202

Photovoltaics are modular and installations can be expanded easily. Utility scale PV plants and residential installations can be scaled up incrementally as resources allow. Modularity allows PV arrays to be easily dispatched for grid support where needed. PV cells have no moving parts to wear out or break down making them highly reliable. Satellites are powered by PV because it is a highly reliable power source; repair is not an option in space and the failure of a power system could render a multi-million dollar satellite inoperable. Reliability is needed in terrestrial applications, especially in the remote applications where PV is currently cost effective. PV is used in such remote applications as powering pumping stations and navigational buoys. Several of the motorist emergency call boxes along interstate 95 in southern Rhode Island are powered by PV panels.

The photovoltaic industry employs more people per kilowatt-hour than fossil fuels. The creation of jobs can be considered an economic benefit; however, the large number of jobs per kilowatt-hour contributes to PV's higher costs. Although the number of jobs per kilowatt-hour will decrease with more efficient PV factories, this loss in jobs may be offset by an increase in production. A robust PV industry will help to augment the U.S. high-tech sector. More than fifty percent of the world's solar manufacturers are U.S. based companies, and they export nearly seventy percent of their product.[15] This helps to reduce the foreign trade imbalance and secures a greater share of the world's market for the U.S. Increased domestic use of photovoltaic energy will also help restore the balance of trade by decreasing foreign dependence on fossil fuels; particularly beneficial due to the volatility of the oil-producing regions.

Photovoltaic power it is not without drawbacks. One drawback is that PV is land-use intensive. The light from the sun is highly diffused by the atmosphere, and producing a significant amount of electricity requires a large area of PV cells. An area equivalent to 140 X 140 kilometers at an average location in the United States would be required to generate all of the electricity needed to meet the entire domestic demand.[16]When the land used in extraction of fossil fuels is considered (including strip mining) the land use intensity of these generating technologies is higher than would be required for PV.[17] Moreover, because PV is modular it can be incorporated into the design of existing structures, such as rooftops, without requiring additional land use. PV can also be used to provide additional benefits such as the Sacramento Municipal Utility District's substation that shields part of the parking lot at the Sacramento Airport. In this case PV keeps the waiting cars shaded and produces electricity without taking up additional space.

By its nature solar power is intermittent. This intermittence requires the use of a back-up power source. Auxiliary power can take the form of a battery bank or connections to the conventional grid. Solar power can be supplemented with other renewable powers such as wind, geothermal, biomass and hydropower as well as conventional fossil use.

The biggest hurdle to PV power is its prohibitive cost. Costs have come down dramatically, but in the absence of a wide scale carbon tax on conventional fuels PV still cannot compete. A discussion of costs of photovoltaics and other types of electricity is given in Chapter Two.

Other Renewable Technologies

Hydroelectric plants have been in operation since the beginning of the electric era. They contribute the largest percentage of any renewable energy source to the electricity mix. However, the available hydroelectric resource is nearly fully exploited and the creation of new hydro projects is politically unpopular. New dam projects incite debate about the cultural and ecological value of the flooded land, and new large scale projects are unlikely. The percentage of electricity supplied by hydropower has been declining in recent years.[18]

Biomass and municipal solid waste include such generating technologies as garbage-to-energy incinerators, methane reclamation, and wood burning plants. Most paper and wood-product plants produce their own electricity on site by burning their scrap material; this accounts for one-sixth of biomass electricity generation[19] and is unlikely to increase. Municipal solid waste incineration has issues related to emissions and ash disposal. Biomass is land intensive and takes farmland away from crop production. The cultivating of biomass crops also may involve pesticides and fertilizers that reduce its environmental benefit.

Wind power is cost competitive with conventional power, but like all renewable technologies there are a number of drawbacks to the use of wind power. Birds, particularly raptors, are often killed by the blades on wind turbines. Wind has siting issues such as the noise associated with the turning of the turbines and the aesthetic quality of the assembly. In Rhode Island wind turbines would likely be placed near the coast to take advantage of the breeze off of the ocean, but there would almost surely be objection to the visual pollution of the coastline. Despite these drawbacks, wind power is a very promising technology and a good supplement to solar power.

The Current Situation

At the present time the United States consumes about one-third of the world's electricity, approximately 3225 billion kilowatt-hours in 1997.[20] The Energy Information Agency forecasts U.S. electricity consumption to increase at about 1.5 percent per year until 2015.[21] The biggest decrease in generation technology (from 20% to 9% of the supply) is expected to be in the nuclear sector with many reactors being decommissioned and no new plants planned; this shortfall will most likely be made up for with an increase in natural-gas generation.[22]

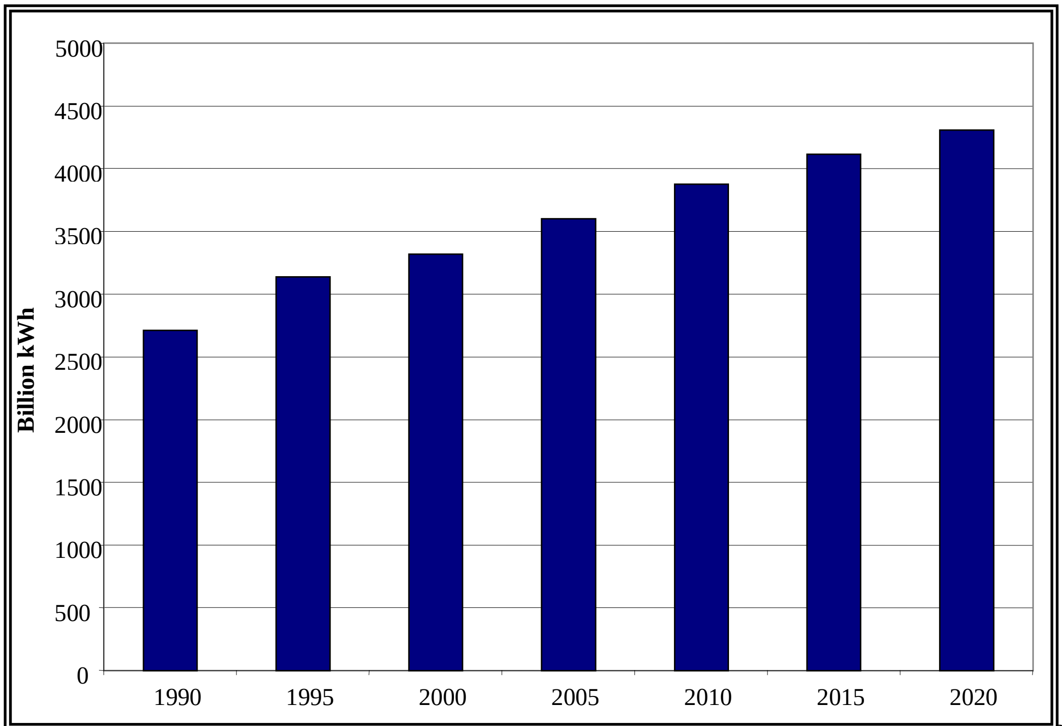

Figure 1. Net energy consumption in the U.S. 1990 - 2020 (billion kilowatt-hours).[23]

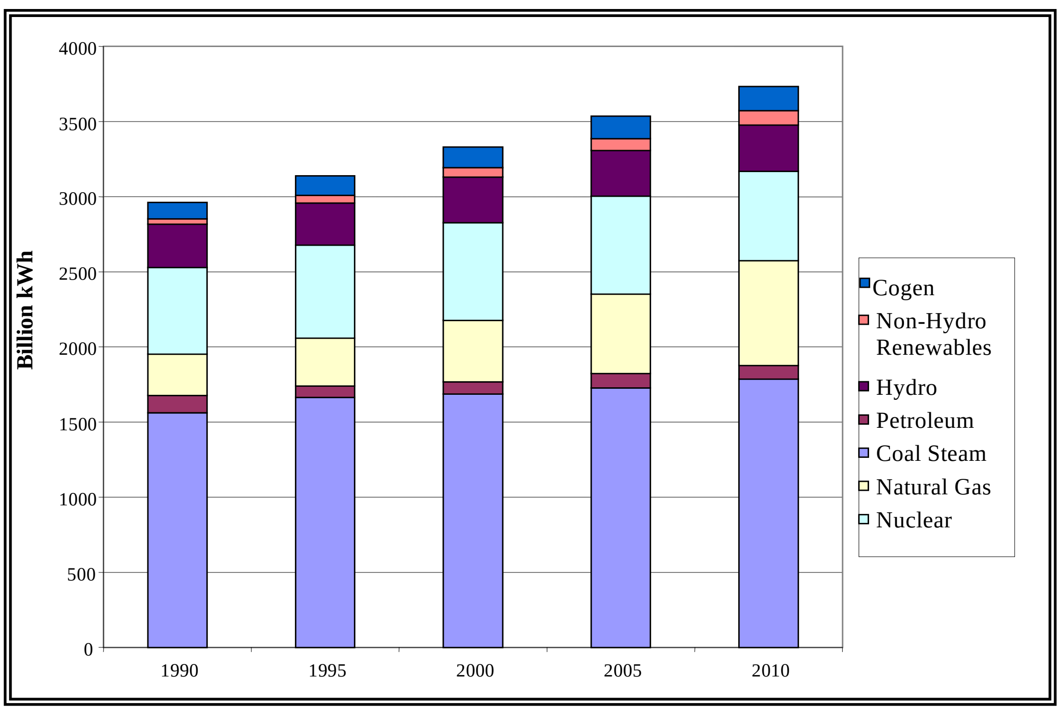

Figure 2. Electricity generation mix U.S. 1990 - 2010 (billion kilowatt-hours).[24]

New England electricity generation plants have the capacity of about 25,000 megawatts. Because of the new competitive electricity market in most New England states many developers are hoping to build new plants locally. Most of the proposed planned capacity additions in Rhode Island, such as plants in Johnston and Tiverton, mirror national trends in that they will be natural gas-fired plants. The renewable energy sector will increase over the next twenty years, but without a concerted national effort that growth will be minimal. The Tellus Institute estimates that with business as usual, meaning no meaningful programs, in 2010 there will be 98 billion kilowatt hours of non-hydro renewable electricity being generated; however, with a concerted national effort this could increase to 427 billion kilowatt hours,[25] slightly more than ten percent of all generation.

Photovoltaic Technology

The photovoltaic effect was observed in 1839 by the physicist Edmond Becquerel, but the first attempts in commercialization were not made until 1954 at Bell Laboratories (now Lucent Technologies). These early crystalline silicon solar cells had efficiencies of about four percent.[ii] In the late fifties and early sixties the main commercial application for photovoltaic cells was the powering of space satellites; solar cells still power most satellites and the space shuttles use PV to generate onboard electricity. PV finds a place in space applications because it is a highly reliable power source and can operate remotely. PV costs, which twenty years ago were around $180/Watt, were not prohibitive to the highly funded space program. In the intervening years the price of PV power has fallen to about $6/Watt[26] and terrestrial applications are becoming cost effective.

<u>The Photovoltaic Effect</u>

Photovoltaic cells are able to convert the energy from incident sunlight (made up of photons) into electricity via the photovoltaic effect. In the photovoltaic effect the energy of the photon is absorbed by the active material producing a charge carrier (such as an electron) which, when connected to an external circuit, produces an electric current. The active material is made of a semiconductor material; a material that has the properties of both a conductor, which carries current freely, and an insulator, which does not carry current at all. A semiconductor can carry current well, but some energy has to be supplied first; energy such as that carried by a photon. A semiconductor needs some

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[ii] The efficiency of a solar cell is the percentage of the energy of the incident light that is converted into usable energy, or electricity.

external energy to overcome its intrinsic bandgap, the amount of energy between the top of the valence band, where the electron usually resides, and the bottom of the conduction band. An electron can reside in either the valence band or the conduction band only; therefore, it must absorb energy from the photon at least equal to the bandgap to be able to make a band transition.

Table 3. Bandgaps of common photovoltaic materials.

MATERIAL	BANDGAP (eV)
Silicon	1.12
Gallium Arsenide (GaAs)	1.43
Cadmium Telluride (CdTe)	1.44
Copper Indium Selenide (CuInSe2)	1.0
Calculated Optimal	1.5

Sunlight is comprised of a range of energies that correspond to different wavelengths of light from the infrared to the ultraviolet. The spectrum peaks at about 2.5 eV. When selecting an active material one wants to optimize the amount of the sun's energy the material can absorb because increasing the amount of the energy that can be absorbed will increase the efficiency of the cell. Silicon can utilize photons with energy between 1.12 eV, and 3.4 eV.

It might seem that the best photovoltaic material to employ would be the one with the lowest bandgap because that material would be able to use the largest range of photon energies. Actually, photons with energies much higher than the bandgap of the material cause the material to heat up. The excess energy of the photon that can not be absorbed by the material is converted to heat. This heat causes the lattice[iii] of the semiconductor material to vibrate. This vibration increases the chance that a freed electron will collide with the lattice and recombine. The recombination of electrons makes the cell less efficient because these electrons do not contribute to current. A balance is necessary to absorb the most energy while minimizing the amount of costly heating.

Photovoltaic cell fabrication

The fabrication of a solar cell is a relatively easy task, much less complicated than the fabrication of any but the simplest microelectronic circuit. The challenge is in the creation of the active material (the semiconductor); once that is accomplished the subsequent steps are quite straightforward. The finished material is etched to trap light and printed with a current collecting grid and ohmic contact pads. The formation of the contact grid is a challenge in that it is formed on the face of the cell, the active area. The grid must be robust enough to conduct electricity well, but its dimensions must be planned such that the grid minimizes the area of the cell's face that is obscured. The larger the area covered by the grid the lower the amount of insolation per unit area that can be utilized and thus the lower the cell’s efficiency. The face of the cell is covered by a coating that helps to reduce the amount of sunlight that is reflected, reflected sunlight is

[iii] The atoms in many solids are arranged in a regular, repeating pattern. This structure is called a lattice.

lost energy to the cell. Once these layers have been fabricated the cells are soldered together and encapsulated under glass with a plastic laminate to protect the cells from the environment and minimizes the loss due to reflection. The cells are wired together on a framework creating a solar panel.

PV modules come in two general types, flat-panel modules and concentrators. Flat-panel modules have the cells arranged in a matrix on a flat backing surface and can utilize global insolation, both direct and diffuse sunlight. Diffuse sunlight is sunlight that has been scattered by clouds or other atmospheric conditions or sunlight that is reflected off of other surfaces such as the ground. Concentrators use lenses or reflectors to focus sunlight onto small solar cells. Concentrator efficiencies are much higher than typical flat-plane efficiencies; however, concentrators can only utilize direct sunlight and are therefore most useful in areas with clear skies and limited atmospheric interaction, such as the desert of the Southwest.

Photovoltaic Materials

The original, and still most widely used, photovoltaic material was crystalline silicon. However, many other materials are being used and developed for commercial use in solar installations. Silicon was the first choice for cell fabrication because of the abundance and low cost of semiconductor grade silicon. Recent research efforts have focused on “thin film” solar devices. Thin film cells have a layer of active material deposited on a low-cost substrate, such as glass or ceramic. Because of the lesser amount of material used thin film technology will produce more cost effective cells. Photovoltaic materials are discussed in detail in Appendix I.

Table 4. Efficiency forecast for various photovoltaic technologies. Efficiencies are given in percentages. [27]

TYPE	1990	1995	2000	2010
Single crystal Silicon	10 - 12	13 - 14	18	22
Polycrystal Silicon	9 - 11	12 - 13	16	20
Ribbon and Sheet	10 - 12	13 - 14	17	21
Concentrators	15 - 17	22	25	30
Amorphous Silicon	4 - 6	5 - 8	10	14
Cadmium Telluride		7 - 9	12	14

Efficiency

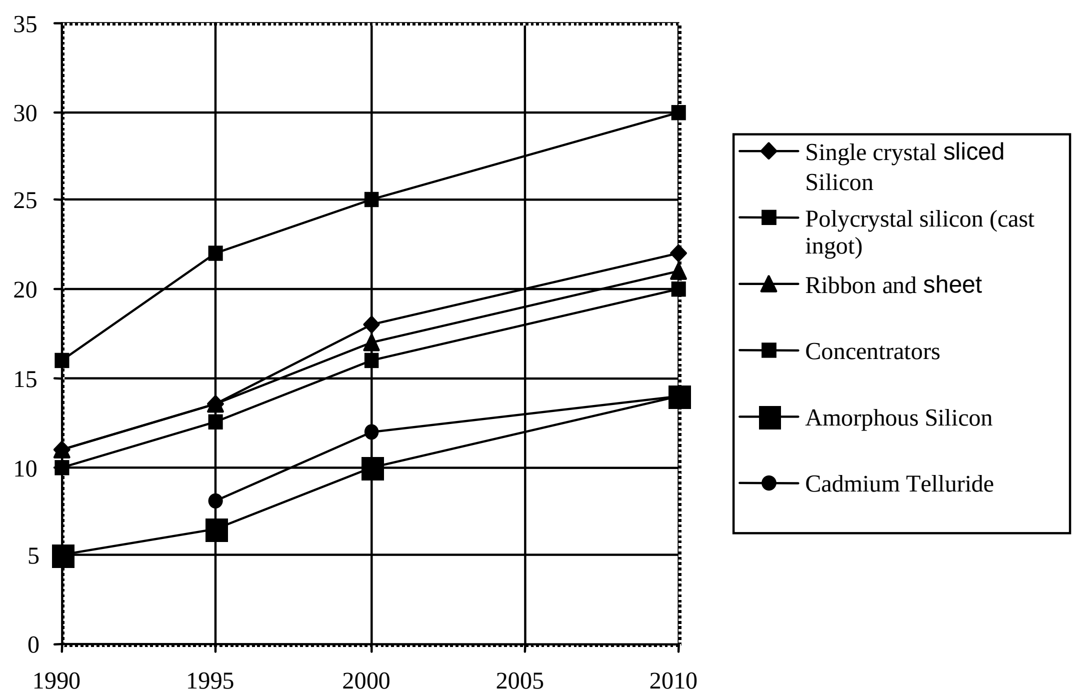
Since the 1980's cell efficiencies have increased dramatically and are expected to increase even farther in the future. As one can see from the efficiency forecast, all technologies can expect a doubling of efficiency between 1990 and 2010.

Summary

Although all technologies can expect a dramatic increase in efficiency and all technologies will benefit from the economies of scale that will result from the increasing demand for environmentally benign power sources, it is my opinion and the opinion of others[28] that there will need to be a shift from a single-crystal dominated industry to a thin film industry. Many U.S. manufactures produce single-crystal only and thin film production, where it does exist, is experimental or only a small portion of the manufacturer’s sales. Single crystal silicon is too materials-expensive and materials-inefficient to be viable in the long run. Solar manufacturers are also in competition, competition that will only increase, with other industries for semiconductor grade silicon, an influence that could drive raw silicon prices higher. Manufacturers who must purchase wafers (instead of drawing and finishing their own boules) will be outpaced by the increasing standard wafer diameter; the industry standard is now twelve inches. As standard diameter increases, PV manufacturers must either retool their equipment to accommodate the increase or they must try to find a vendor who will furnish them with obsolete smaller diameter wafers.

The PV industry can meet the challenge of higher efficiency and lower costs, but only through a wide-scale change in the industry. Like all new technologies thin film photovoltaics is experiencing a lag between its promise and its reality. If thin films can come online as a full-scale-production commodity in the next 20 years PV will take off as a electricity generating technology on a global scale.

Figure 3. Forecasts for efficiencies (in percent efficiency) for different PV technologies.[29]



State of the Industry

No company has recorded net profits from PV manufacturing. Most have spent more on R&D than they have made in product sales. Federal funding of PV began in earnest in response to the OPEC oil embargo of the early seventies and several other factors. The Department of Energy created a PV program in 1975 to provide for R&D. This was supplemented by the Photovoltaic Research, Development and Demonstration Act of 1978 (PV RD&D). The Act, whose goal was for PV to be economic for central power generation ($0.12 per kWh) by 1988, called on the DOE to invest $2 billion from 1978-1988. The Reagan administration cut much of this program's funding, scaling back from the $200 million per year called for by PV RD&D to $50 million per year. Research was limited to that done on basic cell material instead of allowing the money to be used for development of large-scale manufacturing. This restriction impeded the transfer of technology from the laboratory to the factory. As Caldwell points out cost reductions occur in the factory, not the laboratory.[30]

PV manufacturers also found it difficult to secure capital and could not build new plants. The situation improved under the Bush administration and funding increased, but more markets will have to become available if costs are to continue to fall. As the industry matures and manufacturers ship more capacity, factory costs will decrease, making PV a more cost-effective electricity generating technology.

Table 5. Number of manufacturing companies and total shipments of PV in peak kilowatt (1985-1996).[31]

YEAR	# OF COMPANIES	TOTAL SHIPMENTS
1985	15	5,769
1986	17	6,333

1987	17	6,850
1988	14	9,676
1989	17	12,825
1990	19	13,837
1991	23	14,939
1992	21	15,583
1993	19	20,951
1994	22	26,077
1995	24	31,059
1996	25	35,464

CHAPTER TWO -- COSTS

To ask whether photovoltaic power can be feasible in Rhode Island is really to ask whether PV can be cost effective when compared to conventional fuels. Can PV compete with conventional fossil fuel or nuclear-generated electricity in terms of costs per kilowatt hour? There are other feasibility issues that can be considered such as siting issues and land use issues, but these same issues face every type of generating project and are so small compared to the price issue that I won't consider them in this analysis. In addition to the obvious cost factors, the price to the consumer, there are the more "hidden" or "local" costs. These costs are factors that can influence the value of a photovoltaic installation based on its geographic location or the local electrical industry environment.

Local costs are central to this thesis. I will show that photovoltaic installations in Rhode Island are not a prudent use of either a private consumer's resources or the state's resources based on cost considerations. Location is important in PV costs because the amount of the solar resource that is available ranges considerably across the United States. The amount of electricity produced by a solar installation is directly proportional to the amount of sunlight received. An installation has the same cost in the cloudy Northeast as it does in the sunny Southwest, yet the Southwestern installation produces between thirty and forty percent more electricity. In this chapter I will discuss the costs of a PV installation in both of these geographic regions. I chose Rhode Island in the Northeast and Arizona in the Southwest to compare the relative costs.

Electricity Costs

Generating Types

The cost of electricity is a function of the plant's installed capital costs, the price of fuel, and operating and maintenance costs. Fuel prices fluctuate and fossils are currently quite cheap. Combined cycle gas turbines produce electricity at approximately 4.5 - 5.5 cents per kilowatt-hour. Older paid-for coal plants produce at about 2.5 cents per kilowatt-hour.[32] Utility contracts in the upper Midwest are paying 4.5 cents per kilowatt-hour for wind power. This price includes an approximate 1 cent per kilowatt-hour federal production tax credit.[33] Photovoltaic electricity is reported to be produced at a cost of 15 to 25 cents per kilowatt-hour; however, in the example constructed in this chapter the actual costs to a homeowner are calculated to be much higher (30 to 43 cents per kilowatt-hour). The actual cost per kilowatt-hour of PV electricity can be difficult to determine; the same panels may produce significantly more electricity in one array than another due to factors such as local insolation levels, tracking mechanisms employed, and installation tilt, making the cost per kilowatt-hour lower.

Narragansett Electric

Above I discussed the prices of generation for different generation types; however, the generation cost is not the only cost to the consumer. One of the consequences of electric utility restructuring in Rhode Island is the unbundled bill. The unbundled bill breaks all electricity charges out into their individual components; it doesn't increase the total bill, but it lets consumers examine where each cost originates. If one examines a bill from Narragansett Electric, for example, it is evident that the greatest portion of the bill is for auxiliary charges, charges other than electricity production. In my example I will consider the Basic Residential Rate.

The first section of the bill is for Delivery Services, the costs of carrying the electricity from the generating plant to the consumer's residence. Narragansett Electric is now a delivery company and does not generate electricity. Every month each basic residential customer pays a $2.54 base charge. This is the minimum charge that each customer must pay regardless of the amount of electricity used. There is a transmission charge of 0.436 cents per kilowatt-hour. Transmission is the high-voltage delivery of electricity from the generating plant to the local distribution node. The next charge is the distribution charge of 3.68 cents per kilowatt-hour. Distribution is the low-voltage carrying of electricity from the local distribution node to the individual customer. Delivery charges also include a non-bypassable transition charge of 2.8 cents per kilowatt-hour. The transition charge is a charge that reimburses the utility for its stranded costs.[iv] The transition charge of 2.8 cents per kilowatt-hour will be collected from July 1997 until October 1998. In October 1998 the transition charge will decrease to 1.5 cents per kilowatt-hour.[34] A transition charge will also be collected at a rate set by the Public Utilities Commission through 2009. The last charge in the delivery section is a conservation charge of 0.023 cents per kilowatt-hour. This conservation charge, effective January 1997, funds demand-side management and renewable energy projects and will be discussed in detail in Chapter 3.

[iv] Stranded costs are costs that the utility prudently incurred in the regulated market to serve their customers

The price paid for electricity generation is found under the heading "Supplier Services". Every customer in Rhode Island is able to select an electricity supplier. Until a customer selects their own supplier (customers must select a competitive supplier by the end of 2009) their supplier will be the local utility either under the “standard offer” or as the "last resort service" provider. Although there were twenty-five generation suppliers registered to sell electricity in Rhode Island as of January 1998, the standard offer rates are low enough that there has been no real competition in the local electricity market. Effective January 1, 1998 the interim service, called "energy charge" on the bill, was available at the following costs:

- Narragansett Electric 3.382 cents per kWh
- Blackstone Valley Electric 3.051 cents per kWh
- Newport Electric 3.341 cents per kWh

Narragansett Electric’s standard offer rate will increase annually to 7.1 cents per kilowatt hour in 2009.[35]

Table 6. Electricity bill charges (Narragansett Electric).

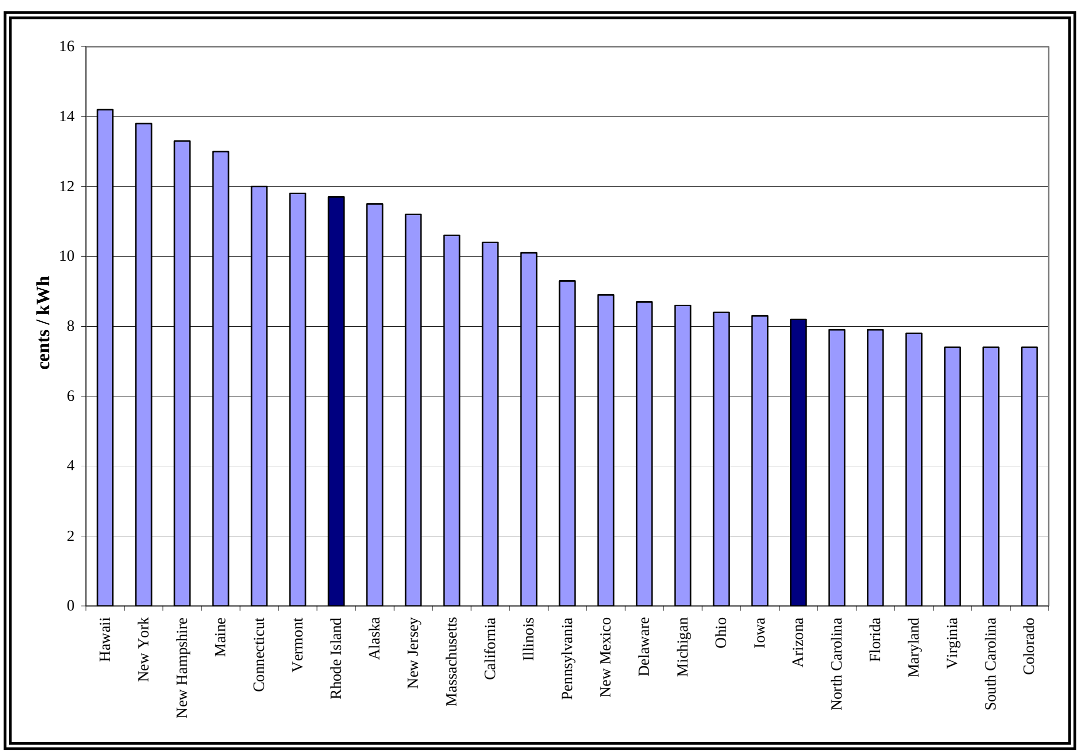
CHARGE	$/kWh
Customer Charge	2.54 (price per month)
Transmission Charge	0.00436
Distribution Charge	0.0368
Transition Charge	0.028
Conservation Charge	0.0023
Energy Charge	0.03382

An average residential customer of Narragansett Electric consumed 5,543 kilowatt-hours of electricity in the period July 1, 1996 through June 30, 1997.[36] This is

but which cannot be recovered if the consumer chooses another electricity supplier approximately 15 kilowatt-hours per day; at current prices that would translate to $614.05 in electricity for 1998 or approximately 11.1 cents per kilowatt-hour when all auxiliary charges are considered. I will use this number as the baseline for electricity costs in calculations to determine whether photovoltaic electricity is feasible in Rhode Island.

Because of the high price of electricity in the state, Rhode Island was the first state to deregulate its electricity market. In my calculation of feasibility, I will be comparing the price of photovoltaic energy in Rhode Island and in Arizona. One issue to consider is the relative cost of electricity in each state. Figure 4 shows that Rhode Island has an electricity price of 11.7 cents per kilowatt-hour, compared to 8.2 cents per kilowatt-hour in Arizona (i.e. electricity prices in Arizona are approximately seventy percent of those in Rhode Island). In each of my pricing calculations I will highlight system costs in Rhode Island and in Arizona.

Figure 4. Average revenue from electricity sales to all residential consumers. Rhode Island and Arizona are highlighted.[37]



Installation Costs

To determine if photovoltaics are feasible for a residential homeowner I have prepared a cost estimate for a photovoltaic installation for the average electricity consumption found above (15 kilowatt-hours per day) and compared the cost to that of a yearly electricity bill. Figure 5 details the equipment that a consumer has to purchase for a PV installation.

Household Electricity Demand

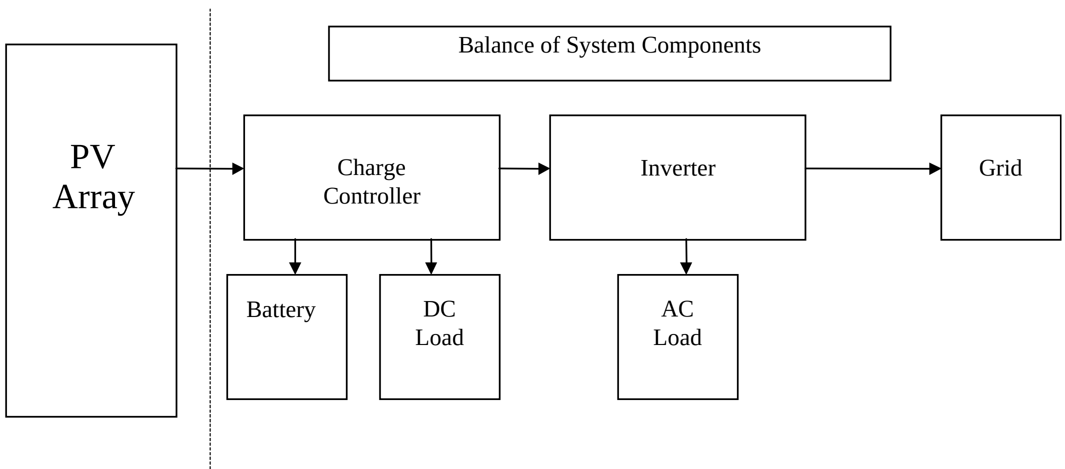
The first step in installing a PV system is to calculate how much electricity it will have to produce. This is done by determining the wattage of each appliance and estimating how long each one is used. This information is used to determine the load of the residence. I assume a usage of 15 kilowatt-hours per day, the average usage of a Narragansett Electric customer. I am assuming that average residential electricity usage will be approximately equal in Rhode Island and Arizona. This introduces error into my comparison because it does not take seasonal cooling usage, which would be higher in Arizona.

Photovoltaic Installation Components

A photovoltaic installation can be split into two pieces. A photovoltaic array which converts incident solar energy into electricity, and the Balance of System (BOS) components, which can constitute up to half of an installation's cost.

For my example I choose mid-range panels, the Solarex MSX-64 to make up the array. Solarex is the largest domestic solar manufacturer. Solar panels make direct current (DC) electricity and most appliances run off of alternating current (AC) power, therefore a DC/AC inverter is needed. DC appliances do exist, but they are very expensive. DC appliances also preclude the use of grid supplied electricity without an inverter to change the AC electricity to DC, which would cancel out the benefit of not buying an inverter. Some panels now come with built in inverters but I didn't consider them in this model.

Figure 5. Photovoltaic Installation Components.



Solar radiation's intermittence makes it imperative to provide for obtaining power during darkness or inclement weather. I only considered a system that is tied to the grid for auxiliary power needs. Being tied to the grid allows the opportunity to draw reserve power from the grid when needed and to sell excess power into the grid. This sale generates revenue that can help offset the cost of an installation.

Another essential piece of equipment is a charge controller, which routes the electricity generated by the panel. When there is a load the charge controller sends electricity from the panel to the load. If no electricity is being generated it directs power from the auxiliary power source. In a system with battery storage the charge controller directs power to the batteries when there is no load.

Local Solar Resource

Our purpose in this section is to determine the cost effectiveness of a solar installation in Rhode Island. I also have the additional goal of comparing the cost effectiveness of PV in Rhode Island with that in Arizona. The main factor that will drive this difference in cost effectiveness is the local solar resource of each location. A PV panel produces a set amount of electricity instantaneously (watts). In real terms electricity is measured as a function of its power (kilowatts) and time of use (hours): kilowatt-hours.[v] The more hours that a panel receives insolation the more hours it will be producing its rating of watts, and therefore producing kilowatt-hours of electricity. The more kilowatt-hours of electricity a panel produces, the more lightbulbs it will be able to light. Rhode Island receives only two-thirds the insolation of Arizona[vi], and the same solar installation would therefore produce two-thirds as much electricity. This makes the same installation more cost effective in Arizona.

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[v] One kilowatt is the amount of energy consumed when one thousand watts are used to one hour. This is equal to lighting a 100 watt lightbulb for 10 hours (100 watts x 10 hours = 1 kilowatt-hour).

[vi] The amount of insolation (incident sunlight) that a location receives is dependent upon latitude, cloud cover and atmospheric conditions (e.g. humidity). Some array types (concentrators) can only utilize direct sunlight, sunlight that hasn't been obscured by clouds or reflected off any surface. Others can use global insolation. Global sunlight is direct sunlight and diffused sunlight.

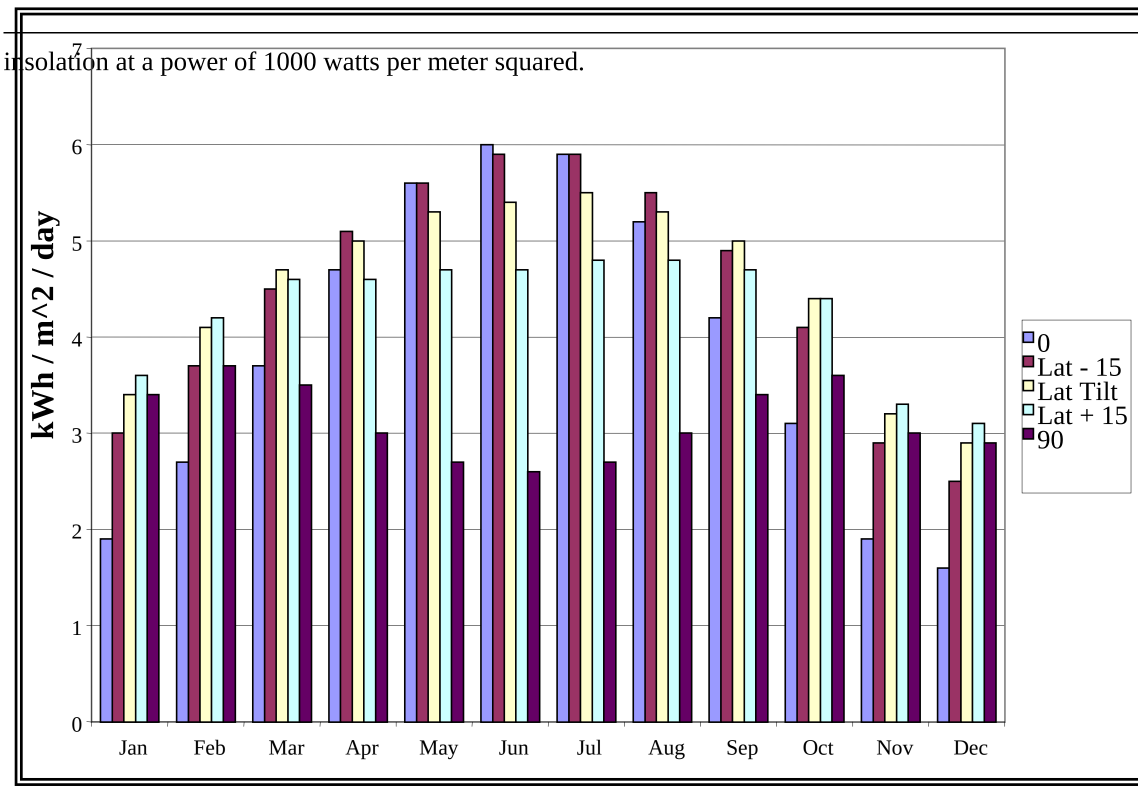
Figure 6 shows the amount of insolation in Providence, Rhode Island for each month in average number of "solar hours" per day.[vii] The chart gives the number of kilowatt-hours per meter squared per day. For each month four values are given. Each of these values corresponds to different tilts of the solar array. From the figure it is evident that the proper tilt is essential to producing the maximum amount of electricity for an array.

For my example I selected a tilt that maximized the average year-round collection. It is also possible to select a tilt that maximizes energy production in a selected time of year, for example, an installation on a summer home might be tilted to maximize the amount of insolation collected in the summer months. A consumer might want to maximize the amount of insolation collected in the summer to offset the load of an air conditioner. Summertime peak electricity is also more valuable, so maximizing summer generation would produce the most possible electricity for sale via net metering.

In Providence a tilt equal to either the latitude or the latitude minus fifteen degrees will yield approximately the same average amount of insolation per year. It is possible that a median tilt angle might receive more insolation, but hard data is only available in fifteen-degree increments. I selected latitude minus fifteen degrees because it allows for the collection of slightly more insolation in the summer months. Figure 7 shows the solar resource available at this angle. Phoenix, Arizona has a similar profile and I selected the same tilt for my contrasting example.

[vii] Hours are given in terms of hours at "solar noon". Times give the number of equivalent hours of

Figure 6. Insolation Providence, Rhode Island. Flat - Plate Collector Facing South at a fixed tilt. Four different tilts are presented.



insolation at a power of 1000 watts per meter squared.

Figure 7. Insolation -- Providence, Rhode Island. Fixed tilt (Latitude minus fifteen)degrees).

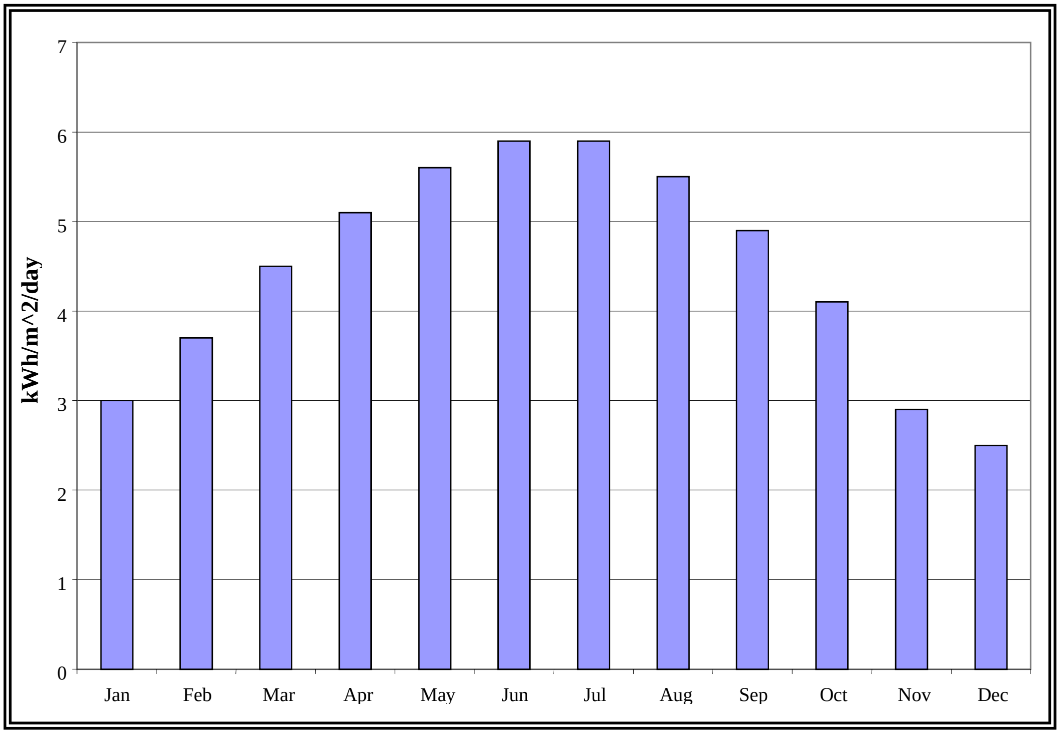
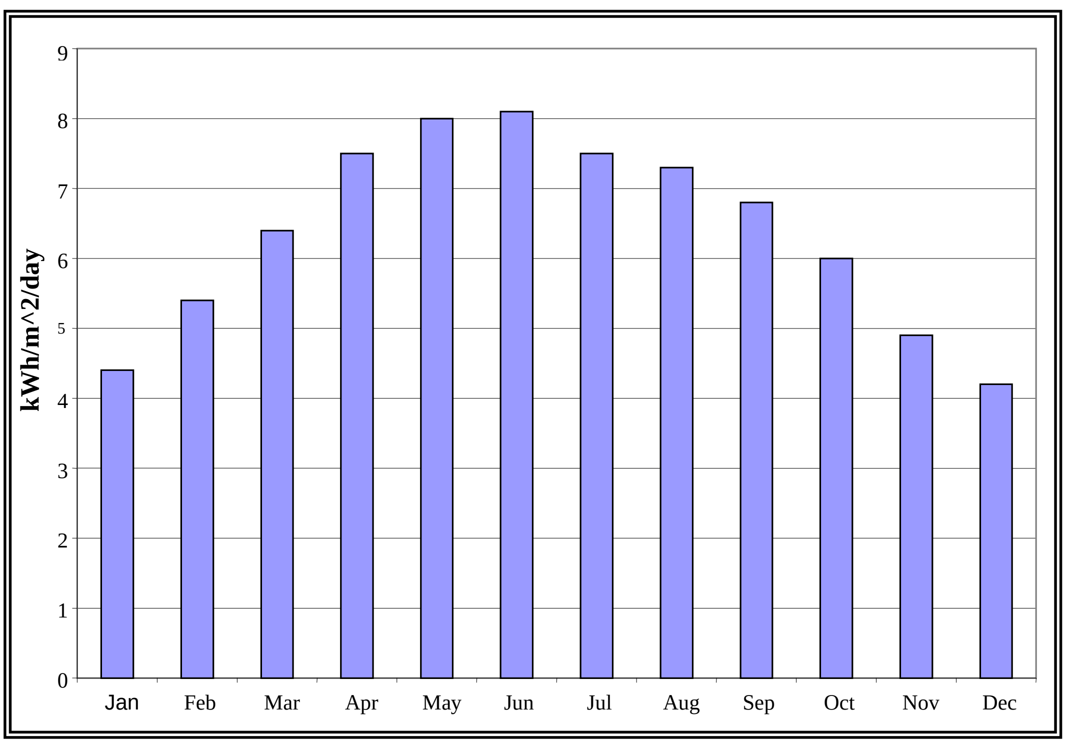


Figure 8. Insolation -- Phoenix, Arizona. Fixed tilt (Latitude minus fifteen degrees).



In calculating the cost of this installation I consulted several on-line components catalogs.[38,39,40,41] In each instance I selected the same panel, the Solarex MSX-64, and other mid-range pieces of equipment in an attempt to balance price and reliability. A consumer may be able to find a better deal or negotiate a bulk-purchase discount; neither of these scenarios was considered. All the sources that I consulted charged approximately the same price for the equipment, varying only about five percent between the least and the most expensive. The pricing information does not include shipping costs or additional costs for a contractor to install the panels, an electrician to do the wiring, or an inspector to approve the wiring. I assumed an inverter efficiency of 90%. I assumed that on an average day the system receives 4.5 hours of insolation in Rhode Island and 6.5 hours in Arizona.

I considered two cases: one was a grid-dependent system capable of meeting the demand of an average household (Table 7), the second was a 250 watt system (Table 8). I have selected a 250 watt system because it is the anticipated size of the majority of installations resulting from the Rhode Island system benefits charge discussed in Chapters 3 and 4.[42] In the full-sized system I assume that the electricity usage would be the Narragansett Electric average; however, any person who would choose to run their home entirely on solar energy would buy energy-efficient appliances in order to reduce their total load. This scenario is not considered, but although this would decrease the cost of the system, the cost reduction due to the smaller demand would be partially offset by the increased cost of energy-efficient appliances. There also my be more intangible costs due to life-style changes and other steps taken to reduce demand.

Table 7. Rhode Island and Arizona: equipment and cost comparisons. Full sized system.

	RHODE ISLAND	ARIZONA
Kilowatt hours / Day	15	15
Amp Hours / Day	1,388	1,388
Amp Hours / Day(account for system losses)	1,667	1,667
Sun Hours / Day	**4.5**	**6.5**
PV array amps	370	245
Peak amps of module	3.66	3.66
Number of modules required	**101**	**67**
COSTS		
Solarex MSX - 64 per panel	$420	$420
Cost of Panels	**$42,420**	**$28,140**
Charge Controller	$815	$815
Inverter	$3,680	$3,680
TOTAL COST	**$46,915**	**$32,635**

In my comparison the system in Arizona had sixty-nine percent of the cost of a system in Rhode Island that would produce the same amount of electricity. The cost per kilowatt-hour of each system can be calculated by making a few quick assumptions. Assuming a lifetime of twenty years for a photovoltaic system (based on the manufacturer's standard warranty) and that each system will produce fifteen kilowatt-hours of electricity every day, the total lifetime electricity production for each system is 109,500 kilowatt-hours. In Rhode Island this translates to $0.43/kilowatt-hour; in Arizona it is equal to $0.30/kilowatt-hour. Comparing the Rhode Island system cost to my earlier calculation of a yearly electricity bill shows the disparity in costs between PV power and conventional power. The payback period for a $46,915 system, which is replacing a yearly bill of $614.05, is nearly one hundred years.

The second system I considered is a 250-watt system without back-up storage. I considered same panels, Solarex-MSX 64, which produces 64 watts of power. To construct a 250-watt system requires 4 panels. To calculate the actual amount of kilowatt-hours of electricity produced the reverse of the calculation in table 7 must be done. This calculation includes system losses and conversions to Amp-hours from watt-hours. The installations required the same pieces of equipment and the same consumer cost; the disparity in the value of this system scales directly with the insolation ratio of the two locations.

Table 8. Costs and Electricity Production for a 250-watt system.

COSTS	**Rhode Island**	**Arizona**
Sun hours per day	4.5	6.5
kWh / Day	0.569	0.913
kWh Produced per Year	**208**	**333**

In this example, the system installed in Rhode Island would only produce seventy percent as much electricity as the system in Arizona. The electricity produced by this array can run one 100-watt bulb a bit less than five hours per day. In an entire year in Rhode Island the system would produce approximately two weeks worth of electricity. A solar installation this size is not an electricity generating device, it is a gesture. This system is viewed most appropriately as a demand-side management device, and as such it is the most expensive demand-side management device available to a homeowner. If a homeowner took this money and did anything else (such as buying more efficient appliances or weatherizing the home) the return on investment would increase.

Solar Installation Location

In both of my examples, locating a solar installation in Arizona is between thirty and thirty-five percent more cost effective than locating it in Rhode Island. An equal sized system produces one-third more electricity; or the same amount of electricity is produced at two-thirds the cost. When these savings are examined in the context of the relative price of electricity in each state the picture is less clear; electricity prices are roughly thirty percent less in Arizona than in Rhode Island which reduces the net benefit of building a system in that state.

As stated earlier, a major reason for supporting the photovoltaic industry is to produce electricity with a minimum of carbon emissions. Although their high costs currently preclude the derivation of a large percentage of the domestic electricity supply, to reap the largest benefit from the amount of photovoltaic capacity that is affordable now the installations should be sited in locations that are either sunny or remote. If we have a national policy, such as that proposed by then Secretary of Energy Federico Pena in a speech given on June 15, 1998 to the American Power Association in San Antonio, of a Renewable Portfolio Standard of 5.5 % by 2010[43], then the location of these installations becomes very important. In this case the most efficient practice would be to install these generating facilities where in the Southwest where they would produce more electricity. Other national policies, such as the Million Solar Roofs initiative discussed in Chapter 5, should be directed to where they will make the best use of public funds and displace the largest amount of carbon dioxide.

Cost Lowering Mechanisms

Consumer Pricing

The price that a consumer pays for a photovoltaic installation can be looked at from two sides, the manufacturing side and the retail side. Each part of the pricing equation influences what the consumer ultimately pays for the product. The manufacturing side of the equation will be looked at in detail in Chapter 4, Photovoltaic Technology. The manufacturer can bring the price of the installation down by making more efficient panels, enabling the purchaser has to buy a smaller array to produce the same amount of electricity. The manufacturer can also reduce prices by increasing yield and streamlining the manufacturing process to make the same parts more cost effectively. Currently most PV installations are custom made. A larger market would enable standardization of components and designing in of PV components into construction instead of the costly practice of engineering custom components into existing structures. If these costs can be reduced from their current levels making PV more cost effective for the consumer.

Tax Incentives

There are programs and incentives to assist the consumer on the retail side of the market. The primary example of this type of cost reduction is a tax incentive. Tax incentives do not really reduce the cost of installations, they spread the costs over a greater population, but they can stimulate demand. Both the federal government and state governments offer (or propose) some type of tax break for solar-powered installations. Previously Rhode Island offered tax incentives for the purchase of renewable energy generating equipment, but they were repealed 1 July 1995.[44] The tax incentives available in Rhode Island were:

- *All purchases of solar equipment were exempted from sales tax.*
- *Solar installations had no higher value than the conventional systems that they replaced for property tax assessments.*
- *Businesses installing PV were eligible for a state tax credit up to 10 percent of the system's value not to exceed $1,5000.*
- *Individuals installing PV in their primary residences were eligible for an state income tax credit of 10 percent on the purchase and installation cost of the system.*

Massachusetts still offers tax breaks for consumers[45] by exempting solar power facilities from all local property taxes for a maximum of twenty years. Massachusetts also provides a fifteen-percent personal income tax credit up to a maximum of one thousand dollars. This can be carried over to the next year if the credit is greater than the tax liability for one year. There are also corporate tax incentives in Massachusetts.

On January 30, 1998 in Fairfield, California at the dedication of a British Petroleum manufacturing plant, Vice President Gore proposed a federal income tax credit on the purchase of photovoltaic panels. This tax break is part of the Million Solar Roofs project that will be discussed further in Chapter 5. This incentive would be very similar to the one in Massachusetts. The credit would be equal to fifteen percent of the cost of a rooftop photovoltaic system up to two-thousand dollars. The credit would be effective 1999 and extend up until 2005. The tax credit is part of the 6.3 billion dollar package of tax incentives and research and development money to promote energy efficiency and renewable energy resources announced by the President in the 1998 State of the Union Address. It remains to be seen whether this package will receive funding from Congress and in what form it will be funded.

Net Metering

A factor that can make the installation of a photovoltaic system by a homeowner more cost effective is the availability of net (reverse) metering. Net metering is the situation whereby a customer is able to reduce the amount of electricity for which they are billed by running their meter backwards by the amount of excess electricity they have supplied to the grid. This can help offset the price of an installation because systems generate the most electricity during the times that residential demand is low. Once the basic energy needs are met (such as the refrigerator and some other fixtures that run continuously) a grid-connected system can route the excess electricity into the grid. Net metering can be beneficial to the utilities also because it allows them to claim that a certain percentage of their electricity comes from renewable sources. Although the utility may not know exactly how much electricity is being supplied to the grid instantaneously, customers who net meter must inform the utility of the size and type of their installations, and the utility is responsible for supplying this information and an estimate of the kilowatt-hours produced to the Public Utilities Commission semi-annually.[46]

Net metering has existed in Rhode Island since 1985, and there are currently nine customers in the state that take advantage its availability.[47] The method of tracking net metering was recently a source of debate. The Public Utilities Commission wanted to change the method of tracking net metering because they felt that reverse metering unfairly subsidizes renewables customers.[48] In reverse metering a meter is run backward; decreasing a customers bill by the amount of electricity added by the customer to the grid, which reimburses the customer at the retail rate. As I discussed earlier in the chapter, the retail rate for an average residential customer is 11.1 cents per kilowatt-hour, but only 3.382 cents per kilowatt-hour is charged for electricity, the balance is made up of auxiliary charges. Because the renewables customer is producing wholesale electricity and being reimbursed at the retail rate, the PUC sees this as an unfair subsidy. The National Resources Defense Council estimates that the current cost of the program is $3,252, or approximately 0.3 cents per year for a residential customer.[49]

The Public Utilities Commission wanted to switch to using two meters, one to measure the amount of electricity coming in and one to measure the amount being added to the grid. The excess energy would be sold separately, avoiding the rate differential present in reverse metering. Buying a second meter would cost Narragansett Electric about $1,000 per customer, and the utility is opposed to the change.[50]

This issue was resolved in a PUC docket in which the Commission stated that the public policy of the state is to support renewables generation because the benefits of such generation outweighs subsidies by other customers.[51] The PUC concluded that having two meters would cause high administrative costs. Existing installations will continue under the State's previous policy, and new installations will be subject to the following limitations.[52] Usage and generation will be netted for a 12-month period. Generation credits will accumulate from month-to-month for one year; at the end of the year unused credits will be discarded. Reverse metering is limited to the renewables technologies in the Utility Restructuring Act, R.I.G.L. § 39-2-1.2(b). Reverse metering for Narragansett Electric is limited to one megawatt. Avoided charges are limited to kilowatt-hour charges and do not include kilowatt-based charges. The Commission also ordered that $3,000 be used from the renewables fund[viii] be used for meters to monitor the first ten to twelve installations, to record their performance. Modems on the meters will supply Narragansett Electric with data at fifteen-minute intervals. The data is to be reported to the PUC as requested.

Narragansett Electric plans to buy and put into the power exchange any net metered electricity. Blackstone Valley Electric and Newport Electric haven't yet filed a net metering provision with the PUC, but they have indicated that they are likely to use any purchased power for last resort power.

Time-of-Use Value

Electricity loads vary during the course of the day. Residential use peaks at about 7 p.m. and is at a low level from 1 a.m. to 5 a.m. Electricity use also varies during the year peaking in late December with a smaller peak in July and August. Winter peaking hours for residences occur at roughly the same hours as summer peaks, but the size of the peak varies. Figures 9 and 10 show usage patterns for residential customers.

The electricity load is not distributed evenly in time, and since electricity must be used instantaneously, generators must have capacity available to meet demand for the highest peak. This means that suppliers must have dedicated plants that come on-line

[viii] This fund is a system benefits charge and is discussed in Chapter Three.

only during these times of peak demand. Bringing plants on-line is directed by the independent system operator, an entity that is described in the following chapter. Providing for a peak demand requires excess capacity that is often idle, i.e. not producing any electricity to bring in revenue. Peak plants, and therefore peak-time electricity, is more expensive or valuable than non-peak electricity. A residential PV installation produces the most electricity at noon, at time when a residential electricity use is moderate which may leave excess electricity available for sale. This corresponds well with peak usage system wide; although residential customers have lower demand during these times, the demand from commercial and industrial customers is highest during midday. This correspondence with overall system peak makes PV electricity particularly advantageous to suppliers.

Figure 9. Average Residential Load in Total Daily kWh.[53]

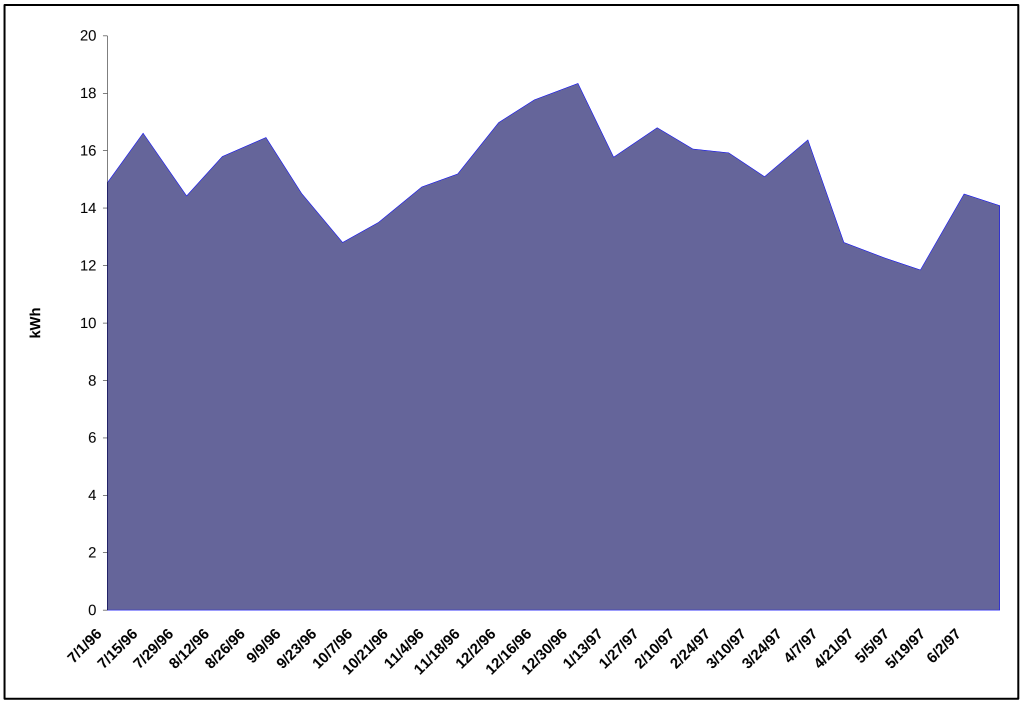
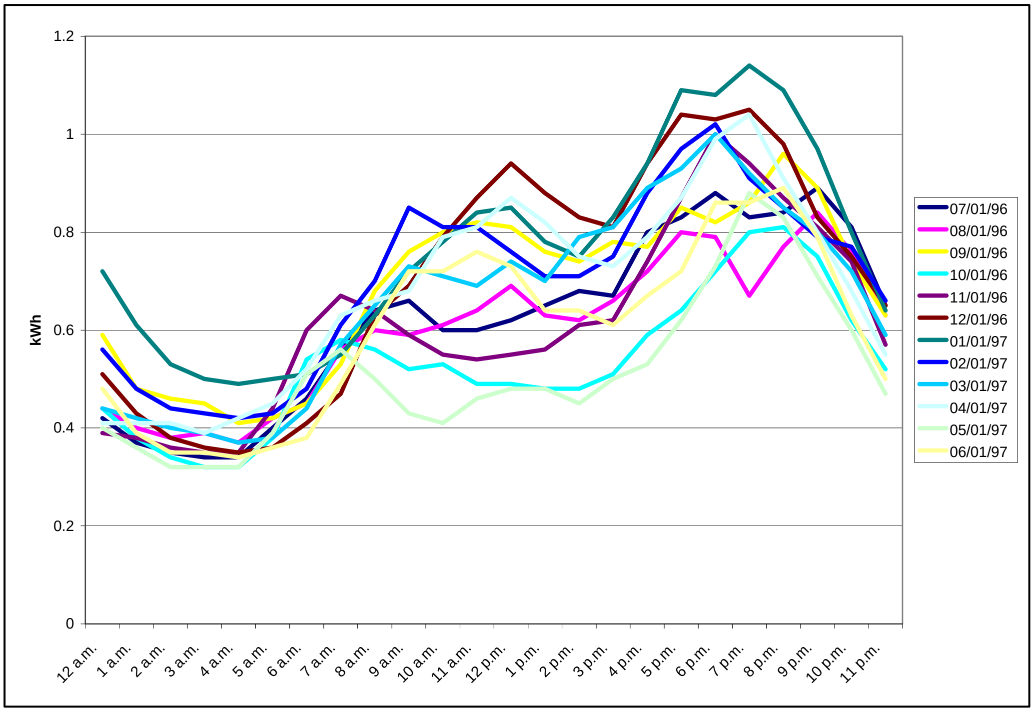


Figure 10. Average Residential Load in Hourly kWh Usage by Month.[54]



Externalities

A topic that is beyond the scope of this thesis but is important to mention is the social costs, or externalities, of electricity production. Social costs due to electricity production include:[55]

- *Impacts on human health (short term, long term, and intergenerational)*
- *Environmental damage*
- *Long term costs of resource depletion*
- *Structural macroeconomic effects (e.g. employment)*
- *Subsidies to fossil-fuel generators*
- *Costs of increased probability of international conflicts (wars, nuclear proliferation)*
- *Costs of radioactive contamination*

Because the market does not reflect all of these costs when the value of photovoltaic power is compared to conventional-fuel generation resources may not be allocated efficiently. If these social costs are assumed to be high, PV became cost effective in 1996.[56]

CHAPTER THREE -- DEREGULATION OF THE RHODE ISLAND ELECTRIC INDUSTRY

What is deregulation?

The Rhode Island electricity market was deregulated though the Rhode Island Utility Restructuring Act of 1996. The Act was first introduced on February 7, 1996. It was signed into law on August 7, 1996. The deregulation of the electric industry changed utilities from being vertically integrated,[ix] and from a situation in which generation, transmission, and distribution are subject to oversight from the Public Utilities Commission, to one in which the generation of electricity is open to competition. In the new competitive market the price of electricity **generation** is no longer regulated and its price is set purely by the market. Customers are free to buy their electricity directly from the generator or through a power marketeter.

Most customers in Rhode Island are customers of one of two registered holding companies. The first holding company is New England Electric System (NEES) which is the parent company of Narragansett Electric. The second is Eastern Utilities Associates (EUA) which is the parent company of Blackstone Valley Electric and Newport Electric. The parent companies, which had supplied all of the electricity for their retail affiliates, are now in the process of selling off their generation plants. NEES' generation company,

[ix] A vertically integrated utility is on in which the same company controls the means of generation, transmission and distribution of electricity.

New England Power, has sold its fossil fuel plants to U. S. Generating Company which is an affiliate of Pacific Gas and Electricity (PG&E).

Utilities are still responsible for maintaining transmission and distribution lines. Transmission is conducting high voltage electricity from the point of generation to local distribution nodes. Distribution is the process of transforming high-voltage electricity to lower voltage and delivering it from distribution node to individual customers. In Rhode Island utilities still meter electricity use and bill for usage unless the customer requests individual billing from their supplier.

As of January 1, 1998 all Rhode Island customers of either a NEES or an EUA utility were eligible to purchase electricity from an independent supplier (either a generator or a power marketer). Customers who do not opt to switch will remain customers of their utility and will pay an energy rate which has been approved by the PUC.[x] An approved energy rate is in effect and will be the default power package until 2009 at which time all customers will have to purchase power through the competitive market. The utility is also the supplier of last resort service, if a customer is unable to secure electricity from the competitive market the utility must supply them.

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[x] This energy rate is the standard offer referred to in Chapter 2.

Electricity Delivery Structure

When electricity is purchased from a certain supplier your home does not exclusively receive electrons generated by that entity; that would require the running of individual transmission lines directly from the power plant to the customer. The generator delivers enough electricity to the power grid to cover its contracts and also provides extra electricity to balance transmission losses.[xi]

Since the advent of deregulation an entity known as "ISO-NE" -- independent system operator-northeast directs electricity from generator to customer and ensures that there is an adequate supply to meet demand even at peak time. Prior to the creation of ISO-NE this job was done by the New England Power Pool (NEPOOL). NEPOOL was created in 1971 in response to the Great Blackout of 1965. NEPOOL was responsible for preventing large scale losses of power and for ensuring that electricity was generated in the most cost-effective manner. NEPOOL knew what each power plant's cost of generation was and used this information to schedule plant shut-downs and start-ups in a manner that would produce electricity most cheaply. This meant that plants that were expensive and slow to start were constantly kept running as the baseline for power production. These plants were the coal burning plants and the nuclear plants. Other plants were brought on-line to meet demand as needed. NEPOOL also provided for the dispatch of power when certain plants would be off-line for regularly scheduled maintenance. NEPOOL also supplied replacement power if a sudden loss of a generating unit or transmission line occurs.

[xi] Electricity lost due to the intrinsic resistivity of transmission lines.

In the deregulated market power generators will run first to meet their contracts. Once their contracts have been met they can bid their excess capacity at any price they want, not at their cost as was bid previously. When demand is greater than what is contracted or if another producer's generation equipment is down for some reason the independent system operator brings capacity on-line according to the bid cost.

History of the Electric Power Industry[57]

At the turn of the century, vertically integrated utilities produced only 2/5 of the nation's electricity. Many businesses generated their own electricity on-site. When utilities began to install larger and more efficient generators and more transmission lines, the associated increase in convenience and economical service prompted many industrial consumers to shift to the utilities for their electricity needs. The invention of the electric motor caused an increase in the use of electricity by households electricity, which were serviced by the utilities. As consumption of electricity increased so did the utilities' share of electricity production.

Utilities operated in designated service areas. With the designation of these exclusive franchise areas (usually municipalities), came the responsibility to serve all consumers within that territory. Utilities were seen as natural monopolies.[xii] The most efficient source of power was seen as a single generation, transmission and distribution entity. Monopolies were outlawed by the Sherman Antitrust Act; therefore, regulatory oversight to protect consumers from exorbitant prices and to provide reliability and a fair rate of return to the utility was necessary. This resulted in the traditional rate of return regulation.[xiii]

Electric holding companies, which by the 1920s controlled much of the industry, formed and expanded during this time. No legislation existed to limit the size or number of holdings of these companies, nor was there a limitation on other companies that these holding companies could control. In some cases electricity companies were managed inefficiently. The losses from these companies were hidden in the profits of other companies held by the parent company. Unregulated holding companies were able to abuse their power over their subsidiaries. This sometimes resulted in increased consumer costs. These companies often had holdings in more than one state and state governments were not able to regulate them; there was a need for federal authority.

The Public Utility Holding Company Act of 1935 (PUHCA, P.L. 74-333) brought holding companies under the authority of the Securities Exchange Commission. Utilities

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[xii] Natural monopoly -- A situation in which one firm can produce a given level of output at a lower total cost than can any combination of multiple firms. Natural monopolies occur in industries that exhibit decreasing average long-run costs due to size (economies of scale). According to economic theory, a public monopoly govern by regulation is justified when an industry exhibits natural monopoly characteristics).

[xiii] Rate of Return Regulation -- A regulatory system whereby electricity prices are set to allow the providers just enough sales revenue to recover the expected total costs incurred in producing or acquiring

in interstate wholesale marketing or transmission became regulated by the Federal Energy Regulatory Commission (FERC). Before the PUHCA was passed almost half of the electricity produced in the United States was produced by three huge holding companies. The Securities Exchange Commission was given the authority to break-up the massive interstate holding companies, which were required to divest their holdings until each became a single consolidated system serving a circumscribed geographic area. Holding companies were permitted to engage only in business that was essential and appropriate for the operation of a single integrated utility. This restriction practically eliminated the participation of non-utilities in wholesale electric-power sales.

For decades utilities were able to meet increasing demand at decreasing prices. Economies of scale were achieved through capacity additions, technological advances and declining costs. Even during periods when the economy was suffering the utilities performed well. The monopolistic environment left them free from the worries that competitors would have created. This period of prosperity continued until the late 1960s when the electric utilities saw decreasing costs and rapid growth give way to increasing unit costs and slower growth. This was contributed to by:

- *The Northeast Blackout of 1965 which raised concerns about reliability*
- *The Clean Air Act of 1970 (amendments of 1977) which required reductions in pollutant emissions*
- *The Arab Oil Embargo of 1973-1974 which caused higher fuel costs*
- *The Three Mile Island accident in 1979 which caused higher costs, regulatory delays and uncertainty in the nuclear industry*

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electricity including a rate of return equal to the utility's cost of capital.

- *Inflation which caused interest rates to triple*

In response to these conditions Congress enacted legislation to reduce the United States' dependence on foreign oil, develop renewable and alternative energy sources, sustain economic growth, and encourage the efficient use of fossil fuels. The Congress produced the Public Utility Regulatory Policies Act of 1978 (PURPA, P.L. 95-617). PURPA allowed non-utility facilities called Qualifying Facilities (QF's) that met certain ownership,[xiv] operating[xv], and efficiency criteria established by FERC to enter the wholesale market.

Utilities were mandated to purchase power from Qualifying Facilities (QFs) at their incremental or avoided costs. Utilities resisted this mandate at first, but found that buying power from the QFs made sense because of the increasing uncertainty of recovering capital costs resulting from building new plants to meet increased demand. Congress exempted most QFs from rate and accounting regulation from FERC, from regulation by the SEC and from state rate, financial and organizational regulation of utilities. It also simplified contracts, streamlined the power sales process, increased financial certainty for creditors and equity sponsors and generally eliminated several procedural and planning problems that had made entry into the electricity market prohibitive for smaller energy producers.

The Energy Policy Act of 1992 (EPACT, P.L. 102-486) created a new category of power producer: the exempt wholesale generator (EWG). EWGs differ in many ways from QFs. They are exempt from PUHCA's corporate and geographic restrictions.

[xiv] QF's can not have more than fifty percent of their equity interest held by an electric utility.

[xv] QF's must be renewables or cogeneration units only.

EWGs are not regulated and may charge market based rates. Utilities are not required to buy power from EWGs. EGWs also differ from QFs in that they are not required to meet PURPA's cogeneration and renewables fuels limitations. EPACT also provides transmission-dependent utilities the ability to shop for wholesale power.

The marketing of EWG power was facilitated by transmission provisions that gave FERC the authority to mandate that utilities provide access to their transmission system. Independent power producers, publicly owned utilities, rural cooperative and industrial producers gained the ability to receive from FERC orders that require transmission-owning utilities to provide transmission service at FERC-defined "just and reasonable" rates.

Deregulation's impacts on existing legislation

The distinction between federal and state jurisdiction over power supply will become more important in a deregulated environment. Federal authority over electric power is vested in FERC, which regulates wholesale power transactions. The Federal Power Act defines "sale at wholesale" as any sale to any person for resale. With deregulation a greater percentage of power sales will be wholesale transactions.[58] The Supremacy Clause of the United States Constitution affirms that states may not interfere with federal authority and that federal law is paramount should there be a conflict. Therefore, there will be increasing federal control over power sales.

FERC is tending towards regulation that promotes market-based pricing. FERC has ruled against deliberate above-market pricing for renewable resource power. The states have been barred from causing wholesale power transactions from renewable resources to be carried out at higher sales prices than sales from non-renewables by either regulation or the configuration of markets.

If a state wants to promote the use of renewable electricity sources by means of provisions in their restructuring legislation or by creating other programs, it is constrained in their actions by the federal authority over wholesale electricity transactions. The states must operate on the retail side of the market. For example, a state can require that all electricity providers market a certain percentage of renewable electricity (a portfolio standard). This seems counter to the fact that states must utilize market based pricing since renewable electricity is more expensive than conventional electricity. The FERC ruling prohibits a state from compelling retailers to purchase renewable energy at a fixed price. It does not prohibit a state from compelling a retailer to purchase a fixed amount of renewable energy. The retailer is free to pursue the best price for the renewable energy, but the energy must be purchased. What options are open to states?

- *Voluntary "green power" marketing*
- *Portfolio standards for retailers of power*[xvi]
- *State tax incentives for renewable power generation*
- *System benefits charges to create funds to support renewable energy*
- *Expedited state regulatory approval or removal of financial, siting or other market barriers*

Most states that are restructuring have selected either a system benefits charge or the combination of a system benefits charge and a renewable portfolio standard. See

Appendix II for a state-by-state break down of renewables. Rhode Island has selected the system benefits charge as a means to influence the amount of renewables in the electricity mix.

System Benefits Charge

A system benefits charge (SBC) is a mechanism for collecting revenue which can be used for some purpose, such as subsidizing renewables electricity. In Rhode Island's case the SBC creates a pool of revenue by attaching an extra charge to each kilowatt-hour of electricity as discussed in Chapter 2.

Pursuant to the Restructuring Act Title 39 Public Utilities and Carriers Chapter 39-2 Duties of Utilities and Carrier Section 39-2-1.2 Utility base rate states:

> (b) Preservation of environmental ....programs. Effective as of January 1, 1997, and for a period of five (5) years thereafter, each electric distribution company shall include a charge of 2.3 mills per kilowatt-hour delivered to fund demand side management programs and renewable energy resources. The allocation of this revenue between demand side management programs and renewable energy resources shall be determined by the commission.....As used in this section, renewable energy resources shall mean power generation technologies that produce electricity from wind energy, small scale (less than 100 megawatts) hydropower plants that do not require the construction of new dams, solar energy, and sustainably managed biomass. Fuel cells may be considered an energy efficiency technology to be included in demand-side management programs.

The SBC is expected to generate approximately $20 million in 1998. The Public Utilities Commission (PUC) has determined that the bulk of this fund will go to demand side management (DSM), and that only one million dollars will be expended on

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[xvi] A portfolio standard mandates that power retailers derive a certain percentage of their power from

renewable resources in 1998. The PUC has the authority to switch money between DSM and renewables so that if either DSM or renewables lag, more money can be spent on the other.[59]

A Request for Proposals (RFP) for the distribution of the renewables portion of the fund was issued in the fall of 1997. The RFP was sponsored by the Rhode Island Renewable Energy Collaborative, a group patterned after the Rhode Island Demand Side Management Collaboratives and is comprised of members representing Narragansett Electric, Newport Electric, Blackstone Valley Electric, Pascoag Fire District, the Division of Public Utilities and Carriers, the Conservation Law Foundation, The Energy Council of Rhode Island , and the Rhode Island State Energy Office. The RFP made available funding of up to $500,000 per project.

The Collaborative's long term objectives were stated as being, "to overcome barriers to the increased use of .... renewable technologies and aid in the commercialization of renewable resources." Previous to the RFP the Collaborative commissioned a study of the potential of renewable resources in Rhode Island and Massachusetts to "gain a thorough understanding of feasible technologies". The Collaborative sees commercialization efforts involving:

- *Improving sales, installation and servicing infrastructure of renewable technologies*
- *Increasing customer awareness*
- *Lowering high up-front costs of the technologies and*

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renewable sources.

- *Installing and maintaining renewable technologies by well-qualified and/or certified contractors in the New England region*

The Collaborative also conducted a market development study for the photovoltaic industry. This study identified four niche markets in the PV industry to help commercialize PV sustainably. These niche markets are outdoor lighting, residential rooftop PV, PV-augmented uninterruptible power supply systems for computer networks, and PV for new communication technologies.

The Requests for Proposals were sent to more than 70 bidders. These bidders were developers, manufactures, installers, RI-registered non-regulated power producers, etc. The RFP expressed interest in immediately employable projects on the supply side, or customer side, of the meter. Bidders were expected to seek funding and other in-kind contributions from other parties. Bids were constrained to be for new projects not yet constructed or begun to be constructed. Technologies that are already commercially available were the only ones available for funding. Funded projects were required to be finished by the end of 1999.

Projects were expected to be realistic and economically attractive. Projects were desired that would stimulate demand, reduce market barriers, and grow the local renewables energy industry. Funded projects were expected to supply energy on a reliable basis within the intermittence and dispatchability of the technology. Technologies that could defer distribution system upgrades and could be easily interconnected with the grid were described as particularly attractive. As were ones that could produce energy during Rhode Island's peak load which is December 1 through

February 28 from 4:00 to 7:00 p.m. in the winter and July 1 through August 21 from noon to 4:00 p.m. for summer. Large-size industrial-installation projects as well as smaller-sized residential projects were to be considered. The Collaborative sought a diverse cross-section of customers.

Funded projects were expected to demonstrate sustainability. Proposals were expected to address barriers to renewable resources such as lack of financing mechanisms; lack of sales, installation, and servicing infrastructure; lack of standardized product; lack of information by qualified consumers; and high transaction costs. It was the intention of the Collaborative that by addressing these barriers the funded projects could be replicated and create a sustainable market for renewable energy that would exist without further financial assistance.

The successful bidders for the System Benefits Charge monies were disclosed in the State of Rhode Island and Providence Plantations Public Utilities Commission Docket number 1939 in response to the Narragansett Electric Company 1998 Conservation and Load Management Adjustment Provision. The Stipulation of Parties was issued November 24, 1997. The two funded proposals, which are to be funded in 1998 and 1999, were selected from 14 submissions. The Renewable Energy Collaborative has issued an additional RFP focused on commercial solar installations and fuel cells.

The first funded proposal funded is a supply-side wind turbine project. The Collaborative is funding up to $500,000 of the estimated $2.1 million total project cost, the balance will be made up from other renewable energy funding projects and other sources. The wind project was awarded to Endless Energy which is based in Maine. At this time Endless Energy is working in conjunction with town planners in several coastal communities to do assessments on the feasibility of siting of wind generation in Rhode Island based on both wind resources and community acceptance.[60] After the assessments are completed, Endless Energy expects to install one to three turbines.

The second proposal is for a rooftop PV program. This program is being run by a company based in Vermont named Solar Works. The target markets for this program are new construction, existing homeowners, and a PV-uninterruptible power supply program. This project is a two year phased-in project with a goal of 100 installations in 1998 and 500 installations in 1999. At the end of two years this would correspond to a total installed capacity of 250 kW of grid-connected PV power. This project has been given a two year budget of up to $250,000. Up to $90,000 of this will be spent in 1998 and the remainder will be spent in 1999. This money will be paid in a dollar per installation performance basis, and 1999 funding is contingent on meeting certain milestones in 1998. In addition to Collaborative funding this project will receive $250,000 from the Department of Energy Utility Photovoltaic Group. The total project costs are estimated to be $1.6 million.

Solar Works is currently in the marketing phase of their project. They are looking at both residential and school customers. An update of their progress was handed to the PUC the week of May 25, 1998

CHAPTER FOUR -- PROGRAMS

In order to provide context for the Rhode Island program, I give examples of diverse programs being run on both the national and local level. Other programs and private companies entering the solar market in New England are also presented.

Funding Programs

Team-Up

Technology Experience to Accelerate Markets in Utility Photovoltaics or TEAM-UP is a program of the Utility PhotoVoltaic Group (UPVG), which is an association of U.S. and international electric utilities and power producers was formed in 1992. The UPVG's mission is to "accelerate the use of cost-effective small-scale and emerging large-scale applications of PV for the benefit of electric utilities and their customers."[61] TEAM-UP is a 50 megawatt photovoltaic hardware initiative for large scale application and grid-independent applications.

A significant portion of TEAM-UP funds, approximately one-third, comes from the Federal government. In all the UPVG hopes to fund $509 million over six years; however, their original budget has been reduced dramatically.

The first TEAM-UP request for proposals was issued in late 1994. This RFP was for grid-connected installations. It resulted in the installation of 5.6 megawatts of PV.

The next RFP in late 1995 was for both grid-independent and grid-connected PV. The recipients of these monies are listed in Appendix III.

TEAM-UP grants are important because the securing of these funds can be used to leverage funding in other programs, such as the program that Rhode Island is funding this year. The UPVG supports these installations because they have determined that up to 250 to 350 megawatts of grid-connected PV may be required for sustained PV commercialization.[62]

Million Solar Roofs

The Million Solar Roofs Initiative was announced by President Clinton on June 26, 1997 in a speech before the United Nations Session on Environment and Development. The Initiative aims to put one million solar energy systems, both photovoltaic and solar thermal, on the roofs of public and private building by the year 2010. “The Initiative will not direct and control the activities at the state and local level nor will it typically pay for the installation or solar energy systems. Instead, the Million Solar Roofs Initiative will bring together the capabilities of the Federal government with key businesses, state and local governments."[63] The goals of the Million Solar Roof Initiative are to:

- *Reduce Greenhouse Gas emissions*
- *Save Energy*
- *Create high tech jobs*
- *Keep the US solar industry competitive*

The Million Solar Roofs initiative does not create any new funding, as far as the program has evolved so far. A 10 Point action plan that is detailed in Appendix IV has been developed for creating a MSR bureaucracy wherein the Department of Energy (DOE) will work with other federal agencies, such as the Environmental Protection Agency, to pool funding to reach the million roof goal.

The Million Solar Roofs program does propose monies for solar installations. As mentioned in Chapter 2, there is a proposed federal tax credit of up to $2,000 for photovoltaic installations. This tax credit is part of a $6.3 billion dollar package of incentives for energy technologies designed to combat global warming. MSR also calls for increased support for research, development and demonstration. The DOE's 1999 budget request calls for a 49% increase in solar technology funding.

All of these monies are currently in the form of funding requests. PV has not faced a politically friendly climate in the past few years, and the actual disbursements are certain to be less, perhaps dramatically so, than the requests. It is not evident that MSR is a change in the ideals of the federal government, but rather, it appears that it is an attempt by the government to count the systems that are being installed and claim credit for them.

Rooftop Photovoltaic Programs

Several utilities and private companies across the country are implementing rooftop solar generating installations. These programs are mainly targeted toward residential installations and draw upon the recent popularity amongst the public for "green" technologies. PV can be land-use intensive and utilities and other power producers who are considering using solar power are faced with obtaining large tracts of land. Employing rent-free roof area can make large-scale installations possible without prohibitively expensive land purchases.

City of Austin Electric Utility has a centralized solar power plant, but Austin also has rooftop installations on public buildings such as a convention center and an installation on a housing project for the elderly.[64] Other utilities such as Detroit Edison and the Sacramento Municipal Utility District have substantial rooftop programs. Utility PV projects have been concentrated in the regions of the country with the highest insolation, but are beginning to appear in other regions such as New England.

Sacramento Municipal Utility District -- PV Pioneer

One of the most studied, talked about, and modeled upon rooftop programs in the country is the Sacramento Municipal Utility District (SMUD) PV Pioneer program. The PV Pioneer program was started in 1993 and is responsible for 400 residential rooftop installations and 20 commercial and church installations. These units produce 1.5 Megawatts of electricity. SMUD also has localized PV systems which produce 5.7 Megawatts. Between 1998 and 2002 an additional 10 Megawatts of capacity will be installed.

Homeowners that enter the PV Pioneer program have a 499 square foot, four kilowatt grid-connected "plant" installed on their roofs. The electricity generated on the roof is not patched directly into the host home, but rather it is fed into the grid. The host homeowners pay a monthly premium of four dollars on their electricity bill. Despite the fact that the homeowner is paying a monthly charge for no personal benefit and providing a rent-free service to the utility, the demand for PV installations far exceeds the available hardware.

The SMUD program has been successful because it has tapped a huge market of consumers willing to pay a premium for clean energy and they have been able to secure federal funds for their installations. In addition, as a result of SMUD's long-term large-volume PV purchases they have been able to secure favorable pricing from manufacturers. Installations have also become standardized such that the entire system can be installed in under 3 hours reducing contractor charges and charges for custom equipment. Sacramento's commitment to solar power also extends to manufacturers. Energy Photovoltaics, Inc. will build a PV module manufacturing plant that will employ 200 people in Sacramento in 1998. Trace Engineering, which builds inverters, is also planning to construct a factory in Sacramento employing an additional forty to eighty people.

Local Programs

Programs such as SMUD's are not as mature in the New England area, but recently, in part because of the deregulated electricity industry, such programs are appearing. I will discuss three such local programs. One is SunRIse, the selected project of the Rhode Island system benefits charge funding for this year; another is a venture of AllEnergy, a NEES company, and the third is a proposed program by a private company that has not yet been implemented.

<u>SunRIse</u>

SunRIse is a project of Solar Works, a company based in Montpelier, Vermont, which had one of the successful proposals for the system benefits charge monies allocated earlier this year. SunRIse also receives funding from the U.S. Department of Energy. SunRIse is striving to install 250 kilowatts of PV in Rhode Island by the end of 1999. The SunRIse program is unique to other rooftop installations I discuss in that the host consumer is actually purchasing the array and the electricity is for their use. SunRIse is effectively providing a financing company for solar installations. Installations will be paid for over a twenty-year term. Solar Works is providing the installation and panels plus a ten-year service contract.

In Table 9 pricing for project SunRIse installations are given in total installed cost and in size of monthly payment. Recalling the analysis in Chapter 2, installing a 250 watt system would produce 208 kilowatt-hours of electricity, reducing an annual electricity bill from $614 to $591, a savings of $23. In return for that reduction the owner of this system would have to make mortgage payments of $288 per year. This increases the customer's total yearly electricity bill to $879, an increase of nearly fifty percent.

Table 9. Project SunRIse installation sizes and prices.

INSTALLATION SIZE	INSTALLED COST	PAYMENT / MONTH[xvii]
250 watt	$2,800	$24
500 watt	$5,130	$44
1,000 watt	$9,370	$81
1,200 watt	$11,500	$100

[xvii] Based on 20-year mortgage financing, 8.5%annual rate, no downpayment.

2,000 watt	$12,630	$110

AllEnergy

AllEnergy, a marketing company which is a subsidiary of New England Electric System Company, has begun marketing a "product" called ReGen in Massachusetts. In the ReGen program consumers can purchase blocks, 2,000 kilowatt-hours of electricity per year, of renewable resource electricity.[xviii] The first block of electricity costs eight dollars per month and additional blocks are available at six dollars per month. In their advertising literature AllEnergy points out that in the restructured environment the average consumer will be saving approximately eight to ten dollars per month and therefore could purchase the ReGen product with no additional electricity expenditures per month.

Interestingly, the consumer does not actually receive the electricity that they are purchasing. The literature available from AllEnergy promotes remaining with the utility under the standard offer agreement. In some of their promotional materials AllEnergy does not point out that they are a NEES company and therefore affiliated with a utility. However, they invite you to “change the world, not your utility company”.[65] This may not be dishonest, but it is misleading. AllEnergy might appear to some consumers to be an environmental group endorsing remaining with a utility.

Customers are purchasing a promise that AllEnergy will sell renewable resource electricity. AllEnergy enters into long-term contracts with renewable generators and resells that electricity. Monthly customer charges make up the difference between the

[xviii] Currently AllEnergy is marketing an electricity mix of 95.5% landfill gas and 0.5% photovoltaic, but it plans to expand into photovoltaic and wind electricity.

market price for conventional electricity and the cost AllEnergy must pay for renewable electricity. Customers will receive quarterly reports detailing the amount and generating type of electricity produced by AllEnergy contracts and the environmental impact of this power.

Sun Power Electric

An example of the type of project vying for funding from the DOE TEAM-UP program is Sun Power Electric (SPE). Sun Power is a division of an energy conservation non-profit consulting firm based in Boston, Massachusetts called Conservation Services Group. SPE is aspiring to create a solar utility company in Massachusetts or Rhode Island. This would be a rooftop power "plant" based somewhat on the Sacramento Municipal Utility District PV Pioneers rooftop project. SPE is hoping to find a large number of consumers in Rhode Island (or Massachusetts) who are willing to pay a monthly fee to support their project.

Sun Power Electric hopes to collect revenue in one of two ways. The first option is to sell what they call "subscriptions" to consumers. A purchaser of a subscription has a per kilowatt charge added to their electricity bill each month. This monthly charge will be either half a cent or one cent per kilowatt-hour. The second option is to buy a yearly membership. A membership cost is two-tiered and is either twenty-five or fifty dollars per year. Sun Power plans to use ninety percent of their collected revenue on hardware costs, thus incrementally adding to their generating capacity.

If Sun Power Electric does get funding and go forward with their plan their initial installation is slated to go onto a BJ's Wholesale Club. When they applied for Rhode

Island Renewables Collaborative monies they were targeting the Middletown or Johnston BJ's stores.[xix]

BJ's will provide the roof space for the panel installations free of charge. BJ's will also provide space for an informational kiosk where their shoppers will be able to find out about PV power and SPE. In return BJ's will receive the ability to portray an environmentally friendly face to their customers.

The panels will be producing power once installed; power that SPE plans to sell; BJ's is their most logical electricity customer. If SPE were to sell their power to BJ's from the rooftop installation at the price that BJ's is paying to their utility company, SPE would be able to collect the transmission and distribution and other charges included in utility billing. The electricity could also be sold to a marketer or utility for resale. Sun Power Electric plans to use this money from power sales as operating revenue. This would pay an administrative staff and also pay for maintenance and marketing.

If a consumer buys a "subscription" that is tied to electricity usage Sun Power must have a way to bill for that use. This would be done through partnerships with power marketers and brokers. In return for their billing the marketer would receive compensation for five percent. The marketer may also be able to market the fact that a portion of his portfolio is renewable.

Analysis

When I first heard about Sun Power's plan I was interested in it. This was the first large-scale project that I had heard of and I was thrilled to find out that solar energy

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Subsequent to the writing of this thesis, Sun Power did receive support from the Rhode Island Renewable wasn't just my interest but that other corporations and venture capitalists were interested in it too. Then I started to look more closely. I have several problems with this plan and with the others that I discussed in this chapter.

First, in the case of Sun Power, it doesn't seem to make sense to tie a "subscription" to power use if the power isn't actually coming from the panels. In the first year of their business plan they project receiving close to seven million kilowatt-hours worth of subscriptions. They only plan to generate one hundred thousand kilowatt-hours of electricity. Although their plan numbers are clearly very optimistic, the lopsided numbers make it clear that their intention is not to sell electricity to their subscribers (which agrees with what the company maintains).

A premium subscriber, or one who pays one cent per kilowatt-hour, will pay approximately thirty seven dollars and fifty cents per year; a basic subscriber will pay half of that. Having the amount of contribution tied to electricity used will cost much more than paying a flat rate in terms of overhead. The billing information will have to be collected and either attached to the electricity bill or independently billed. The money will have to be collected and forwarded to Sun Power. This seems significantly more trouble than a one time up-front fee. Unless the idea is to give the impression that the monthly surcharge is a premium charge for solar electricity, a more logical idea would be to collect a standard fee, perhaps with more than two tiers, on an annual or monthly basis.

The AllEnergy proposal seems equally flawed. According to the service terms of the ReGen program, if one is late in their quarterly payment, AllEnergy charges 1.5% interest on your unpaid balance. Not only are they selling you nothing for $96 per year,

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Collaborative. A commission vote is expected on the allocation.

they're going to penalize you for late payment. From a cynical viewpoint, these two companies seem to have found misleading ways to generate a charitable capital equipment fund. These plans would make sense if the consumer were purchasing a stake in the company, or actually purchasing anything at all. These are both for profit companies so their customers don't even get a tax write-off. I can understand the sentiments of people who buy into this program, but no other industry relies on charitable donations for operating revenue. If a truly charitable organization , a non-profit, did begin a photovoltaic project which relied on private donations, many of my objections would be lessened because of the tax benefit of the contribution.

Although the SMUD program has on the surface the same problems (participants in the PV Pioneer program pay four dollars per month and give the utility free rent on their roofs in return for no electricity) the cases are not exactly analogous. Since the utility is a part of their community and a public department, these people are investing in their town.

The SunRIse program is noteworthy in that the homeowners in this program are actually buying their own PV installations. However, despite the cost reductions available through this program the price differential still doesn't make sense. For example, the 250-watt array would produce 410 kilowatts-hours of power per year, about eight percent of what the average residential customer consumes in one year, with a monthly payment nearly equal to a monthly electric bill. A SunRIse customer may receive a piece of equipment, but because of the high cost and low electricity output of the installation, they are essentially purchasing nothing at quite a high cost.

CHAPTER FIVE – CONCLUSIONS AND RECOMMENDATIONS

The main conclusion one can draw from this thesis is that photovoltaic electricity in not currently an economically feasible energy source in Rhode Island. PV isn't feasible even when government subsidies and other funding mechanisms such as the Rhode Island system benefit charge help to reduce consumer costs below actual market prices. There are ways that a committed environmentalist can contribute to the local photovoltaic industry, both through "charitable" donations to for-profit companies and through rooftop installations, for which personal rewards may outweigh the substantial costs. However, such concerned citizens are likely to be few and far between. These people will install PV installations regardless of cost. It therefore is unnecessary for the state to subsidize their altruism.

Proponents of Rhode Island's current policy cite several reasons for installing PV here:

- *Raising the profile of PV in the state to foster public acceptance*
- *Developing expertise amongst contractors in PV installation*
- *Spending local monies locally*

However, installations likely to result from the Rhode Island program are so small and will be so few in numbers that they will not be profile-raising fixtures. As PV becomes more commercially developed, through installations in sunny or remote locations, more standardized hardware that will be easier to install will develop also – hence lowering the overall costs. When Rhode Island does start to utilize PV the technology will be much more easily installed, negating the need for developing expertise now. The last objection, that Rhode Island's money should be spent in Rhode Island, is a personal preference and one that cannot be rationalized away. The only counter point that I can make to this statement is to return to chapter one, where I outlined the threat of global climate change as the major reason to promote PV use. Because climate change is a global issue when a national option is a more effective solution it should outweigh prejudice toward local action.

The electricity industry is currently an interesting topic. Articles on the industry occur in local papers with almost daily frequency. Consumers are weighing their choices and trying to decide whether to change their power providers. This recent interest is sure to be raising awareness of consumers about the sources of their power. This climate will raise interest in exploring renewable energy options and companies like AllEnergy and SunRIse will attract customers. This deregulation climate is occurring to some extent in every state multiplying the number of people who will invest in renewable electricity. The public has a notoriously short attention span leaving in doubt the fact that interest in renewables will be sustained. Rhode Island's enabling legislation for the system benefits charge only provides for five years of funds collection.

Imagine the effect that fifty states rushing to spend money on photovoltaics in the next two to three years would have on the PV manufacturing industry. To meet demand the manufacturers would hire additional labor, expand their production facilities and make investments in new equipment. The ramping up of production and the reduction of costs would begin in earnest. Now imagine this same industry five years later when the

PV fad has passed. Companies now must layoff excess employees, they are saddled with debt from capacity expansions and many of them will surely fail. How can this be avoided? The cultivation of incremental increases in demand.

Rhode Island could play its part in this gradual increase by deferring the start of a PV program until the industry matures. The state should tie the start of a PV program to a milestone in cost reduction, an often-quoted break-even price is $3 per watt. By deferring the inception of its PV program until this price level is reached Rhode Island could avoid contributing to a flood of the market while simultaneously giving security to the solar manufacturers. The promise of large-scale contracts tied to price performance is a powerful motivator to manufacturers.

My analysis focused on residential rooftop programs because the majority of projects being considered now are of that type. There could be other projects that would be a better use of state money. If Rhode Island does want to install photovoltaics locally, the state should seek the most feasible markets in the state. There are no exceptionally sunny locations in the state, but there are remote locations. For example, the Department of Energy has awarded nearly $400,000 dollars to Block Island to develop renewable energy.[66] Block Island is attractive for PV because electricity costs are nearly three times as high as on the mainland; however, reduced insolation on Block Island due to fog could decrease the benefit of placing installations there. It would be a better use of public monies for Rhode Island to invest in solar where it was most cost effective in the state.

On the national level, the introduction of a national renewable portfolio standard could stimulate demand for PV power. A renewable portfolio standard requires that marketers of electricity derive a prescribed percentage of their power from renewable resources. If this type of national policy included a trading provision, similar to emissions trading, concentrating PV development in Arizona and other sunny states would be most cost effective. In such a system power providers in Rhode Island could purchase the production of solar kilowatt-hours in Arizona. Although this electricity would not reach customers in Rhode Island it would still reduce the net amount of conventional generation electricity produced in the country.

Following policy options such as those detailed in this chapter would accomplish two goals. They would stimulate the PV market and help to lower costs. These policies would lower costs in the most efficient manner possible. If it is a public goal to make renewable-resource electricity cost effective it should be done in the most efficient manner possible.

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