Alternative Renewable Energy Resources

An Interactive Qualifying Project Report

submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

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Date: March 6, 2006

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Abstract

This project examined the energy usage by current human society and analyzed instances in which renewable energy could be applied. A comparison was made between the Northeast and West South Central Region of the United States. A renewable energy community was designed to provide a feasible and environmentally advantageous standard of living. The design integrates solar, biomass, and hydrogen technologies. The project also examines the impact such a community may have on the environment and global society.

Executive Summary

(QE)Technology is constantly advancing and as it does so the possibilities for societal advancement become more apparent. Currently the industrialized would is examining its energy consumption and slowly coming to the realization that the existing energy infrastructure is becoming inadequate. While supplies of fossil fuels are dwindling the one that is most widely felt is oil. With the price of oil consistently increasing alternative energy sources are now being considered. Renewable energy is the most appealing as it has the capability to once and for all supply humanity with clean and renewable energy. However while these energy resources are capable of producing energy the problem lays in doing so efficiently and in a manner that is economically feasible for global applications.

To address this issue this report first examines the present non-renewable energy sources comprised of forty percent petroleum, twenty three percent natural gas, twenty two and a half percent coal and eight point two percent Nuclear power. Each was analyzed for their current roles in society with respect to the benefits and side effects incurred through their use. Also examined were the consequences of the continued dependence on such resources. As a result the remaining six percent of present energy sources, Renewable Energy, was then inspected to determine if they are a viable replacement option for the resource types.

Photovoltaic, solar panels, biomass and hydrogen technology were assessed and chosen for application in this project because they complement each other well. In order to gauge the success of these applications as well as the capability for global integration a design for a small one hundred person community was established. Contrasting locations within the United States were chosen. The first was located in the Northeast, specifically western Massachusetts, with its constantly changing climate and brutal winters. Conversely the other was proposed in the West South Central Region of United states where Texas was chosen for its potential of solar energy.

In the design of the community several benefits were discovered to aid in lowering the cost while increasing energy yields. Multi unit homes were implemented since it was found that they would be more thermally efficient and require 50% less natural gas for heating and would therefore cost 50% less to heat. In addition passive solar techniques were used to reduce heating bills by 50%. For active solar, radiant heating was chosen, as opposed to convection heating because it would reduce annual heating requirements by 20-25%. To regulate energy distribution a net metering system was applied that would eliminate the need for backup power sources. Biomass was utilized using switchgrass that would undergo gasification. From biomass methane was obtained and converted to hydrogen using solar heat because you can produce 1.8kWh more of energy by converting $1m^3$ of methane to $3.9\ m^3$ of hydrogen.

The integration of these renewable resources was then examined for both economic and societal implications. Solar hydrogen generation is still in its early stages of development so the cost of that system is unknown and thus it was not represented in the cost analysis. However the technology exists to implement the rest of the system today. The solar, photo voltaic, and biomass system totaled $30,000 per household in the Southwest, and $40,000 per household in the Northeast. Since this system supplies all the electrical and heating needs of the home the expected payback period is 13 years in the

Southwest and 16 years in the Northeast, which is less than the average life expectancy of the individual parts.

Our community will also encourage a change in lifestyle. Each home will live very close to the next in an apartment-esque style. While the reason for this is purely for energy savings, it will foster a sense of community. This is important because the people will also depend on each other to maintain their energy systems and to conserve energy. Finally, because of the acreage required for the biomass fields, the community is likely to be located far from any major city which will favor a telecommuting way of living.

Chapter I: Introduction

(QE)This project performs an analysis of renewable energy and the applications of those that are, or soon to be, feasible energy sources that would alleviate the demand on fossil fuels. The goals of this project are to spread awareness of alternative and cast light upon the future implications of current energy usage. Through the dissemination of this knowledge it is hoped that the efficient usage of the resources of humanity will be achieved. To aid in this process the project consists of a design for a small community of about one hundred people, 25 homes, which would be maintained through mainly renewable energy methods. These consist of solar energy for water and space heating as well as photovoltaics for electricity. Biomass will also be used to make thermal energy that can power turbines and supplement solar to give electricity to the community. Biomass was also examined to achieve greater energy efficiencies through the altering of gases produced such as methane to yield hydrogen that could be sold or combusted for a greater amount of heat energy than simply combusting methane.

This project is being conducted to determine whether or not current methods for alternative renewable energy resources are yet feasible to be incorporated into society. The societal aspect and the technological aspect both have been considered to ensure a successful implementation. In terms of the societal aspect the impact on the working lifestyle as well as the economics involved have both been considered and addressed. The technological features were analyzed to be able to become assimilated into current society without causing major lifestyle changes. Recommended change by this project is in the housing practices, since multifamily housing units are much more thermally efficient. This fact was used in the community design. The hope is that with this design for efficiency it will also foster a sense of community that would allow for smoother operations between members of the community. All these issues will be addressed later in greater detail.

This project will be a source of motivation or guidance for one interested in renewable energy. The information provided in this document will be useful for those seeking advantages to renewable energies or those who are simply curious as to the nature of some of the renewable resources such as biomass, solar, or hydrogen. The data given will allow companies, students and faculty to gain direction into which technologies if further developed would lead to significant advancements in the energy usage of the both United States and also give a glimpse of the resulting global impact. This project is directed to everyone no matter whether this is a specific area of focus or simply a spark of interest. It provides relevant information to spread awareness of the possibilities of renewable energy.

The report begins with an analysis of current energy sources such as coal, oil and natural gas. It then examines then in terms of energy distribution and consumption of each source and displays the disadvantages of using these energy sources. From there it proceeds into an analysis of solar techniques and rationalization for why the ones that were chosen should be implemented into the community design. Comparisons are made based on two regions one in Western Massachusetts and the other in Southern Texas. Costs and energy information was prepared to show the feasibility of a renewable energy implementation in different climates. Finally this report goes over Biomass and Hydrogen technology and stipulates actions that would allow for them to integrate with each other as well as with solar energy. The aspect of the societal impact is then evaluated based on the data obtained throughout the project and critically analyzed for impact on the micro and macro scale.

Motivation of Project Members

(QE)The quest for cheap reliable energy has been a long enduring battle for mankind. Where in the past we would have used either man power or wind power to sail across the vast oceans, we now come to rely upon fossil fuels. This deviation from using what you have available, to abusing what can be used has left us wanting more and more from already dwindling supplies. The demand for energy is on the increase and while there are several new ways being developed to supply energy, these are just not applied or researched enough to fill the demand.

With this IQP I hope to help alleviate this demand for energy especially as more and more of the world becomes industrialized. I feel that dependence on natural resources is only feasible if it is examined with respect to the future implications. Also, we should learn from the past and utilize all the sources of free energy we can. As a chemical engineer, I am often faced with the problem of energy and material balances. I feel as though this is just a global expansion of this concept and that my background will well prepare me to look at the several aspects involved in the production and distribution of energy. In this project I hope to begin the implementation of an energy source as a supplement to our current sources that we could one day transition to as a permanent source of renewable energy. If this is not yet attainable I would at least like to try to raise awareness about the several sources of possible energy that would alleviate the current demand.

(RJ)The primary motivation for accepting this Alternative Energy IQP stems from an interest in efficiently utilizing the resources available to the human race. We already have an established infrastructure for extracting energy from fossil fuels. It is time to broaden our knowledge and skill by developing creative techniques for extracting energy from alternative sources. By sourcing our energy supply from many different areas, we can be confident that large-scale disasters or war will not cripple the livelihood of the global population. Distributing our energy demand over several sources will also lessen the environmental impact of any one fuel supply - the same load can be supported at multiple points.

By investigating such alternative energy sources and assessing the economic, environmental, and technological feasibility of each, this IQP can be a source of inspiration and guidance. Students who read the completed project report may be inspired to re-center their area of study around developing new technologies for extracting energy. The report can act as a guide to policy-makers who are overwhelmed at the alternative energy possibilities. A summary of the report may be useful to the layperson looking for more information about alternative energy sources. Providing a realistic feasibility assessment is essential; we should avoid hype and unreasonable expectations such as that surrounding a Hydrogen economy.

WPI has developed critical thinking skills and an engineer's logic in me. ME and ES courses have provided me with an understanding of mechanical, thermodynamic, and fluid systems. This should help to spot unreasonable energy generating claims, as well as speed up comprehension of an unfamiliar system. ME4429, Thermofluid Application and

Design, is especially applicable: my team designed an ethanol-powered plant that would supply the estimated energy needs for a community of 500 homes. We accounted for energy estimates to distil ethanol from corn, as well as co-generation to supply hot water to the community.

As of now, a future career is still very uncertain. However, a deeper understanding of alternative means of procuring energy can do no harm. Mindfulness of where our energy comes from can help me to make environmentally conscious decisions whether buying a vehicle or designing one.

I hope the project can be accessible to people with a variety of backgrounds. A summary (more detailed than the abstract) should be created to make our research easily digestible for Joe Everyman. Electronic dissemination strikes me as the quickest and most prolific method for getting the information out, and may be appropriate for the abstract or summary. The full report should be constrained to more academic channels so that it may gain credibility.

(AK) With the rising fear of an energy crisis I am constantly bombarded by opinions about the state of our energy well being from the media, at home, and from friends. I've heard everything from there is plenty of oil and renewables can not keep up with demand, to renewables are far cheaper and we could have cars that run on water. This project offered the perfect opportunity to sort out the facts from the hearsay and to get caught up on the latest energy news and technologies.

From the list of available IQPs I found few to be appealing. I found the Renewable Energy Resources project to be interesting because it not only addresses a global issue, but it addresses a current global issue. I also have an affinity for solar panels ever since my early science fair days when the devices powered my little vehicles. In general I find energy production to fascinating because it is an essential component of how the world works and I am constantly astounded by the ways humans have devised to make the world work.

I believe this project will have relevance to my professional career as well. At the career fair, over half of the companies I talked to dealt with energy production in some way. I've always enjoyed the idea of making new, more efficient energy systems. This project will give me a firm background in all the related areas concerning energy for when I enter the job market. It will also help to give me a taste of what my future job will be like.

With this project I hope to determine the feasibility of a renewable energy installation and if so, to help increase awareness among the general population. I feel that the main reason why renewables are not more prevalent is because the general belief is that they are costly, time consuming, or that they are just not a viable option for their situation. Changing public opinion is the first step towards having a safe and reliable energy economy.

Chapter II: Background

Energy Resources

(QE)The first law of thermodynamics states that energy can neither be created nor destroyed, only converted. As humanity marches forward on its quest for more efficient and helpful products, the amount of work we want to do ourselves has diminished, resulting in gap that is being filled by a demand for resources. However the current resources that we use are limited and are only decreasing in supply. It is as if we are drawing water from a well that is diminishing while ignoring the river flowing nearby. There is an abundance of energy that is simply being allowed to go unused, such as: solar, hydroelectric, wind, tidal, and geothermal. While attempts have been made to tap these resources it, has not been on the same scale as the usage of other energy sources such as petroleum, natural gas, and coal. Combined, these three alone account for about eighty five percent of the US energy consumption. Despite the fact that there are a variety of ways in which to acquire renewable energy, these only contribute six percent.[2] (See figures 28-30) However, while these sources of free energy may seem appealing, it is well understood that nothing in this world comes free. The efficiencies of the resources are not yet at an optimal performance level to begin the widespread implementation of these renewable resources as substitutes for the current major energy sources. Also the cost of the installation and maintenance are another hindrance in the free energy transition. That said, one would wonder if we can simply change the dependence for energy from one of the major sources that is in decline to one that is in abundance.

The US is the world's second largest coal producer and consumer.[1] This could be the next band aid for the energy crisis that threatens the US and world economy. Our current usage of coal is for electricity in which the combustion of coal supplies the US with half of its electricity. However there are two sides to every coin. While coal is abundant in the US it has the propensity to go the same path as petroleum: at some point in time it will be in diminishing supply. The exact time of the decline of coal is difficult to pinpoint because it has not really been tapped to its full potential. When it is, there will be the factor of how well other energy sources are doing also. For the current situation it could serve as a valuable source to alleviate demand on other energy sources. As stated before it is easy to acquire in the US and it is also rather inexpensive. The draw backs occur in terms of environmental impact. Coal causes pollution which then requires costly means to safely regulate it.[3] Otherwise it will cause global warming as well as acid rain. Another factor is that while coal is abundant, the means of transportation required would be very extensive. No matter which way you go, whether it is towards the free energy or relying on the old constants such as fossil fuels, there are advantages and disadvantages that hinder the progression of these energy sources. However it is only a matter of time before they will begin to run dry and the amount of energy and resources put into acquisition of a resource such as petroleum outweigh the energy potential. Hence, it is imperative that supplements be examined because at this stage we are not yet ready for a total transition to an alternative energy source.

Coal

(RJ) About 50% of the electricity generated in the US comes from burning coal. It sustains the base load in the electricity grid. Figure 1, from the Department of Energy's annual energy review, shows the historical share of coal for electricity generation. Coal has always been a major source of energy for producing electricity, but in the past few decades, the gap between coal power and all other sources has widened dramatically.

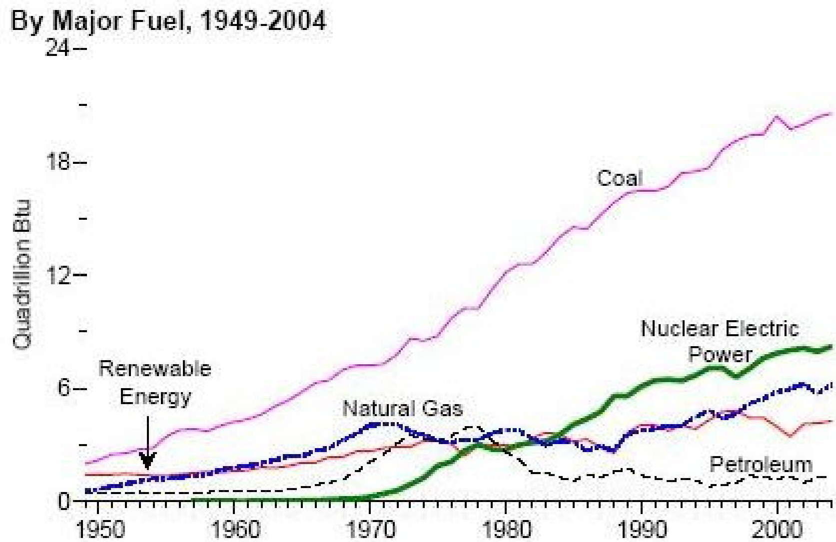

Figure 1: Historical share of electricity generation by fuel.[1]

Historical coal prices and consumption for electricity generation are shown in Figure 2. The sharp decline in coal prices in the '90's was attributed to more efficient mining techniques in Energy Information Association literature. The projections of coal demand and price show the continuing steady increase in coal consumption, as well as the leveling off of the price for coal. Environmental concerns about the pollution generated by coal energy should intensify as the rate of consumption continues to increase.

[1] *Coal*. Annual Energy Review, 2004. Energy Information Administration. August 15, 2005. <http://www.eia.doe.gov/emeu/aer/>

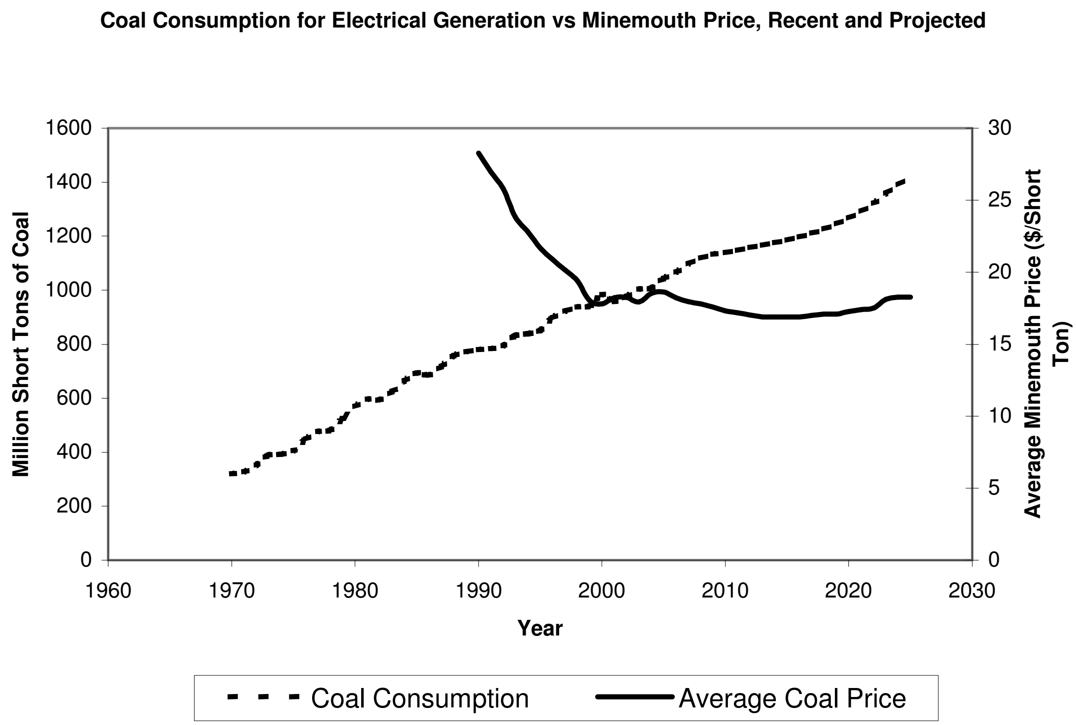

Figure 2: Coal consumption for electricity generation and mine mouth coal cost.[2]

Environmental Costs of Burning Coal to Generate Electricity

(RJ)Most current coal-fired power plant emissions reduction technology has focused on controlling SO_2, NO_x and particulate emissions. SO_2 and NO_x emissions both contribute to the formation of acid rain, and NO_x emissions contribute to the formation of urban smog. Also, there's a new focus on reducing trace mercury-vapor emissions. This is developing technology.

Small-particulate emissions are also cause for concern. Specifically particles referred to as PM2.5. They are classified as particulate pollution with a maximum diameter of 2.5 micrometers. Associated with harmful effects on environmental and human health, these also contribute to haze and power plant exhaust opacity. 138 000

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[2] Data from: *Coal*. Annual Energy Review, 2004. Energy Information Administration. August 15, 2005. <http://www.eia.doe.gov/emeu/aer/>

metric tons are emitted annually in the US by coal-fired power plants; accounting for 3% of total PM2.5 emissions.

The biggest concern about burning coal for energy is CO_2 emissions. Carbon dioxide is the biggest factor in global warming, which is an increasingly urgent problem. CO_2 emissions control technology does exist. Chemical scrubbers using amine compounds can remove up to 98% of CO_2 from the exhaust stream.

A report for the Ontario Ministry of Energy concluded that environmental and social effects of coal fired power plants cost $0.10/kWhr. The report conducted a cost-benefit analysis for four different scenarios of power generation. The base case, where coal-fired power plants continued to supply the energy needs of Ontario, concluded that total cost of coal power was around $4.4 billion/year of which 77% is due to environmental/health costs. Other scenarios, though they are more expensive generating power, are less costly overall as the environmental and health costs are not nearly as high. The three other scenarios considered were: all electricity provided by natural gas, all electricity provided by a combination of natural gas and nuclear power, and all electricity provided by coal, but with more stringent controls on emissions.

Figure 3, excerpted from the Ontario Ministry of Energy report[3], shows the total cost of generation for the various scenarios, including environmental and health costs. The most important numbers to take away from Figure 3 are found in the last row: Health and Environmental Proportion. The health proportion is the fraction of the total cost of

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3 (RJ) Cost Benefit Analysis: Replacing Ontario's Coal-Fired Electricity Generation, DSS Management Consultants Inc., April 2005.

generation due to damage to humanity and the environment. The cost to humanity from coal power is then easily estimated from financial generation costs by:

Health Cost Multiplier = 1/(1 - 0.01*Health and Environmental Proportion)

Cost to Humanity = Health Cost Multiplier * Coal Electricity Rate

	SCENARIO			
	1 Base Case	2 All Gas	3 Nuclear/ Gas	4 Stringent Controls
Total Present Value (2007-2026) ($Billions)	**$49** ($21)[a]	**$29** ($26)	**$22** ($18)	**$32** ($21)
Annualised Costs ($Millions)	**$4,377** ($1,836)	**$2,605** ($2,279)	**$1,942** ($1,635)	**$2,802** ($1,895)
Levelised Costs ($/MWh)	**$164** ($69)	**$98** ($86)	**$72** ($61)	**$105** ($71)
Health and Environmental Proportion	**77%** (46%)	**20%** (9%)	**21%** (6%)	**51%** (28%)
a: Values shown in brackets are based on acute premature mortality damage estimates.				

Figure 3: Total cost of coal-powered electricity generation.

In the base case where coal generation levels stay the same, the Health Cost Multiplier equals 4.35 or 435% of the financial cost of coal electricity. It is obvious then that the financial cost to generate electricity using coal is a small fraction of the total cost to humanity. Other scenarios yield much lower costs to humanity where case 2 equals 125%, case 3 equals 127%, and case 4 equals 204%.

The report should be interpreted as a warning against the continued large-scale use of coal for producing energy. The human and environmental cost per kilowatt-hour for continuing to burn only coal is the highest of all cases. Offsetting some coal power with other forms of electricity generation will greatly reduce the cost to the environment and human health.

Oil

(AK)At the moment the world has not reached peak oil production capacity. According to Cambridge Energy Research Associates (CERA) "Global oil production capacity is actually set to increase dramatically over the rest of this decade. CERA indicates that worldwide capacity could rise by as much as 16 million barrels per day (mbd) between 2004 and 2010 -- a 20 percent increase over the period. Supply is expected to outpace demand growth in the next few years, which would take the pressure off prices around 2007–08 or thereafter and even lead to a period of price weakness,"[4] observe the report's authors, Peter M. Jackson, CERA's Director of Oil Industry Activity and Robert W. Esser, CERA's Director, Global Oil and Gas Resources.

This claim arises from several factors. Firstly the largest producers of oil, the Middle East, have invested billions into upgrading and creating new oil wells. This investment is expected to be operational in a few years, causing a large increase in the supply of oil. Secondly, because of emerging technologies and the high price of oil, unconventional oil sources are becoming more competitive.

After 2010 production is expected to take a turn. "Jackson and Esser argue that "unconventional" oil will play a much larger role in the growth of supply than is currently recognized. These unconventional oils include condensates, natural gas liquids (NGLs), extra heavy oils (such as Canadian oil sands), and the ultra-deepwater (greater than 2,500 feet deep). By 2020, they could increase to almost 35 percent of supply."[4]

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[4] http://www.cera.com/news/details/1,2318,7453,00.html

These unconventional oils will increase their production capacity markedly in the intervening time. However conventional oils from non-OPEC nations are expected to drop in capacity, while OPEC will be able to continue oil productions rates after this time. The United State's oil production capacity is expected to follow past trends of decline. See Figure 4

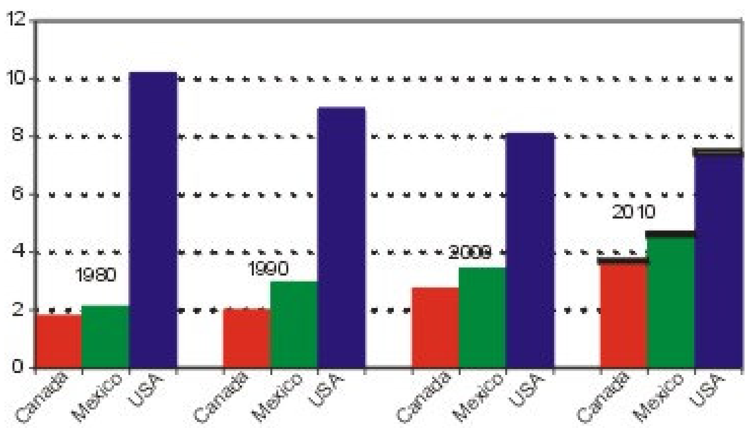

Figure 4: North American oil production, million barrels per day, 1980 – 2010[4]

According to the US Geological Survey(USGS), today's oil reserve estimates are inaccurate because they only incorporate "proven" oil fields, and don't take into account unconventional oil fields, such as heavy oil. The estimated world reserve of oil is about 1.1 Trillion barrels, but if these other sites are accounted for than the world's oil reserves are as high as 3-4 trillion barrels.[5] See Figure 5 for conventional and USGS view of

[5] http://www.radford.edu/~wkovarik/oil/

world oil reserves. Though more expensive, there is always the possibility of expanding production capacity into the unconventional oil fields.

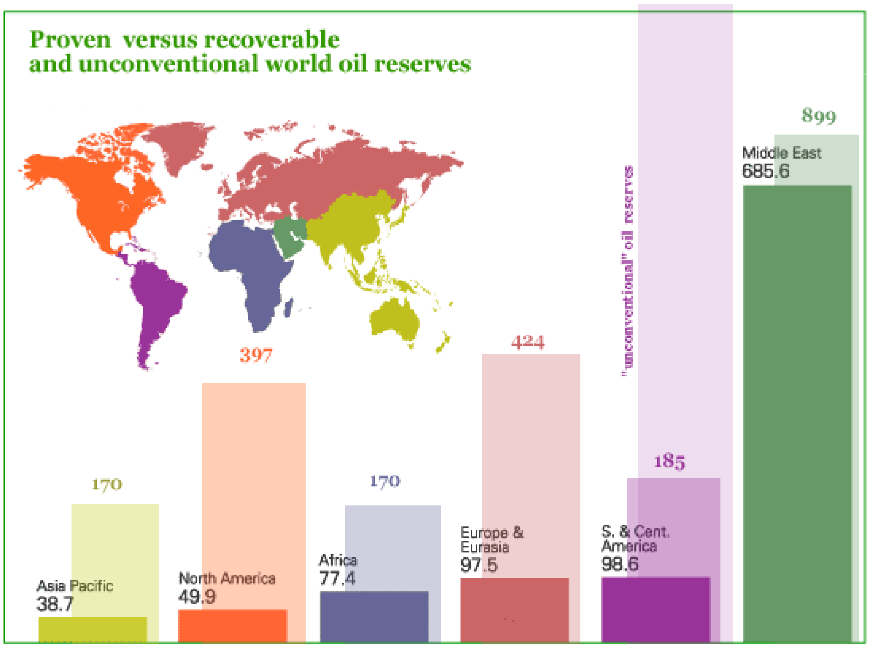

Figure 5: Conventional view of oil reserves in solid colors, USGS view in transparent colors.[6]

A similar chart amended to include USGS estimates of ultimately recoverable oil reserves presents a more accurate impression of overall world oil reserves.

*Note: The "unconventional" oil reserve of South America is the Venezuelan Orinoco heavy oil belt with one to four trillion (with a "T") barrels of oil. This is the 3rd purple bar

The Caspian Sea area was a prospective site for a massive increase in oil production. However, surveys of the area have proved the Energy Information Agencies' estimates to be highly inflated. "Noted petroleum geologist Colin Campbell states that exploration in the Caspian region has been very disappointing, with the discoveries being much smaller than predicted and much of the oil discovered being of poor quality."[7] The four proven Caspian oil reserves are only expected to have from 39.4-50 billion barrels total, instead of the EIA's estimated 200billion barrels. "Caspian Oil represents four

[6] http://www.radford.edu/~wkovarik/oil/
[7] http://www.fromthewilderness.com/free/ww3/120502_caspian.html

percent of the world's reserves. It will never dominate the world's markets..."[7]. Much of the region has yet to be explored and hopes are still high that earlier Caspian oil estimates will be fulfilled.

"The CERA analysis rejects the current fear that a near-term "peak" in world oil production and a coming exhaustion of supply are near. The report indicates that the "inflexion" point will come in the third or fourth decade of this century. Moreover, rather than a "peak," it will be an "undulating plateau" that will continue for several decades."[8]

Despite this analysis it is also generally believed that the world will reach its peak oil production very soon. This period will cause massive economic turmoil as the price for fuel and production skyrockets. Mitigation of the oil supply could ease off the pressure, but these plans must be initiated at least 10 years in advance. "The concept of "Reserves" is an estimate of the amount of oil in an oil field that can be extracted at an assumed cost."[54] At a higher cost, roughly 10-20% more oil can be supplied.

Many studies have been performed concerning when peak oil production will occur, and most suggest that it will happen within the next 10 years. To mitigate the coming economic blow, one option is for governments to mandate more fuel efficient vehicles. This includes hybrid and diesel technologies. Another option is improved oil recovery via the tertiary process of pumping CO_2 into the wells to act as a solvents and/or pressures to more residual oil. Another option is to expand oil production into heavy oil and oil sand regions such as Canada and Venezuela. They have estimated reserves of 3-4 trillion barrels, though only about 600billion is recoverable. Liquid Natural Gas and Coal

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[8]http://www.cera.com/news/details/1,2318,7453,00.html

liquefaction have advanced greatly and are capable of tapping into remote reserves. In addition, coal liquefaction is believed to be as effective as $30-35 per barrel. Biomass derived fuels are promising, but currently they are heavily subsidized and not economically feasible. Finally, without further breakthroughs, current hydrogen technologies can not be improved as much as they need to be in order to be a viable option.

A forecast was given for what would happen if mitigation occurred at peak production, 10 years before, or 20 years before peak production. By addressing the peak oil production problem when it happens, leaves the world in a severe liquid fuel deficit for more than two decades. If mitigation occurs ten years before the peak, then a decade of deficit still occurs after peak production is reached. If mitigation is performed 20 years in advance, then the oil crisis can be adverted. In general, “without massive mitigation at least a decade before the fact, the problem will be pervasive and long lasting.”

Natural Gas

(QE) Natural gas may seem like a growing dependence for energy but, is it worth it? Natural gas has its advantages such as it emits almost zero sulfur particles; this compared with coal that emits 10grams of sulfur dioxide. Natural gas also emits ¾ less nitrogen than coal and the nitrogen it produces are used to create nitrogen fertilizers for agriculture. In terms of fossil fuels it is environmentally friendly, producing less greenhouse pollution than heating with electricity. Thanks to the new technology there have been great strides in improvement of the conversion of natural gas to electricity such as fuels cells that allow for the acquisition of energy from natural gas without combustion. Due to the advantages of natural gas demand for this product is rapidly increasing without attention to the possible drawbacks that come with reliance on fossil fuels.

While for now natural gas may be relatively clean and efficient source of energy as the demand for natural gas increases so will the flaws. Natural Gas occupies about four times the space of gasoline for the same amount of energy[1]. Thus its transportation involves more weight as well as fuel storage tanks. Natural gas is not easy to transport requiring pressure pipelines or special ships which pre-process it into liquefied natural gas (LNG)[2]. There is also the fear of terrorism, knowing that a fully loaded LNG ship could equal the power of 55 Hiroshima nuclear bombs there must be security implemented to prevent this during the transportation of natural gas. At our current stage natural gas is useful mainly for heating and electricity. It simply costs too much in terms of energy and money to convert it to a fuel for ships or aircrafts.

While the actual consumption of natural gas has stayed relatively constant the price for natural gas is increasing. This may be due to the fact of increased imports of natural gas by the United States. From 1998 to 2001 alone, the amount of imports went from 85 billion cubic feet to 235 billion cubic feet. Compared to the 1st quarter of last year imports are already up 5.8%. The current tax is 26 cents per million Btu[3]. The average price of gas is $6.19 per MBtu vs. $5.48 last year first quarter. Production of natural gas has also stayed constant despite the addition of 34,000 wells since 1994[5]. However the wellhead prices have continued to rise, an increase that is clearly evident in the 400% increase of wellhead price in 2000.

There are several advantages to natural gas but there are also several disadvantages, which have the potential to only increase as our dependence on natural gas increases for electricity and heating. Already places such as the Northeast have a greater reliance on natural gas and thus experience a greater cost to supply the basic necessities of energy. However with the improvement of technology and the understanding of the current places for loss in terms of energy and financially it may be possible to turn natural gas into an energy source with few if any hidden cost. One must also keep in mind that like its cousins it is a fossil fuel and does have the potential to run out, it is only a matter of time.

Nuclear

(AK)As new energy technologies are developed, older technologies like nuclear power will have to stay competitive in order to survive.

The nuclear sector is expected to see tremendous growth by the year 2020 the Energy Information Administration's International Energy Outlook for the "2005 edition projects a total of 411GWe of installed worldwide nuclear capacity in 2020, a mere 108 nuclear plants with an average capacity of 1000MWe more than envisaged five years ago!"[9] The rising cost of oil has started a new nuclear boom. Instead of petroleum-derived fuel, a nuclear reactor uses fissionable uranium. "U_30_8 is the uranium product which is sold. About 200 tonnes is required to keep a large (1000 MWe) nuclear power reactor generating electricity for one year. Some 25 tons of fresh fuel is required each year by a 1000 MWe reactor."[10]

9 http://www.neimagazine.com/storyprint.asp?sc=2030800
10 http://www.uic.com.au/nfc.htm

Accelerator Driven Nuclear Energy[11] is a promising technology now leaving the infant stages of development. This system uses an accelerator to provide high energy neutrons to as much as eight reactors. The extra neutrons allow the use of Thorium as a fuel substitute, which is 4 times more plentiful than Uranium. These reactors can also use spent fuel rods to increase the longevity of the system and decrease the radioactivity of the waste material.

Research is being conducted into laser enrichment, which appears to be a promising new technology and should significantly reduce the cost of enriching fuel.[10]

The Integral Fast Reactor or Advanced Liquid-Metal Reactor is a new technology that was unfortunately cancelled after the prototype phase. "The goals were to increase the efficiency of uranium usage by breeding plutonium and eliminating the need for transuranic isotopes ever to leave the site."[12] It had many promising advantages:

> Ease of fuel fabrication, because casting is simple, the fuel can be fabricated remotely, reducing the hazards of its radioactivity. Reprocessing is simplified because there is no need to stringently reduce the radioactivity of the fuel. Pyroprocessing and electrorefining are feasible with this fuel. This allows on site reprocessing. Two forms of waste are produced, a noble metal form and a ceramic form. Both are suitable for geological disposal. The waste produced contains no plutonium or other actinides. The radioactivity of the waste decays to levels similar to the original ore in about 300 years. [12]

The main advantages of the system are more efficient use of the fuel, and less dangerous and easily disposed of waste materials. The main disadvantages are that the medium, sodium, is highly reactive and that the system produces radioactive sodium.

11 http://www.uic.com.au/nip47.htm

12 http://en.wikipedia.org/wiki/Integral_Fast_Reactor

Pebble bed reactors offer the promise of eliminating the risk from nuclear meltdown by creating many small nuclear fuel pellets that are easily controlled. "Instead of water, it uses pyrolytic graphite as the neutron moderator, and an inert or semi-inert gas such as helium, nitrogen or carbon dioxide as the coolant, at very high temperature, to drive a turbine directly. This eliminates the complex steam management system from the design and increases the transfer efficiency to about 50%."[13] However, the system is not fail safe as can be seen from an accident in Germany in 1986 in which a jammed pebble caused the release of radiation into the surrounding area. This accident canceled Germany's research into pebble bed reactors.

The following is an extensive account of the cost to produce nuclear fuel:

> "About 200 tonnes U_3O_8 gives rise to 24 tonnes of uranium in enriched UO_2 fuel, via conversion and enrichment stages. So, to get 1 kg of enriched uranium in fuel you need about 8 kg of mine product, now @ US$ 40/kg or a bit more, hence US$ 320. (In fact the utility often buys this material, then gets it converted to UF_6, then enriched, then fabricated, rather than buying the finished product.)
> 1 kg of enriched fuel (@3.5% U-235) will normally need an input of 4.3 SWU (Separative Work Unit) @ US$ 110/SWU, hence $ 470. But before this the uranium conversion will cost US$ 10/kg U, so for about 7 kg U it costs about $70. Total cost is thus about US$ 860 for 1 kg enriched fuel, plus about $240 for actual fuel fabrication. This will yield about 3900 GJ thermal energy at modern burn-up rates, or about 360,000 kWh of electricity (at 33% thermal efficiency), and does the same job as about 160 tonnes of steaming coal for a total cost of 0.31 cents/kWh (US$)." [10]

Nuclear fuel costs are cheaper than coal because nuclear power only requires a small fraction of the bulk of fuel. However, nuclear fuel only accounts for about a quarter of the costs of running a nuclear power plant[14]. Plant maintenance and disposal of the toxic spent fuel rods is nearly as much as the cost of fuel. On top of that, the initial investment

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[13] http://en.wikipedia.org/wiki/Pebble-bed_reactor

of a nuclear power plant is significantly higher than the investment for other forms of power.

Because nuclear fuel is a small amount of the total cost, nuclear electricity prices do not fluctuate as wildly as other forms of energy (see Figure 6)[14]. In these times of wild gas prices, nuclear power has gained renewed interest because of its price stability. Price stability is further enhanced because Uranium mining occurs in stable countries such as Australia and Canada.

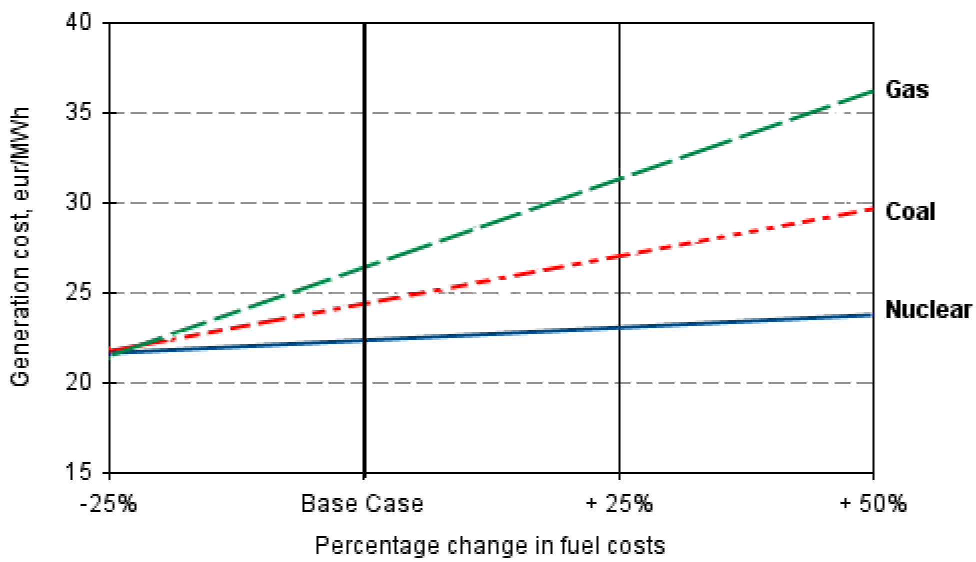

Figure 6: Impact of fuel costs on electricity generation costs. Finland, early 2000[14]

The projected cost of nuclear energy in 2010 is expected to range from 2.3cents/kWh in the Czech Republic to 4.8cents/kWh in Japan, with the USA at 3.01cents/kWh.[14] "Overall, and under current regulatory measures, the OECD expects nuclear to remain economically competitive with fossil fuel generation, except in regions where there is direct access to low cost fossil fuels."[14]

[14] http://www.uic.com.au/nip08.htm

Hidden Costs of Nuclear Energy

(AK)Nuclear energy has historically been cheaper than most energy sources, but the past decade has seen little growth in the nuclear industry. Why? Any development of nuclear power plants are often delayed for years by anti-nuclear activists groups which can add significantly to the cost. Also, the psychological burden of nuclear power is extremely high. The fear of a nuclear accident which could potentially kill hundreds of thousands and leave huge tracks of land inhabitable for centuries has severely injured the nuclear industry. Many people also believe reactors to be prime targets for terrorists. Living next to a reactor, one is constantly under the fear of meltdown, or imminent attack. Residents in the Chernobyl area have seen a noticeable decrease in productivity, health, and happiness due to the psychological damage of the accident.

(AK)Many times when determining the economic feasibility of energy resources the indirect costs are ignored. These costs include the damage to human health and the environment and can be very significant. Nuclear power offers the advantage of low health and environmental costs coupled with high energy output.

Aside from some renewable energy resources, nuclear energy has the highest safety record. **"**The situation to date is that in over 10,500 reactor-years of civil operation there has been only one accident to a commercial reactor which was not substantially contained within the design and structure of the reactor. And only this one, exemplifying the "worst case" disaster scenario, has resulted in loss of life."[15] This was the infamous

[15] World Nuclear Association:
http://www.world-nuclear.org/education/ne/ne6.htm

meltdown at Chernobyl. "The 1986 accident at Chernobyl in the Ukraine was very serious and cost the lives of 31 staff and firefighters, 28 of them from acute radiation exposure. There have also been 800 cases of thyroid cancer in children, most of which were curable, though about ten have been fatal."[15] The close calls of other nuclear accidents still had two or more levels of protection still intact and were not as close as media hype leads people to believe. Table 1 gives a comparison of immediate mortality rates caused by various energy sources.

Fuel	Immediate fatalities 1970-92	Who?	Deaths per TWy* electricity
Coal	6400	workers	342
Natural gas	1200	workers & public	85
Hydro	4000	public	883
Nuclear	31	workers	8
*Basis: per million MWe operating for one year (i.e. about 3 times world nuclear power capacity), not including plant construction, based on historic data - which is unlikely to represent current safety levels in any of the industries concerned. The data in this column was published in 2001 but is consistent with that from 1996-7, where it is pointed out that the coal total would be about ten times greater if accidents with less than 5 fatalities were included. [15]			

Table 1: Comparison of accident statistics in primary energy production.

Nuclear energy produces very low amounts of pollution. The "spent fuel discharged annually from all operating nuclear power plants worldwide, some 12,000 tonnes, can be readily stored for eventual reprocessing or disposal."[16] Whereas a single typical coal plant produces hundreds of thousands of tonnes of waste material.

> The quantity of toxic pollutants and waste generated from fossil fuel plants dwarfs the quantities from other energy options. A 1000 MW(e) coal plant, depending on sulphur content, on average produces annually 44 000 tonnes of sulphur oxides and 22 000 tonnes of nitrous oxides that are dispersed into the atmosphere. Additionally, there are 320 000 tonnes of ash containing 400 tonnes of heavy metals. Abatement procedures themselves can produce as much as 500 000 tonnes of associated solid waste. A 1000 MW(e) nuclear power plant does not release noxious gases or other pollutants and produces annually only some 30 tonnes of high level radioactive spent fuel along with 800 tonnes of low and intermediate level waste.[22]

The nuclear waste is then either reprocessed for later use or it is solidified into large blocks for permanent disposal.

Nuclear power plants can also affect the environment by releasing heated water into nearby rivers and lakes. This can kill fish and promote toxic algae blooms. It is for this reason that nuclear power plants are often required to have their characteristic cooling towers. These towers reduce the waste water to ambient temperatures.

Stochastic Health Effects

(AK)There is a constant background radiation level that bombards us everyday. Of this, "nuclear power related activities add a minimal 0.006%."[16] Compare this to the 11% received from normal medical procedures.

Many probabilistic risk analyses have been performed for nuclear energy. "Since natural radiation is estimated to cause about 1% of all cancers, radiation due to nuclear

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[16] International Atomic Energy Agency: http://www.iaea.org/Publications/Booklets/Development/devfifteen.html

technology should eventually increase our cancer risk by 0.002% (one part in 50,000), reducing our life expectancy by less than one hour. By comparison, our loss of life expectancy from competitive electricity generation technologies, burning coal, oil, or gas, is estimated to range from 3 to 40 days."[17]

"The genetic risks of nuclear power are equivalent to delaying parenthood by 2.5 days, or of men wearing pants an extra 8 hours per year."[17]

Probabilistic deaths caused by reactor meltdown are very low as well. The following gives the likelihood for different degrees of meltdowns.

> "A fuel melt-down might be expected once in 20,000 years of reactor operation. In 2 out of 3 melt-downs there would be no deaths, in 1 out of 5 there would be over 1000 deaths, and in 1 out of 100,000 there would be 50,000 deaths. The average for all meltdowns would be 400 deaths. Since air pollution from coal burning is estimated to be causing 10,000 deaths per year, there would have to be 25 melt-downs each year for nuclear power to be as dangerous as coal burning."[17]

At the present time it seems we should worry more about coal pollution then nuclear meltdowns.

In conclusion the effects of nuclear power on human health and the environment are very limited. Often the expected increase of sickness is within the normal geographic variation. It would take critical failures of a nuclear power plant to cause widespread harm. With the advent of pebble bed reactors and other new nuclear technologies, the possibility of a meltdown may be eliminated as well.

[17] University of Pittsburgh: http://www.physics.isu.edu/radinf/np-risk.htm

Energy Requirements

(QE)The demand for energy is constantly increasing, a fact that is evident in the usage of electricity alone. The United States residential consumption went from 1037 billion kWh of electricity in 1997 increasing to 1140 billion kWh in 2001. This energy increase was also reflected in other household consumption areas such as natural gas, fuel oil, kerosene, LPG and wood. This data was obtained from the Energy Information Association who project that residential energy consumption will increase 17% from 1995 to 2015. Any new energy ventures must incorporate this fact if one wishes to gauge a sufficient alternative energy supply. While solar may be able to replace some aspects of the energy demands of the residential sector it is not enough to simply be a substitute. The implementation must be done such that the energy obtained from solar is used to retain most of the energy absorbed from the sun while simultaneously having a better energy input to work output ratio than the energy source it replaces. Therefore this will allow for the best usage of solar, which will lead to an earlier break even point.

For the purpose of this project we decided to focus on two regions of the United States and compare a solar town of about 100 people. Specifically the areas selected were western Massachusetts in the area that received 4-6kWh/m^2/day and western Texas where they receive 6-9 kWh/m^2/day. Both choices were made in a effort to build in a rural area where they received the optimal sunlight however due to the contrast in their locations there are also contrasts in their energy demands. The northeast, specifically New England consumed most of its energy in the form of space heating with 71.4million Btu per household and while this was also the source of most of the energy consumption in the south, in the West South Central[1a] region they only consumed 25.9 million Btu per household[1b]. This data is from 2001 and in the same year the US Census Bureau reported that Massachusetts consumed 242 million Btu per person but in contrast Texas consumed 564 million Btu per person[2]. What this data then shows is that while the state of Massachusetts may consume more energy per household, the state actually consumes less energy per person as compared to Texas which consumed more per person than it did per household in its region. This is a result of the cooling needs in the region to which Texas belongs and the high energy requirements of air conditioning.

(QE)Another aspect that must be accounted for is the usage and cost of electricity. In New England 2001 there were 0.39 quadrillion Btu as primary consumption and 0.13 quadrillion Btu as site consumption. At which time New England contained 5.4 million households that consumed electricity resulting in a primary electricity consumption of 72.9 million Btu per household and a site consumption of 24.4 million Btu per household. New England then consumed 7142kWh per household in 2001. In 1999 the cost of electricity to New England was 10.09cents per kWh for residential electricity which was a little higher than the nation's average of 8.16 cents per kWh.[1d] This cost rose to 11.5 cents per kWh in New England[3] for 2000 and data from 2002 showing 10.18 cents per kWh. The average household pays 8.5 cents per kWh and uses 10,000kWh per year, see table 2.

Massachusetts Average energy cost per unit (1997 Data from the EIA)		
	New England	US Total
Energy cost per million Btu	$13.41	$13.25
Electricity cost per kWh	12.1cents	8.5cents
Natural Gas cost per thousand cubic feet	$9.67	$6.96
Fuel cost per gallon	$0.98	$0.98
Kerosene cost per gallon	$1.12	$1.15
Liquefied Petroleum Gas per gallon	$1.37	$1.03

Table 2: Massachusetts average energy cost per unit[1c]

In terms of the West South Central electricity usage is considerably higher than in New England with 14,363kWh per household and 146.5 million Btu per household in primary electricity and 49.0 million Btu per household in site electricity. With almost double the New England populations, the West South Central region has a population of 11.8 million households and consumed 1.73 quadrillion Btu of electricity as primary and 0.58 quadrillion Btu as site in data from 2001. This results in this region consuming 170 billion kWh of electricity as compared to New England that consumed 39 billion kWh of electricity. The increase is again reflected in the energy consumed per household 146.5 million Btu per household of primary electricity and 49.0 million Btu per household of site electricity. In 1999 the cost of electricity to the residential sector of Texas was 7.55 cents per kWh a price which declined to 6.62 cents per kWh in 2002 but in the western south region that Texas is in the average cost of electricity was 8.4 cent per kWh.[3] So while Texas may consume more electricity it has rather low cents per kWh for its region.

Based on these numbers we can gauge the success of a solar installation and estimate how much solar will be able to produce. Through further research there will be a lingering debate as to the specifications of the solar technology as well as possible back up technologies to be implemented. However one thing is quite clear and that is the installation will have to be designed specifically to meet a region's energy demand and capabilities in order to prove successful. Once an estimate of renewable energy's capabilities are established a break even point can be determined.

(QE)The prospect of designing a solar town must consider not only how much energy is obtained thorough solar energy but also how much will be used. In an effort to achieve the best energy consumption to production ratio we must first examine the consumption of energy by the type of housing. A town of one hundred can be housed in several ways but to achieve a functional town we must first try to reduce the ways in which energy is used and lost. A simple change in the living style of the town is enough to make a difference in the energy needs as well as the break even point in this design.

From the attached data (Figures 23-29) from the Energy Information Administration one can see that the residential sector currently uses most of its energy for heating and as a result the design of the housing would be best to reduce the need for usage of space heating energies. Whether in a single family house hold to a two to four unit, or even a five or more unit household the percent of households that use heating oil is about the same at ten percent. However when you compare this to consumption the potential savings are immediately clear. While a single family household used 801 gallons per household a two to four unit house hold use a little less with 728 gallons per household. The significant difference occurred with a five or more unit house hold which uses only 466 gallons per household of heating oil, almost half of a single family household. It would then follow that the five or more unit house hold also pay less with only 396 dollars per household versus 893 dollars per household for two to four unit households and single family household with almost exactly 1000 dollars per household. The 5 or more unit household paid 69 cents per gallon while two to four and single family household paid about 100 cent per gallon. Since heating is such a major part of energy consumption the implementation of 5 unit homes would not only lower consumption but lower the cost of maintenance.

While heating oil addresses the issue for space heating, natural gas is still the largest consumed energy source by the residential sector. However the same advantages that occurred with heating oil and 5 or more unit households occur with natural gas. As seen in the charts of Appendix E, they use less, and consume less, reap much lower costs of natural gas as compared to their single family and 2-4 unit counterparts. Thus a 5 or more unit house will be chosen to allow for optimal reduction in the areas of which residential consumption are greatest. This would hopefully allow for a reduction in the amount of energy need overall thus allowing solar to have a greater application in the town. Also the usage of more compact clusters of people may be helpful in that the need for distribution of resources to allow the town to stay running will be less versus networking all the single family houses together.

While the advantages gained by the usage of multiunit households would aid in minimization of the costs of the town, this will only remain constant as long as the prices remain consistent. However the cost of heating oil has been anything but consistent. Data from 1980 has shown a decrease in the cost of heating oil from 1980 to a few years before1990 where there was a slight increase leading to another decrease before 2000 and again there was an increase in 2001. What this data shows is a slight pattern in that over time the cost of heating oil peaks and then declines for about ten years. Following this cycle then a prediction of future heating prices can be assumed.

(QE)Figure 7 shows the heating cost from 1980 to 2001 data from the EIA. Figure 8 shows a forecast of the prices of heating oil, based on EIA data. The curve may prove to be a reasonable assessment of gas prices for the next ten years. This then predicts that heating oil prices will continue to rise but following the ten year cycle I believe that the actual increase in 2010 will only be about 150-170 cents per gallon. This will mainly impact the north since 38% of households use heating oil compared to about 3% in 1997.

Therefore to allow for optimal conditions of the town to break even, the heating efficiency of the units must be monitored and maintained to prevent losses in terms of time to break even due to increasing prices. While no data was available to compare consumption versus housing type just as the price of heating oil is increasing so to did the price increase in the data from the year 1997 and the year 2001. The ratio of cost however stayed the same with single family household paying 2.2 times more than five unit household. Therefore it is recommended that while the price may increase; know that the benefits achieved from multi unit households will remain.

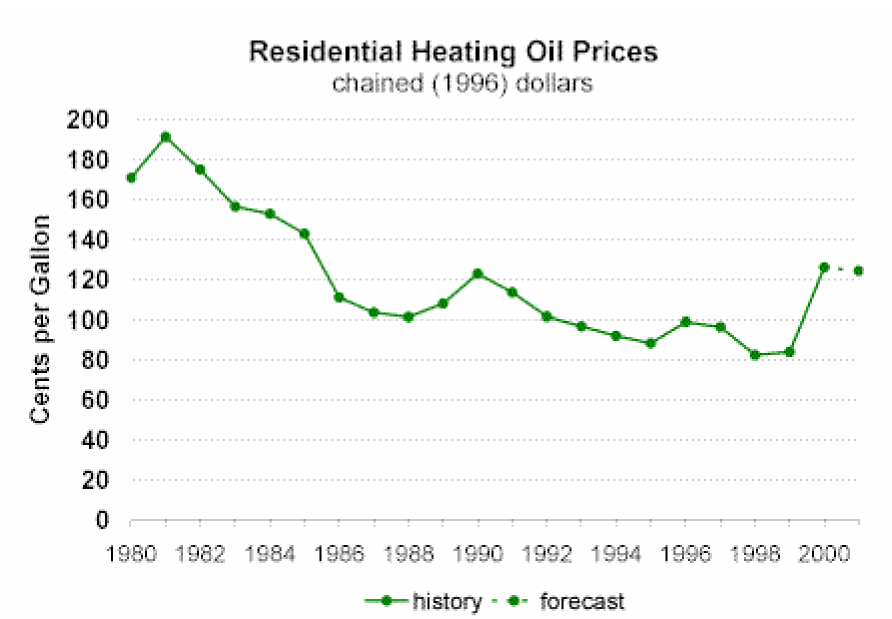

Figure 7: Residential heating oil prices, 1980 – 2000

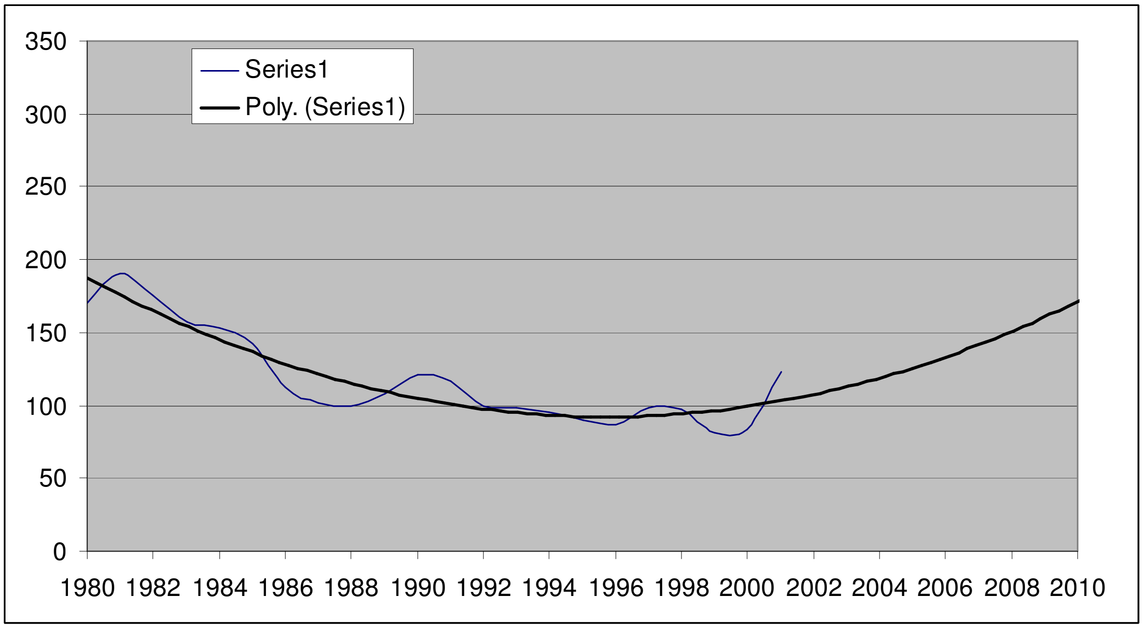

Figure 8: Residential heating oil prices and prediction, 1980 - 2010.

(QE)The concept of a solar house has the potential to replace electricity and drive it into a solely supplemental form of energy. However the downside to solar is that it is at the mercy of the weather, a factor that is rarely to humanity's benefit. A typical northeast winter can be about four to five months with only 6 to 8 hours of sunlight available. This results in the need for energy for heating at a time when the availability of the power source is at its lowest. Another factor to consider is the ability for a region to meet the economic expenses that would be incurred by the widespread implementation of solar energy. To fully reap the benefits there would be the need to somehow lower the cost of the installation of solar panels. Currently it is recommended that the north east setup a delivery plan for solar cells and manufacture them locally to avoid the fee incurred by the price markup of manufacturers. Using the Watson house as a base for the northeast region the total cost of installation in this region is about $35,000 however in an industrious region like the northeast one must wonder how much a solar house is really worth.

The average price of a house in the US from the first quarter of 2005 was $288,500 while the cost of a house in the northeast for the same timeframe was $366,800. The cost of a house in the northeast is almost 27% higher than the US average. The economics would lead one to assume that due to demand for realty in those regions the people are more willing and capable to pay more for a house. The installation of solar would be a 9.5percent increase in the initial cost of a house. This is minimal compared to the 26 percent increase in the price of house from just one year ago. However solar energy is not a quick fix, it is an investment and as in any investment it needs time. The average annual base salary in the northeast is $88,100 a close second to the west with $90,600. Data from 1997 shows that of the nationwide 10.2 quadrillion BTUs of energy consumed nationwide by households, 0.65quadrillion BTUs were by the northeast. Considering that the 5 million New England households account for only 5% of use ,they consumed 6% of the household energy. Over the years one can only assume that this over demand for energy has increased. From the data stated using the average salary and the cost of a house, if only half of the salary was used to pay for a solar house, one could start to break even in as little as ten years. Couple this with the rising price of oil and the dependence of the northeast on oil for heating purposes, the potential savings of a solar house could allow for an even more rapid recovery from both the cost of the house and the installation of the solar panels. Estimated to take at least 11 years to break even, the Watson house has already halved that time to 6.5years by the installation of solar panels. While the Watson house produces an average 23 kWh per day over a year for the renewable potential chart attached in Appendix G, you can see that New England may only be able to produce 4-6kWh/m2/day. This seems like a promising number that could prove solar energy a good supplement for electricity however there is still the issue of heating.

The weather of the northeast combined with the dependence on oil, and energy supply only increasing in price, are the only hindrances to widespread implementation of solar house in the northeast. The International Monetary fund assumed gas prices would be $18 per barrel in 2000 and the reality was slightly higher around $30. Gas prices are continuing to rise with data from the Energy Information Administration showing crude oil price at about $35 dollars per barrel and only one year later an increase to $55 dollars per barrel. The northeast will always have a constant demand for heating and with oil being the main option, this results in a dependence on oil that dictates several prices in the northeast. Prices change so often residents are left at the mercy of the prices. While solar is an option it would have to be readjusted to perform the necessary tasks without the need for energy storage since much of the energy we use today is lost simply through the storage process. This change however is very possible both financially and physically if done with respect to the northeast's needs for energy.

Solar Energy

Passive Solar Techniques

(AK)Before the introduction of cheap energy sources homes were built with their environments in mind. Southern homes had large airy porches to provide shade and to avoid the humidity. In the North, the southern sides of homes were built to absorb as much heat as possible and to retain that heat. However, as cheap oil and electricity became readily available less thought was put into designing a home efficiently and more money was put into additional air conditioners and heaters.

With increasing energy prices, there has been resurgence in designing buildings to make full use of their environments. According to the United States Department of Energy "HVAC (heating, ventilating, and air-conditioning) accounts for 40% to 60% of the energy used in U.S. commercial and residential buildings."[24] The USDE also says that, "incorporating passive solar designs can reduce heating bills as much as 50 percent."[25] Along with the cost benefits, passive solar techniques have been shown to improve health, comfort, and productivity.

Daylighting:

Daylighting is the technique by which natural sunlight is used to light interior spaces. The use of a celestory (Figure 9) can significantly brighten up a room. In conjunction with large open rooms that allow the light to spread, the need for artificial lighting can be reduced significantly. Also, many people report happier, more comfortable lives when using natural light. However, for some, especially the elderly it has been known to be too bright.

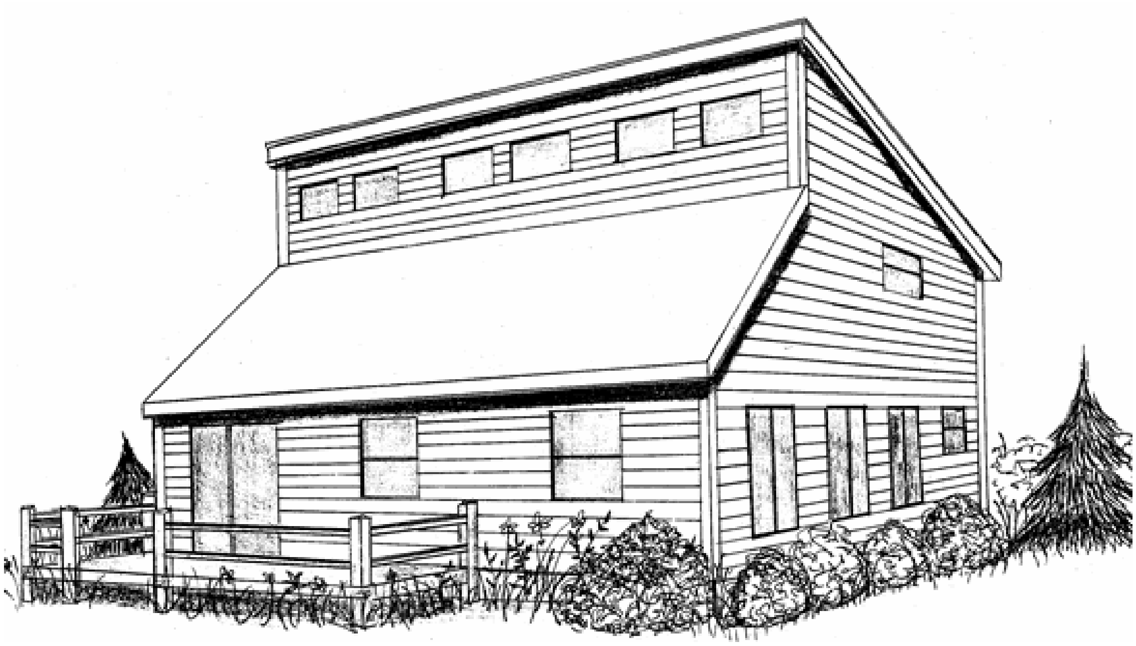

Figure 9: A celestory can be seen on the top floor.[18]

Sun-Tempering:

Sun-tempering is the technique by which large windows directly let sunlight in to warm a house. These windows face true south and have glazing applied to get the characteristics desired. In the north, double or triple glazing is used to trap heat in, while in the south, reflective glazing helps to keep heat out. Sun tempering is a "great strategy for cold climates and costs nothing beyond good planning"[19] which makes it the number one choice for passive solar installations.

Sun windows are accompanied by overhangs which are properly scaled to allow sun in during the winter, and shade during the summer (Figure 10). In the south, large awnings or wooden sun shades are used to block as much sun as possible. Sun tempering is usually used in conjunction with a thermal mass.

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18 http://www.nwjoinery.com/planbook/h_salt_clerestory.htm
19 http://www.eere.energy.gov/buildings/info/documents/pdfs/29236.pdf

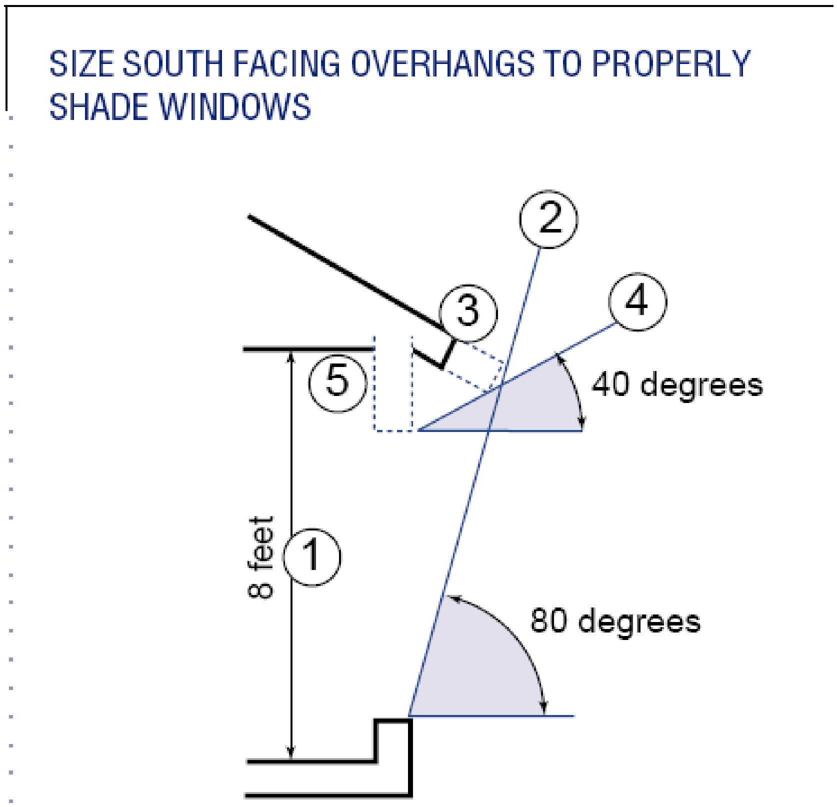

Figure 10: Sizing overhangs for sun windows.[19]

Thermal Mass:

Thermal masses are generally composed of rocks, water, or phase change materials such as eutectic salts. They can be made into the south facing wall to absorb the sun's heat and for greatest efficiency are often painted black. They can also be incorporated into thick concrete floors and rock beds.

Thermal masses serve many purposes in a passive solar home. Firstly, they regulate temperature fluctuations by taking the shock out of the temperature change from day to night. Secondly, at night the thermal mass will slowly release heat back into the house, helping to keep the temperature from dropping. Thirdly, because the thermal masses are usually more than 6 inches thick, they provide insulation for the floors and walls.

Green House:

Green houses serve multiple functions in the passive solar home. Since the greenhouse is generally separated from the main house, the green house temperatures can be much higher. The warmer air in the greenhouse can be vented back into the house via a blower, or if cleverly designed by induced ventilation (Figure 11). The thermal mass is a thermal wall which heats the air causing it to rise. The air is drawn into the house at the top of the greenhouse because the house air is cooler. Cool air from the house is sucked into the greenhouse at the bottom. This sets up a cycle that is continuously warming the house air during the day. Shutters on the vents help regulate the flow if heating is not necessary.

Green houses help boost the usefulness of a thermal mass. Since green houses are warmer, the thermal mass can store more heat. Greenhouses can also be used to preheat water, reducing utility bills.

In hot humid southern areas a greenhouse can be used in conjunction with desiccants to remove moisture from the air. Two desiccant containers are attached to a turn table. One container is open to the house; the other is open to the greenhouse. The container in the house reduces the humidity, which reduces the need for air conditioning. When the desiccant has absorbed as much as possible it is rotated out into the greenhouse. The other container is now in the house continuing the job of dehumidifying.

The greenhouse heats up and evaporates the captured moisture from the first container, allowing the container to be used in the house again.

As a final bonus, greenhouses allow people to grow plants all year long. This increases air quality and general happiness.

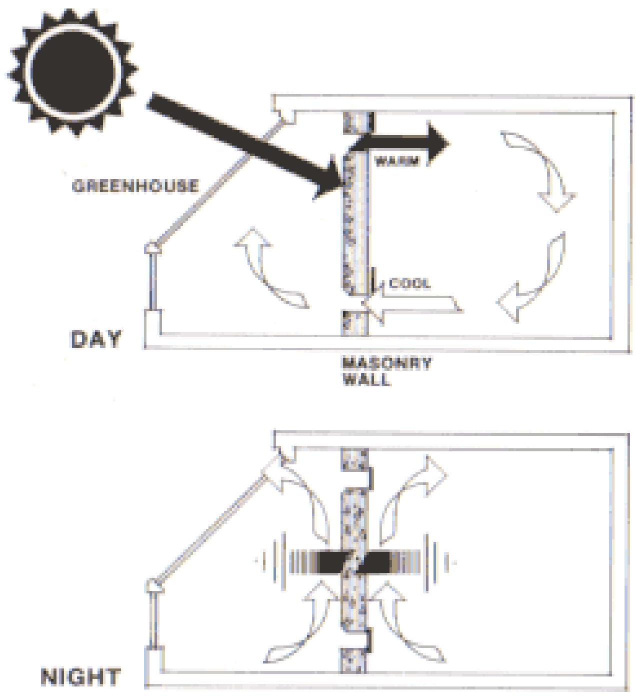

Figure 11: Induced ventilation using thermal walls and a greenhouse[20]

Other Techniques:

Other techniques can be used to help regulate the home's temperature. Earth berms or building into a hillside helps to insulate the house and is best suited for the cold northern side of the home. Trees and shrubs act as wind breakers which diminishes heat loss. Also, during the summer trees act as shade, while during the winter deciduous trees

20 http://www.azsolarcenter.com/design/images/fig9.gif

allow as much as 60% or more sunlight to hit the house[21]. Strategically placed windows on the east and west side of a home can create cross ventilation on hot summer days. If in an extremely hot area, a sprinkler can be attached to the roof. The evaporation of the water greatly helps heat dissipation.

In building a passive solar home, the extra cost is usually not much greater than a typical building. All that's needed is the time and the effort to properly design a passive solar home. According to the USDE, "depending on the aggressiveness of the design, experience has shown that it costs no more than 10% more to build high-performance buildings. Some high-performance buildings cost less to construct. Sometimes additional upfront costs can be justified because the investment will reduce operating costs through the life of the building."[22] With all these advantages, it is easy to see why passive solar design is gaining renewed interest.

Figure 12 is a three family home concept design which incorporates many of the above passive solar techniques. The multifamily design was chosen because as previously stated, the heating requirements of a multifamily home are much less than that of a single family home.

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[21] http://www.eere.energy.gov/buildings/info/documents/pdfs/29236.pdf
[22] http://www.eere.energy.gov/buildings/info/design/wholebuilding/costanalysis.html

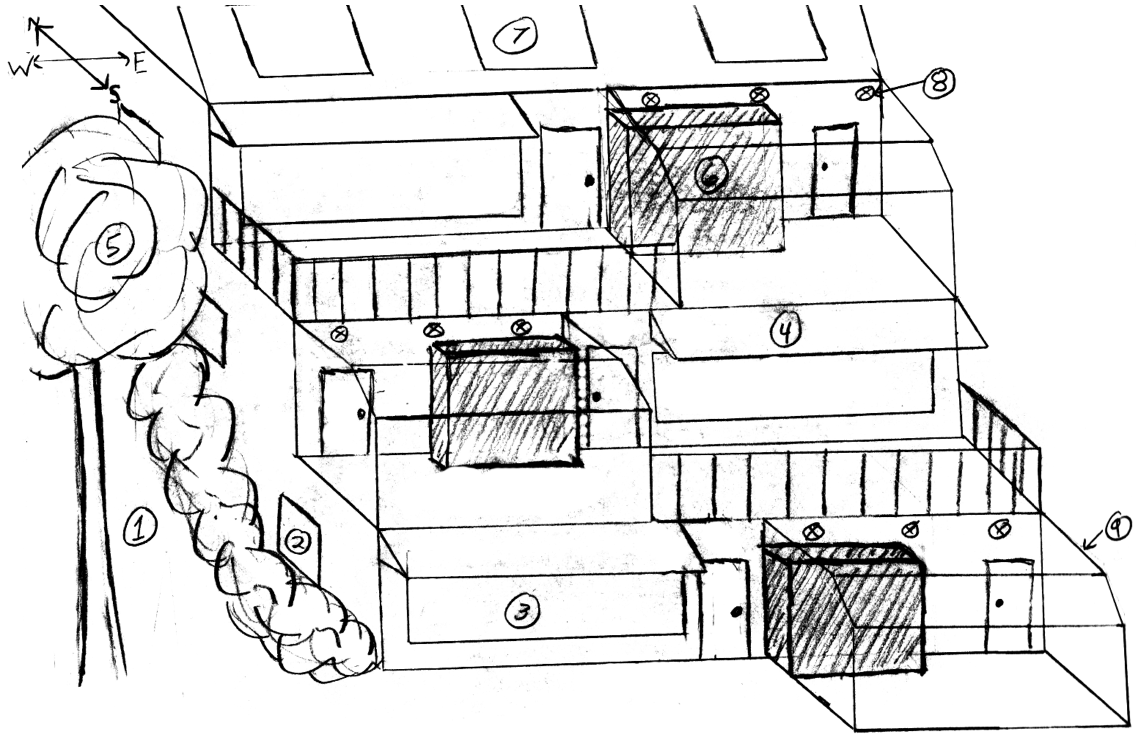

Figure 12: Three family passive solar house concept

1. Earth berm or built into a hillside to protect chilly Northern side
2. Side windows for cross ventilation in summer
3. Large south facing windows for sun tempering. Triple glazed in the North and single glazed in the south.
4. Overhangs that block sunlight in the summer and let sun light in during the winter. The south would have large awnings
5. Trees and shrubs as a wind breaker
6. Thermal storage device to release heat at night and mediate temperature fluctuations. Thermal storage device is filled with stones, water, or eutectic salts.
7. Solar water heaters.
8. Vents and fans to draw in or expel warm air from the greenhouse.
9. Green house to supply warm air and heating for thermal storage device

Active Solar Techniques

(AK)There are two main types of active solar techniques, electrical or heat production. For electrical, photovoltaics are used to convert sunlight into electrical energy. This will be discussed later on. The other type uses solar panels to heat up water or air which is then used to heat the house. For typical convection heating, air is heated and blown into the room. The air is what warms you. However, solar allows for radiant heating, also called hydronic heating, in which the floor is heated by hot water pipes, which in turn radiates heat to the surroundings. This is analogous to warming your back with a campfire even though it is freezing outside. Radiant heating allows for a lower temperature difference between the floor and the ceiling. This is because radiant heating emits heat uniformly over the floor, and thus the room space does not have hot or cold spots.

In convection heating, very hot air is blown out of side vents, and then quickly rises to the ceiling. This creates hot and cold spots in the room, and consequently creates a much greater temperature gradient in the room. These cold spots also prompt the homeowner to raise the thermostat higher than what is necessary, causing a higher heating bill. Also, in radiant heating, the ceiling is cooler, as opposed to convection heating in which the ceiling is the hottest. Because of this, less heat is lost thru the ceiling, which reduces the heating requirements of a household. See figure 13 to view how the two systems differ.

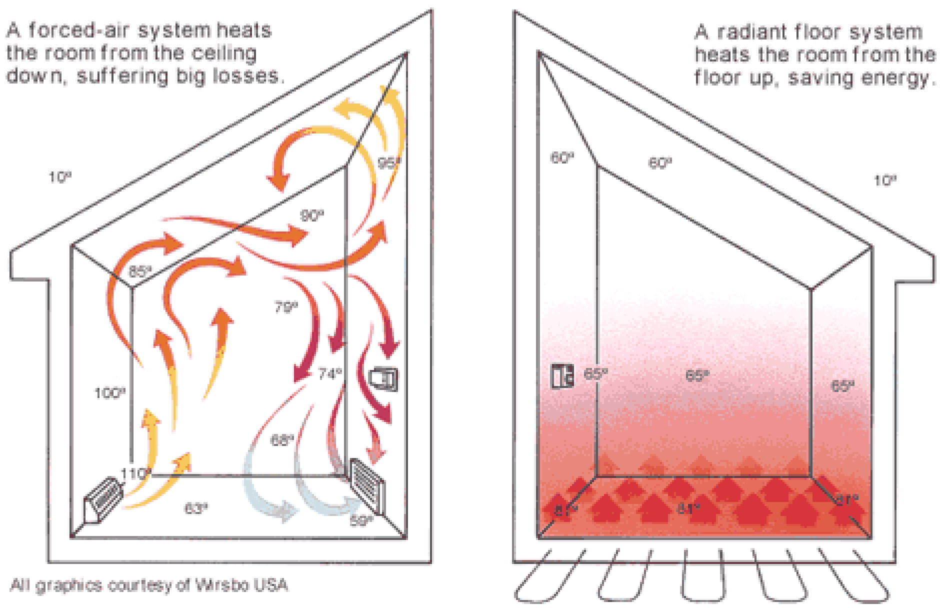

Figure 13: Convection versus radiant heating.[34]

Radiant heating creates a more uniform and comfortable atmosphere when compared to convection heating. Radiantec offers this interesting quote, "Studies conducted by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) indicate that with radiant heating systems people can be comfortable at temperatures 6°F to 8°F lower than with convective systems." This is especially interesting when compared to Table 3. The claim is in Fahrenheit, so in Celsius it would be about a 3 to 4 degree decrease. If a home were to reduce its thermostat temperature 3-4°C from 22°C(72°F) they would reduce their annual heating requirements by as much as 20-25%. This means huge heating cost savings. Not only does the system save money on heating costs, it also encourages a reduction in heating need.

Table 3: Percent Reduction in Annual Home Heating Requirements at Reduced Thermostat Settings(Estimated for the Southwestern Ontario Region)[30]

Original thermostat setting (°C)	Percent reduction in annual requirements by reducing setting in C°				
	1	2	3	4	5
24	6.2	11.8	17.9	23.4	28.8
22	6.5	12.4	18.7	24.5	30.1
20	6.9	13.3	20.1	26.3	32.3
18	7.6	14.4	21.7	28.3	34.8
16	8.0	15.3	23.1	30.2	36.8
14	8.8	16.8	25.3	32.8	—
12	9.5	18.1	—	—	—

Solar by Region

(QE) Currently the United States constitutes less than five percent of the world's population yet it consumes one fourth of the world's energy resources. Data from 2002 has shown that while China had a population of 1295 million and consumed 43.2 quadrillion Btus, the United States had only 288 million but consumed 97.4 quadrillion Btus. Of that amount about one fifth of the energy consumed by the US was by households. With this much demand for energy within the household, one must wonder whether an alternative source of energy such as solar would be advantageous. The breakdown of energy distribution in a household varies dramatically depending on social status and location. However there is a major energy demand in the household that seems consistent and that is the demand for water heaters whether it is for dishwashers, laundry, showers or hot tubs. A 40 gallon water heater uses 4500-5500 watts per day and an average 900 kWh annually. If solar were to be implemented as a source of power it would have to at least meet this demand both daily and yearly. Another factor to consider is the expenses incurred by usage of energy in the average household. About 42 percent of the expense is heating or cooling, 36 percent are attributed to lighting and appliances with the remaining percents going to water heating and refrigeration at 14 percent and 9 percent respectively. All these factors must be such as efficiencies of the house, and its solar panels and the cost of implementation must be compared to accurately prove that running a house on 80% solar energy is not only possible but economically feasible.

(AK)After some research, it was decided that a net metering system should be used. Net metering systems are primarily used in areas with existing power grids and are the most cost effective for reducing utility bills[5]. If the solar panels are not providing enough power, then the electrical grid is used to make up the difference. If the solar panels are producing more power than needed, then the excess can be redirected into the power grid. This eliminates the need for backup batteries.

The cost of the system can vary greatly depending upon location. Areas with the highest rated sun index like New Mexico can produce nearly four times the power as the lowest, such as Michigan, with the same solar panel(See Table 7)[5]. Depending upon need, the cost can vary from $8,000 to $50,000 for a complete system(See Table 6).

Southwest PV Grid-Tied Solar Electric Systems									
Model#	GT1200	GT1500	GT1800	GT2100	GT3000	GT3600	GT4200	GT6000	GT9000
PV Peak watts STC	1,200	1,500	1,800	2,100	3,000	3,600	4,200	6,000	9,000
# and type of PV	8x150W	10x150W	12x150W	14x150W	20x150W	24x150W	28x150W	40x150W	60x150W
PV array sq. ft	114	143	170	200	285	340	400	560	850
Inverter	1xSB1800	1xSB2500	1xSB1800	1xSB1800	1xSB2500	2xSB1800	2xSB1800	2xSB2500	3xSB2500
List Price	$7,799.00	$8,999.00	$10,099.00	$11,899.00	$15,999.00	$20,599.00	$23,199.00	$32,999.00	$49,999.00

Table 4: Examples of PV grid-tied electric systems[24].

Solar for the North East

(QE)There is currently a house that has implemented the use of solar energy as a source of electricity. The Watson Solar house is a project in work and even though the house is up and running on solar energy there are some issues that may dictate whether it is a complete success (Table 5). For example it is located in Boston, Ma and while during the summer or autumn season it can perform well the winter season creates a lack of the solar source from which to draw power along with and increased demand for energy. This brings up the question as to whether or not it is worth it. They are currently in debt from the implementation of the solar house as you can in the table from one of their charts which thoroughly displays an analysis of the house costs. The availability of the sun becomes a vulnerability at times with a solar house. Though current conditions only allow for a certain percent energy conversion as well as current energy prices that may counteract savings achieved by solar use. Based on the numbers from the Watson house it seems very feasible to run a house on 80 percent solar power but again it all depends on location. As shown in the table the solar power produced in a year was almost 9100kWh. The average US household consumes 10000kWh per year but while there is an uncertainty as to the thermal or electrical efficiency of the Watson House it seems that if done with the accuracy to account for places that allow for energy loss, a solar house is a possibility to provide 80% of the energy necessary. However there is one factor that must be changed. As stated earlier it is obvious that the US household consumes far more energy than necessary when compared with its international counterparts. Therefore, in order for a successful change to solar power there will also be the need for change in the lifestyle of the US. That said it would seem very feasible for other parts of the world in terms of energy supplied but other countries may simply lack the solar power or the financial investment necessary to reap the benefits of such an endeavor.

What	Initial Estimate	Current Estimate	Actual After 18 Months
Equipment	$29,000		$29,592
Installation	$6,000		$5,864
Total Installation Cost	$35,000		$35,456
MTC Installation Rebate ($3.50/w)	-$16,000		-$16,632
Total Initial Cost	$19,000		$18,824
Yearly production in kWh	5,000	6,090	9,135
MTC 3-year production incentive @ $0.38/kWh (est.)	-$5,700	-$6,942	-$3,471
Mass Tax Credit (15%) to $1,000	-$1000		-$1000
Annual energy cost savings @ NStar costs (avg.)	-$600	-$838	-$1,257
Annual renewable energy credits @ 0.05/kWh (optional)	-$250	-$304	-$457
Total cost after 3 years, rebates	$9,000	$7,453	$12,639
Yearly savings after 3 years	-$850	-$1,143	
Break even after	11 years	6.5 years	

Table 5: Pricing information of the Watson Solar house

Solar for the South East

(AK) With energy prices increasing daily, the appeal of solar powered homes is increasing. With the advantage of having the sunshine state, the Southeast may be ideal for solar applications.

"The average American household uses about 10,000 kWh yearly."[23] In the southeast most, if not all of this can be generated with photovoltaic cells. The southeast averages an equivalent sunshine hour (ESH) rating of 3.5 kWh/m²/day (Table 6). In these areas the GT9000 net-metering system(Table 7) can provide 730 kWh/month in the worst solar month of the year. That's a minimum of 8760 kWh/year, which covers most of the yearly electricity needs. The minimum is roughly 77% of the monthly average, so the system will typically produce 8760kWh/year*1.3 = 11400kWh/year. However, the complete system costs $50,000.

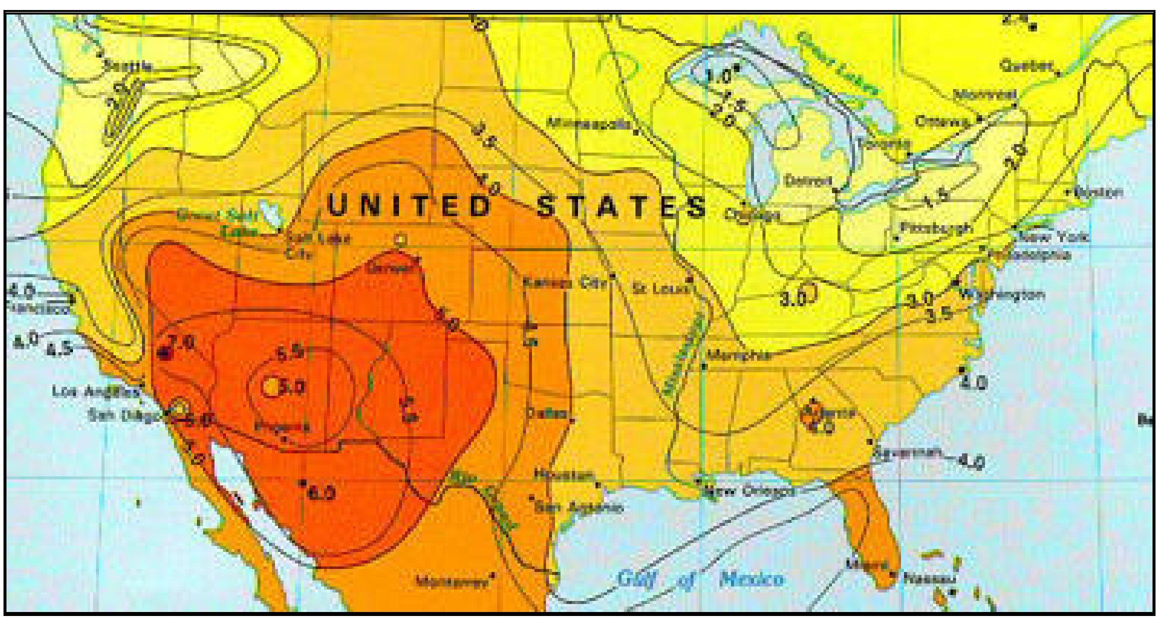

Figure 14: Equivalent Sunshine Hours map of the US

23http://www.larimer.org/compass/wind_en_use.htm

ESH	GT1200	GT1500	GT1800	GT2100	GT3000	GT3600	GT4200	GT6000	GT9000
1.5	41.7	52.1	62.5	73	104.3	125.1	146	208.6	312.8
2.5	69.5	86.9	104.3	121.7	173.8	208.6	243.3	347.6	521.4
3.5	97.3	121.7	146	170.3	243.3	292	340.6	486.6	730
4.5	125.1	156.4	187.7	219	312.8	375.4	438	625.7	938.5
5.5	152.9	191.2	229.4	267.6	382.4	458.8	535.3	764.7	1,141

PLEASE NOTE: The figures supplied above are based on the minimum monthly energy production which can be expected during the worst solar month of the year. Performance is calculated taking 8% inverter, 3% wiring and 4% soiling losses into account. Array temperature compensation is based on 77F. Lower temperatures will improve performance. Higher temperatures will reduce performance. Please contact SWPV with any questions.

Table 6: Estimated typical minimum monthly energy output (kWh/month)[24] (ESH: Equivalent Sunshine Hour in kWh/ m^2-day)

The average cost of electricity in the southeast is about $0.09/kWh.[25] With the photo voltaic cells having a twenty year warranty, the savings on electricity is then 11400kWh/year*$0.09/kWh*20years = $20,520. This is nowhere near the cost of the system and is roughly equal to $0.22/kWh, a thirteen cent disparity. This would imply that the system is not economically feasible, but there are several factors to consider.

"Under federal law, utilities must allow independent power producers to be interconnected with the utility grid, and utilities must purchase any excess electricity they generate. Many states have gone beyond the minimum requirements of the federal law by allowing net metering for customers with PV systems"[26]. Selling electricity back to the power grid will help offset the cost of the system. With increasing energy costs, the disparity between the cost of the system and the cost to buy from the power companies will shrink.

Energy consumption can be drastically reduced. This will decrease the amount of electricity bought from power companies, and increase the amount of electricity sold.

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24 http://www.southwestpv.com/Catalog/Home%20Power/Net-metering.htm
25 http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html
26 http://www.eere.energy.gov/solar/net_metering.html

Fluorescent light bulbs and energy efficient appliances will help reduce the energy need. The major sinkhole of energy is heating. In the warmer southern climates, a thermal solar water heater could preheat the water. Then a tankless propane water heater[27] would heat the water the rest of the way when it is needed. This helps to reduce the propane needed, and is more efficient than electrical water heaters. Large thermal windows and other passive solar techniques would help to heat the house and lower the cost of heating too.

With sufficiently reduced energy requirements a less expensive photo voltaic system could be bought instead, thus easing the initial capital cost burden. Even so, at the present time a solar home in the southeast is not economically feasible without government and third party incentives for green power. Since these incentives only cover individuals and not the overall populace, a full scale conversion to solar power will not be a feasible alternative for the Southeast until electrical prices nearly double.

Solar for the North West

(RJ)The Pacific Northwest currently generates 82% of its electrical capacity through hydroelectric power. The region also has some of the lowest retail electricity costs in the country – around $0.07/kWhr compared to $0.13/kWhr in Massachusetts – and a solar intensity less than that of New England. With electricity costs around half those in New England, the return on investment for an installed residential solar system would take twice as long to pay off. See Figure 15 for a graph of the solar intensity in the United States.

[27] http://www.backwoodssolar.com/Catalogpages2/non-elec2.htm

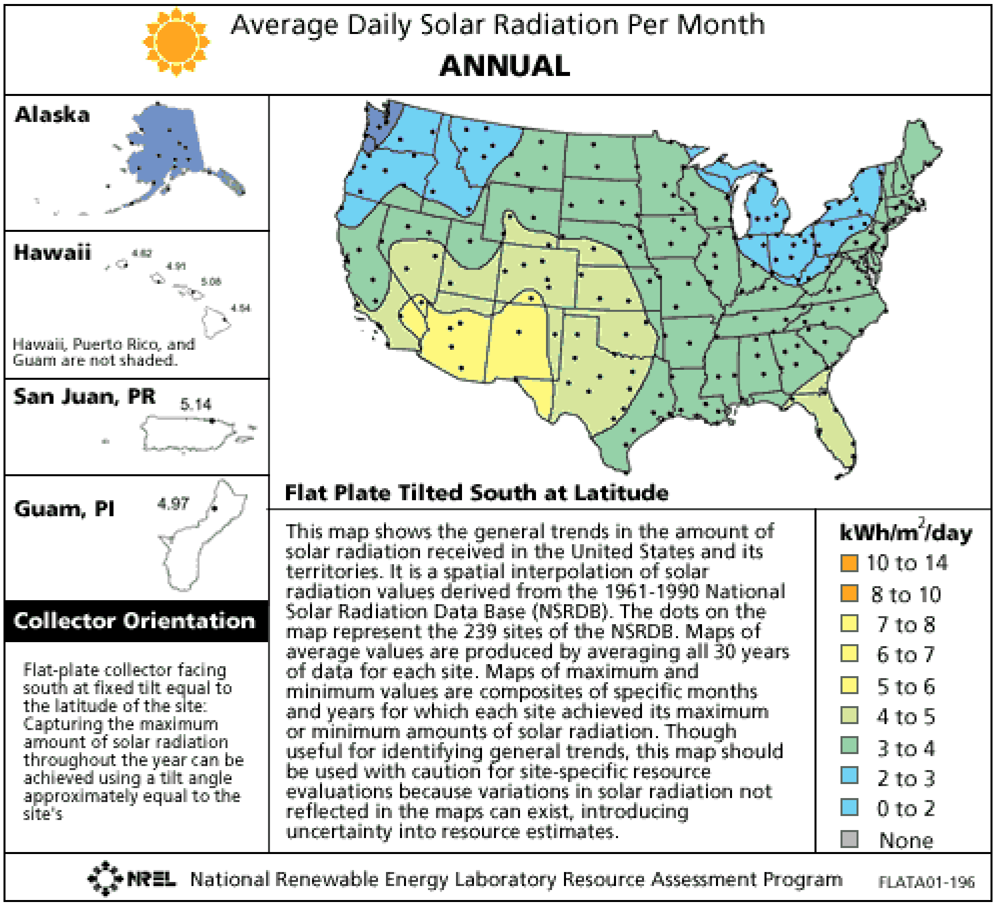


Figure 15: Average daily solar radiation per month. Notice that the Pacific Northwest receives less solar radiation than Massachusetts.

According to the Solarbuzz Solar Electricity Residential Price Index, the installation cost for a 2kW residential system in a cloudy climate, such as the PNW, is currently around \$0.83/kWhr over the lifetime of the system. With average residential electricity consumption around 10,000kWhr/yr, the average annual electricity bill should be around \$750 in the PNW, and \$1300 in Massachusetts. Over 20 years, the cost of electricity in the PNW would be expected to be \$15,000, compared to the \$18,000 capital cost of the solar system that generates electricity for 20 years. In Massachusetts, the electricity cost over 20 years would be expected to be around \$26,000. In this quick-anddirty comparison, solar power in the PNW does not seem to be an economically feasible solution. If most of the electricity generated in the PNW came from burning coal, then environmental costs could be taken into consideration, and might make residential-scale solar power generation economically feasible. In reality though, the overwhelming bulk (83%) of electricity is generated by emission-free hydroelectric systems. Therefore, generating residential power using photovoltaics currently does not make economic sense. This quick calculation doesn't take into account rising energy costs. The Rand S&T report does discuss this, and their conclusions follow.

Currently, most power in the PNW is already generated by non-polluting technology. The Rand S&T report studied various approaches to meeting the rising demand. The primary energy source in the near future will likely be natural gas. The future price and availability of NG is uncertain, and such plants do release air pollutants and CO2. Future costs of natural gas generation can be reduced by supplementing capacity with renewable generation (wind, solar). The EIA predicts that generating 10% of capacity with renewable energy will bring NG prices down far enough to compensate for the higher cost of implementing renewable generation. This statement alone is reason enough to investigate the feasibility of renewable generation on a more detailed level.

On a national scale, the residential sector consumes most of the end use electricity at around 1,293 billion kWh. This compares with the commercial sector at 1,229 billion kWh, and the industrial sector at 1021 billion kWh. Data specifically for the Pacific Northwest has yet to be located. According to an EIA annual energy review report, the industrial sector consumed the most end-use electricity until the early '90s, after which point the residential sector became the major consumer. The commercial sector closely parallels the residential sector, although it historically and consistently has consumed less power. See Figure 16. Assuming this trend continues, it makes sense to focus on generating electricity to meet the demands of the residential sector first.

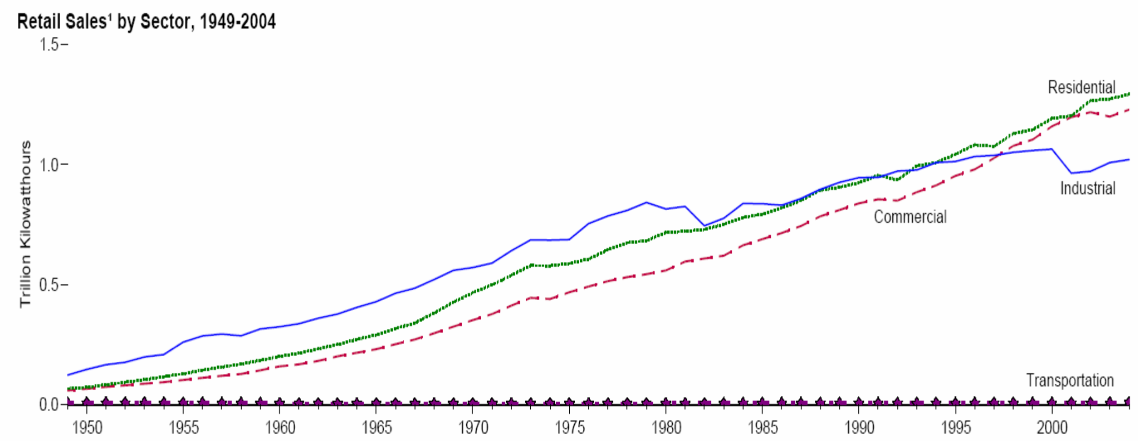


Figure 16: Retail sales by sector[28]

According to the Rand report, peak load generation is costly and polluting with conventional combustion power plants. Typical peak load demands conveniently coincide with daylight hours, making solar generation a viable solution for handling peak loads. The residential sector being the largest electrical consumer, the logical next-step is to determine whether the increase in demand is coming from the construction and operation of new housing units or a general increase in the consumption of existing units. In the former case, it certainly makes sense to incorporate local solar generating capability into new units, especially if natural gas costs do rise in the northwest. This will count toward the 10% of new demand goal mentioned earlier. If that goal is reached, then savings from reducing the natural gas demand may offset the cost of solar generation.

[28] *Electricity*. Annual Energy Review 2004 section 8, Energy Information Administration

Solar/Hydrogen Combinations

(QE)The concept of a solar community leads to a future of clean and free energy. In an attempt to increase these traits in our community we could also use solar to produce hydrogen. The possible uses of hydrogen would extend from an additive to gasoline to lower emissions of ozone depleting pollution, a more efficient carrier of energy than electricity that costs four times to transfer, a way to generate heat and electricity for buildings, as well as an energy storage device in the form of fuel cells. With these benefits one might begin to wonder why there is not more of a wide spread use of hydrogen. The answers lies mainly in that it is new technology that has not yet been efficiently adapted for widespread usage. While NASA is currently the primary user of hydrogen, it is mainly used to make hydrogen batteries, better known as fuel cells. This is however a very costly process to manufacture therefore the process of making hydrogen must first be examined for efficiency to avoid more expenses in the fuels cell process.

There are a few ways that solar energy can be used to generate hydrogen, but the best scenarios would involve the production of hydrogen with little input. For example there is a photo electrochemical water splitting process in which semi conducting electrodes are used in a photo electro chemical cell to convert light energy into chemical energy of hydrogen. Another is a photo biological process in which biological systems use sunlight to make algae split water into hydrogen and oxygen constituents. Both of these processes are a relatively simply way in which to produce hydrogen however they are very inefficient with less than one percent efficiencies. This is not yet economically viable and has not been tested on a larger scale. There are currently ways for the usage of photovoltaic systems to make electricity that can be used to make hydrogen but this would seem wasteful as electricity is energy in its most desirable form and to use it to make hydrogen only to make more electricity would be very inefficient. It takes 51kWh of electricity to generate one kilogram of hydrogen as stated by an article from the Florida solar energy center. The following is a scenario where they prove the inefficiency of the generation of Hydrogen though Photovoltaics; "Let's consider the case of a hydrogen fueling station dispensing 1000 gallons of gasoline per day, which is one-half that of the national average. Note that one gallon of gasoline contains just about the same amount of energy as in one kilogram (kg) of hydrogen. Thus, a fueling station, it will require about 1000 kg of hydrogen per day. Using the lower heating value of hydrogen, the electrical energy needed to generate one kg of hydrogen is 51 kWh (using an electrolyzer efficiency of 65%). This means that 1000 kg/day of hydrogen will require 51,000 kWh per day of electricity. The amount of PV needed to supply 51,000 kWh can be estimated by dividing the kWh by 5 hours/day. Thus, 10,200 kWp or 10.2 megawatts of PV power will be needed for operating a 1000 kg/day hydrogen fueling station. Note that 1 kWp requires approximately 10 square meters in area for PV at 10% efficiency."[4] The amount of electrical energy required to make hydrogen is simply too much for the output, making current technologies very inefficient.

However there may be a simpler solution that yields more efficient results in the production of hydrogen. The Solar Hydrogen Energy Corporation lab (SHEC) has developed a process that requires nothing more than methane and the heat of sunlight. The formulas are

Reaction 1

$CO_2 + CH_4 \rightarrow 2H_2 + 2CO$ $\Delta Hf = 917$ kJ/mole

Reaction 2

$CO + H_2O \rightarrow H_2 + CO_2$ $\Delta Hf = 40.6$ kJ/mole[5]

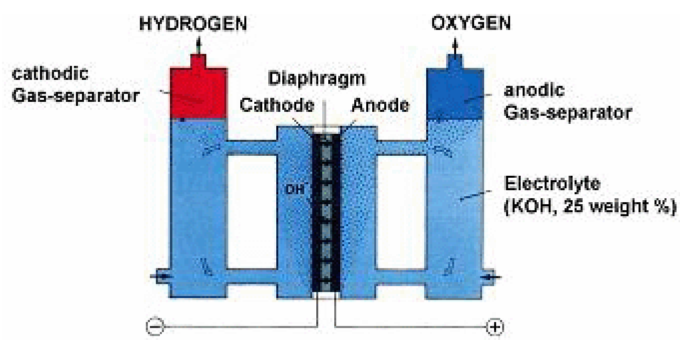
In which reaction one, methane and carbon dioxide are reacted to yield hydrogen and carbon monoxide. The carbon monoxide is then reacted with water to produce more hydrogen and carbon dioxide. The only regulations needed on this process are controlled temperature for reaction one and atmospheric pressure for reaction 2. The process is very efficient with a greater production of energy from hydrogen with $1m^3$ or methane making $3.9m^3$ of hydrogen and the methane having 40 J of thermal energy while the hydrogen has 45.7J of thermal energy. However while the production of hydrogen is almost at its peak yield of sixty six percent and 98.2 percent mole conversion of the methane feed energy is lost when it is converted from one form to another. A conversion chart was found on the SHEC site however it was available for natural gas and not methane but natural gas is almost 90 percent methane. The $3.9m^3$ of hydrogen produces 11.7kWh of energy under STP while the $1m^3$ of natural gas produces11kWh but since natural gas is only about 90 percent methane the actual amount of energy methane produces is closer to 9.9Kwh making for an increase of 1.8 kWh by converting the $1m^3$ of methane to 3.9 m^3 of hydrogen.

From this process it is clear that the hydrogen produced from this process produces 18 percent more kWh of energy as well as increased thermal energy so it would seem that this process would be beneficial in using solar. The only hindrance would be the lack of widespread usage of hydrogen and ways in which to handle it combined with cost of installation of the solar thermo chemical generator needed to execute the process.

If a sufficient and safe process for the storage and conversion back to heat or electricity is maintained this process could prove a feasible addition to the solar town. More investigation into costs will need to be done to gauge its real worth.

(QE)For our town the implementation of the SHEC Labs Solar Thermo Chemical Hydrogen Generator was chosen to extract hydrogen using the power of solar energy. The process would involve first feeding carbon dioxide and methane gas into a reactor and allow this to be heated by a solar mirror array to about 850 degrees Celsius. These would then react to achieve hydrogen and carbon monoxide. These intermediate products would then be fed into a water gas shift reactor controlled to near atmospheric pressure. This then yields hydrogen and carbon dioxide saturated with water. The only controls that would need to be maintained are the amount of heat allowed into the reactor for the fist part of the reaction and the temperature of the second part of the reaction. This would allow for a clean and efficient produce of hydrogen. Combined with a biomass process that can produce carbon dioxide, methane and hydrogen would result in the reduction of need for resources as the systems would rely on each other for cyclic sustenance.

While solar heat may be one way to produce hydrogen the implementation of electrolysis of water using excess photovoltaic energy may also be an option that may prove useful. New solar cells are being designed in the hopes of being more efficient and less expensive. One idea is Dye-sensitized solar cells that use titanium dioxide to generate voltage. Since titanium oxide is cheap it can help reduce the cost of solar cells. The Pyron Solar Company has a design that may aid in the process of achieving hydrogen efficiently. The system uses excess solar energy to produce hydrogen with about a 76%electrical efficiency for the electrolysis process. This results in 3.9kWh of electricity to produce one cubic meter of hydrogen that has potential energy of 3kWh. This would then be able to be used as electrical power at night or at times when solar consumption dwindles. Also the hydrogen could be sold to be used as substitutes for energy such as gasoline, since it has an energy content of 33.3 kW-hr/kg that is four times the energy content of gasoline. Hydrogen fuels cells are three times as efficient as internal combustion engines with an efficiency of about 50 percent. While this is not very impressive, progress is being made and in the meantime Pyron has produced a new concentrating cell design that can produce 800 times more energy than non-concentrating cells the same size. They have an efficiency of 37.3% and with "2,850 kWh/m^{2}yr direct-sunlight as in sunny deserts, the annual electricity yield will be 450 kWh/m^{2}year or 450 GWh per km^{2}year."[2]



While there are varying methods to produce hydrogen from solar energy the main factor is the efficiency. Converting energy from one source to another loses energy therefore a process that minimizes the amount of time energy is converted would be better. Therefore at this time the SHEC Lab's methods of direct sunlight heating appear more efficient but as technology progresses it is assured that the production of hydrogen from photovoltaic will someday be developed to meet the efficiencies of its competitors.

Bio-Mass

Biomass Background Information

(RJ)Biomass refers to plant material and waste that is consumed to generate energy. Biomass-derived fuels can provide residential community-scale power generation with existing technology, that is, the means already exist to propagate renewable distributed generation technology. The practice of generating and consuming power locally is known as distributed generation (DG), as opposed to central generation where power is generated at a central plant and transmitted elsewhere for consumption. As energy costs continue to rise, distributed electricity generation becomes more attractive to communities interested in disconnecting from the grid. Biomass is suited to DG because less energy is consumed in transporting the fuel when it is grown close to the community.

Biomass makes up a small fraction of the energy consumed in the US, as discussed by an Energy Information Administration (EIA) Renewable Energy Trends report and illustrated in figure 34 of Appendix F.

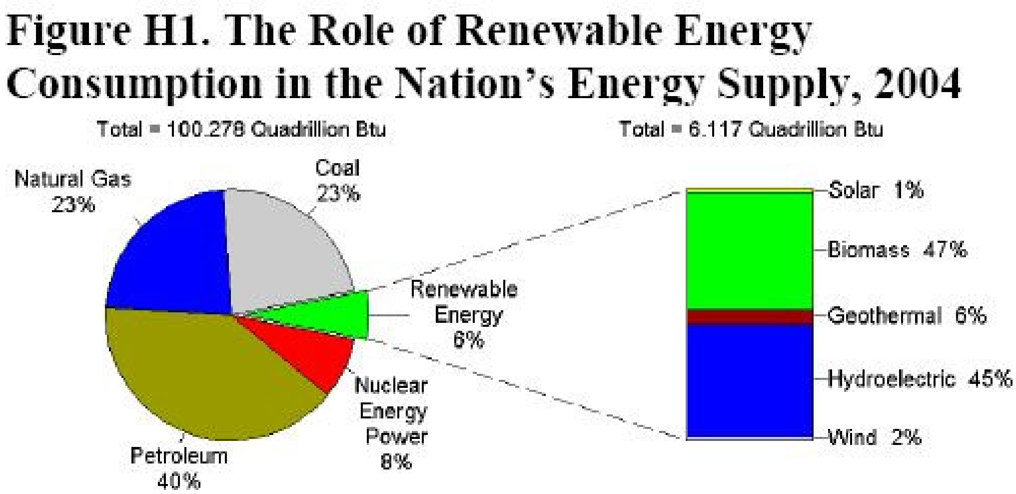


Figure 17: Biomass makes up a fraction of the renewable energy supply, which in turn makes up a fraction of the nation's energy supply.

In 2004, biomass supplied 2.8 Quadrillion BTUs of energy, as illustrated in Figure 17 . Of the total biomass energy, 0.51 Quadrillion BTUs (Quads) were used to generate electricity – only 18% of the biomass supply. The remainder of the biomass energy is consumed as thermal energy. The paper industry uses most of the biomass supply as thermal energy in the paper manufacturing processes.

Biomass energy is broken down into five categories.

- Sugar-Lignin (carbohydrates and cellulose, as in corn and wood)
- Syngas (produced by gasification of biomass)
- Bio-oil (produced by pyrolysis of biomass)
- Biogas (produced by anaerobic bacteria, as in landfills)
- Carbon-rich Chains (as in biodiesel)

The sugar-lignin platform usually refers to ethanol produced from plant sugars and cellulose. Lignin is the non-carbohydrate component of plant mass that binds the cellulose fibers together. Fermenting carbohydrates with the help of yeast traditionally produces ethanol. New, developing technologies allow the cellulose to be broken down into complex carbohydrates, which can then be traditionally fermented. Ethanol produced by this new process is called lignocellulosic bioethanol. The energy ratio is defined as the energy contained within a unit of fuel divided by the energy required to produce that fuel. The energy balance for ethanol is around 1.34[46]. Ethanol is considered a transportation fuel.

The gasification platform refers to the physical process of breaking down biomass into combustible gas. The gasification process entails heating the biomass in an oxygen-free atmosphere to release combustible gasses, then heating the remaining mass to higher temperatures in an oxygen-starved atmosphere. The first heating step is called pyrolysis, and the whole process is called gasification. Gasification feedstock, or material that can feed the process, includes all biomass. Even coal can be gasified, though due to lower concentrations of volatile compounds (30% by weight for coal compared to 70-86% for biomass)[47], it does not produce as much combustible gas.

Pyrolysis produces combustible gas or combustible liquid by heating biomass in an oxygen starved atmosphere. The technology is still in the development phase.

Biogas is produced through the anaerobic digestion of organic mass by bacteria and enzymes. A few municipal waste sites around the country already use biogas to generate electricity and useful thermal energy.

Bio-diesel is produced by converting vegetable oils and/or animal fats into esterified, long chain fatty acids and glycerol. The glycerol is a waste product, and the fatty acids can be burned in a modern diesel engine. Biodiesel has properties very similar to petroleum diesel. The energy ratio of biodiesel is estimated to be 3.2[48]. It is considered a transportation fuel.

To meet the needs of a small community of 25 homes, biomass gasification is the most attractive of the five biomass energy platforms listed above. The variety of feedstocks and good energy conversion efficiency as well as reasonable capital equipment size and cost contribute to gasification's viability.

Feedstock Requirements

(RJ)Gasification systems will process any feedstock. For a community of 25 homes, a reliable and consistent source of biomass feedstock is essential, and energy crops fulfill that need. The most researched energy crops in the United States are short-rotation coppice willow (SRC willow), SRC poplar, and switchgrass. Short rotation coppice willow refers to quick-growth willow tree that is grown in dense rows with relatively short crop rotation times of three years [49]. See Figure 18 for a picture of a willow coppice. Switchgrass is a tall, fast growing grass and crops can be harvested every year, without replanting, for at least 10 years [50].

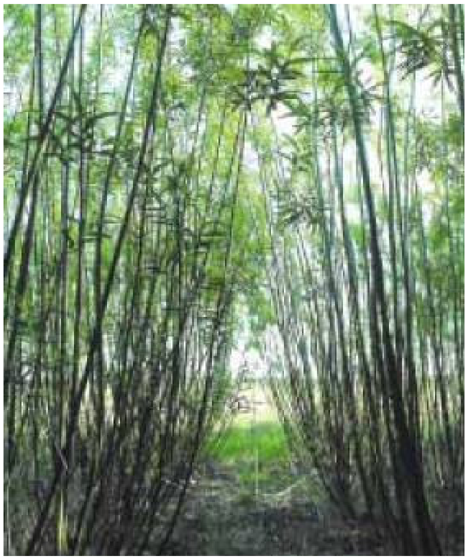


Figure 18: Willow planted in coppice rows.[48]

Harvesting coppice poplar and willow requires custom harvesting equipment, which is already available in Europe. Custom equipment adds to the capital cost, and SRC crops require 3 years to mature, which means three times as much land is required than if the crop were harvested every year. Woody biomass is easier to gasify however; tar and ash are not a concern because the wood gasifies cleanly, as proven by the McNeil power plant in Vermont. McNeil is a 50MW wood chip gasification plant that produces clean, medium density gas to power a standard gas turbine.

Switchgrass is the favorite energy crop of the Energy Information Administration because of its short, one-year harvest cycle and low processing costs. According to Haq [49], "Under the assumed yields and management practices, switchgrass dominates the biomass supply curve due to higher average yields and lower average production costs than hybrid poplar or willow." Also, "Energy content of switchgrass is comparable to that of wood with significantly lower initial moisture content"[51], which means that energy does not have to be expended to dry the crop before it is gasified. It does not require custom harvesting equipment, and will grow in the Northeast as well as the Southwest, the two locations considered for a 25 home community.

Following is an estimate the land required for growing enough switchgrass to meet the energy needs of a community.

- Harvest yields of switchgrass are 1.7-5.7 dry tons per acre per year for idle/pasture land, and 2-6.7 dt/acre-yr for major cropland.
- Estimate an average 4dt/acre-yr or 8 000 dry lbs/ acre-year
- Estimate that harvested switchgrass contains 5 800BTUs per pound of biomass [52]
- Therefore, 8 000 lbs per acre per year * 5 800 BTUs per lb = 46.4 million BTUs per acre per year of gas
- Because 1 kW=. 984BTU/s, then 46.4MMBTU/acre-year = 1.6kW/acre of gas

One acre of switchgrass with a yield of 4 tons per year will provide about 1.6kW of gas for an entire year. A 65kW micro generator from Capstone Turbine, which would supply the base load for a 25 home community, has an electrical efficiency of 29%, and a thermal efficiency of 35%. Therefore, 1.6kW of gas will provide 0.46kW of electricity and 0.56kW of thermal energy. The thermal energy will be dumped into the large water tank and provide heat for the community. In order to power the 65kW Capstone turbine, 142 acres will need to be set aside for growing switchgrass.

In summary, around 142 acres of switchgrass will be needed to power a 65kW micro turbine. Each home will receive 2.6kW of continuous power, which will then be supplemented with solar energy.

Generator Technology

(RJ)Micro-turbine, gas turbine and reciprocating engine technologies all have reasonable capital equipment costs when compared to installation costs of a new grid substation. Table 7 shows the capital installation costs per kilowatt for various combined heat and power (CHP) technologies. Compare the costs to the installation and wiring costs for a new grid substation of ~1500 $/kW (Power Engineering, August 2005).

	Diesel Engine	NG Engine	Micro-turbine
Electric Efficiency (LHV)	30-50%	25-45%	20-30%
Availability	90-95%	92-97%	90-98%
Size (MW)	0.05-5	0.05-5	0.025-0.25
CHP Installed Cost ($/kW)	800-1500	800-1500	500-1300
CHP Output (BTU/kWh)	3400	1000-5000	4000-15000
Useable temp for CHP (F)	180-900	300-500	400-650

Table 7: Comparison of three generator technologies.

Diesel and Natural Gas (NG) engines are mature and well-established technologies. They are readily available and service procedures are well known. They also have many moving parts and are complicated compared to micro turbines. The availability of 90-95% represents the portion of all time that the generator will be available for producing power. Availability for a NG engine is 92-97%. The gasifier gas will most likely be run in a NG-derived engine, so the higher uptime can be expected.

Figure 18: Capstone Corp. biogas micro turbine.

Capstone micro turbines however, have one moving part, and no oil to change. They have a 99% availability, much better than either a NG or diesel engine. It is also compact and relatively quiet. See Figure 19 for a picture of what a 65kW micro turbine looks like. The Capstone micro turbine is our choice for a generator set.

CHP technology allows for higher overall efficiencies by producing useable thermal output alongside electric power; also known as cogeneration. This is what makes distributed generation (DG) so attractive: higher overall efficiencies can be realized by using thermal energy to meet the heating and cooling needs of the community instead of relying on household furnaces or electric heaters to heat the residence. Heat can also be used to power absorption coolers for air conditioning. The Capstone microturbine is capable of producing 78kW of thermal energy for use in our thermal mass system. [29]

Combining the benefits of DG and cogeneration for providing the energy needs for a community with environmentally friendly biomass-derived fuels produces an attractive vision for a new community that economically supplies its own energy demands.

Residential Energy Consumption Surveys provides some detailed information on household energy needs. A typical New England household uses about 7 142 kWh/yr in electricity, or an average of less than a kilowatt per hour. A community of 25 households could get away with 25 kW of electric generating capacity on average. Of course, demand does not stay constant, but peaks at certain times. That's why we plan to provide the base power load with a 65kW turbine, with solar power and battery storage supplying power for peak demands. This way, a smaller generator could be used in combination with fewer solar cells than if the community were to be powered by either technology on its own.

Behavioral Effects of Living in a Small Community

(AK)As the push for renewable energy sources increases one must wonder what the effects on the population, community, and individual lifestyles will be. While the effects are numerable and far reaching the current cause for switching to renewable energy is almost universally the same. Most people have converted to renewables to be

[29] Capstone CR65 Product Brochure, Revision A, December 2005

environmentally friendly, and without this reason there would be little incentive to go green[30].

One of the effects of renewable energy is that people will start to migrate from the urban metropolises to their small independent communities. A work at home trend could also arise which would lead to less of a commute, and hence less fuel consumption. Psychologically, escaping daily traffic jams and long mind-numbing commutes will greatly reduce stress(for every 1% increase in workforce that telecommutes, there is a 3% reduction in traffic delays"[31]). Also, compared to rural living, "because of heat from air conditioners, motor vehicles, engines, and industrial sources cities [are] up to 10-20^{o}F hotter".[32]

The increased heat in cities can have a multitude of interesting effects on human behavior:

> Social behaviors of many kinds are affected by temperature. Anderson (1987) used archival sources from cities across the United States to gather data on the rates of murder, rape, assault, robbery, burglary, and motor vehicle theft. He confirmed that violent crime increases with temperature but that nonviolent crime does not. Subjects exposed to very warm conditions in the laboratory are less likely to help others even after the experiment is over(Page, 1978), and field studies also indicate that extreme temperatures in winter and summer make people less willing to help others(Cunningham, 1979). High temperatures lead to a reduced attraction toward other people we encounter, especially when the heat is accompanied by crowding (Griffit, 1970; Griffit & Veitch, 1971)[32]

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30 http://www.doa.state.wi.us/docs_view2.asp?docid=4509

31 http://www.house.gov/wolf/news/2000/03-01-Teleworkers_Tax_Credit.html

32 McAndrew, Francis T., *Environmental Psychology*. Brooks/Cole Publishing Company: Belmont California, 1993

A further study into the effects of temperature on aggression, "overwhelmingly supports a linear relationship in which increasing temperature is always accompanied by increases in the incidence of violent behaviors such as murders, rapes, and assaults. In these studies, hotter regions of the world and hotter years, seasons, months and days all are linked with more aggressive behaviors."[32] Since large scale use of renewable energy resources will significantly reduce greenhouse gases, and hence the global temperature, one would expect a general decrease in aggression and a general increase of friendliness among the population.

Any true renewable energy activist would have a passive or active solar home. This means having large southern windows that allow an ample amount of sunlight to enter the home. This helps people suffering from seasonal affective disorder (SAD). They require additional light, especially during the fall and winter months. "People afflicted with SAD tend to gain weight, sleep a lot, withdraw socially, and generally exhibit low energy levels during the winter."[32] There is also a theory that natural sunlight is healthier than artificial lights, but this theory has yet to be proved or disproved.

One final example of how renewable energy sources can affect lifestyles is of dairy farmers who install and use biomass digesters to reduce the level of odors on their property to avoid litigation and to operate farms so that their surrounding communities accept them.[40] This allows the dairy farmer to be better integrated into the community.

(AK)Renewable energy resources offer people the ability to be independent of large corporate power stations. One may wonder whether this could lead to a trend of independence at work, or even independence of other people. For now we will investigate the effect of working at home on the individual and the business.

For the past several hundred years our society has primarily had a workforce of manufacturers, but around the 1980s that changed. It was at that time that a "majority of the workforce was engaged in the storage, transfer, or manipulation of information."[33] Telecommuting, or working from home, is well suited for the information society. It is estimated that at some time during the week, 25% of the United States workforce Telecommutes. This high percentage is made possible by the internet revolution. Email, instant messaging, phone calls, and video conferencing can all be done over the internet now, at ever increasing speeds.

Some of the main pros for telecommuting are that it places a "greater value upon the quality of working life"[33]. This is made possible by greater flexibility in work hours, less stress from the lack of commuting, and the ability to work at one's own pace. Also, in recent years greater emphasis has been placed on the family unit, and telecommuting allows one to be in the family environment. In addition, telecommuting offers those with disabilities, single mothers, and the elderly the ability to work when they otherwise would be unable. Finally, telecommuting allows companies to reduce office space overhead and to reduce salaries which are usually inflated to compensate for commuting costs.

Some of the common cons against telecommuting are that the loss of face to face communication and social contact can be very detrimental to the worker's mood and their ability to do their job properly. Another concern is that the management of telecommuting employees becomes extremely difficult. "Performance monitoring and measurement becomes virtually non existent, and the supervisor experiencing the 'out of

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[33] Ramsower, Reagan Mays. *Telecommuting: The Organizational and Behavorial Effects of Working at Home.* UMI Research Press: Ann Arbor, Michigan, 1983

sight, out of mind' phenomenon loses respect for the employee and no longer considers the employee for advancement within the company"[33]. Along these lines it is felt that the employee will become disenfranchised, their performance will drop and they will become less motivated.

In field studies, many of the above statements have proven to be true, while some especially the cons have proven to be false. The following are the results concluded from the field study. It was found that the "experience of the telecommuter is largely depended upon the number of days per week that a participant spend working at home. Full-time is considered 4-5 days a week, part-time is considered as 2-3 days a week, and unable is considered 2 days or less"[33]. Communication can be broken down into 4 categories; face to face, horizontal(talking to your peers), upwards(supervisors), downwards(subordinates). As expected, the full-time telecommuters experienced a decrease in all levels of communication. However, the part-time workers experienced an increase in all levels of communication. The unables had in increase in face to face and downward communication. As expected, the full-time telecommuter spent more time away from the work group. However, the part-time worker spent more time with their work group. It is quite surprising that the part-time telecommuters actually spend more time in contact with their work group.

One detrimental aspect of telecommuting is that the telecommuters were forced to have fewer job tasks than comparable workers in the office. For instance, it is difficult to supervise new workers if one is telecommuting. This tends to make a worker less valuable since they cannot perform as many tasks for the company.

The study also showed the effect telecommuting on the organizational behavior of the workers:

* Full-time telecommuters experienced a decrease in the extent to which work breaks were automatically shortened when work needed to be done.
* All telecommuters experienced a decrease in their extent of trying to improve work methods to solve work problems, while the control participants experienced an increase.
* Part-time and full-time telecommuters experienced a drop in their contentment with the job.
* Part-time telecommuters experienced a decline in their sense of achievement in performing the job.[33]

The fear that a telecommuter would become disenfranchised and lose interest in the company appears to be true. With advanced technologies such as video conferencing starting to be commonplace, this lone wolf feeling will be moderated.

Telecommuting had some interesting effects on job satisfaction:

* All telecommuters reported lower levels of satisfaction concerning office working conditions, while the control group reported no change
* Part-time telecommuters reported higher satisfaction concerning their ability to work alone, while the full-time telecommuters reported lower satisfaction.
* Full-time telecommuters reported lower satisfaction concerning the amount of variety in their jobs.
* Part-time telecommuters reported lower satisfaction concerning their ability to direct the actions of others.

* Full-time telecommuters reported lower satisfaction concerning job security[33]

The job security concern arises from the belief that since they are not around the office, then they are easily disposable.

Finally and most surprisingly the effect of telecommuting on performance was the opposite of what was expected. Telecommuters tended to perform better than their office counterparts. Also, the performance measuring and monitoring of telecommuters was substantially higher than their office counterparts. The telecommuters were often required to check in hourly and/or make weekly written progress reports to their managers. This is due to the common belief that people who work at home will slack off, so management enforces a frequent checkup policy.

(QE)As a society advances the people must adapt the technology to their community as well as adapt their community to the technology. The implementation of renewable energy will be a compromise between current ways of life and a path to a better future. When the colonists first moved to America the lack of easily availably resources forced them to rely on each other. From these humble community beginnings America is what it is today. And while not all of the lessons from the past have faded many are greatly diminished. The abundance of resources and the ‘you can get anything you desire’ attitude has left society thinking of only what it can do to improve itself. The current state of society is leading more towards the individual and away from the community. This seems to be the driving force behind an unseen race to an arbitrary goal.

With the advances in technology and the distribution of energy, more and more desire to be self sufficient at a cost to the community. Single person cars clutter the highways in a society where people desire to be so isolated from each other that public transportation is seen as a last resort despite the fact that it is for most an environmental as well as financial benefit. The colonial days are gone but the introduction of renewable energy will lead to the reestablishment of a self reliant community. The most obvious impact will be the living arrangements. Instead of single family houses there will be three to five family housing units. While this may be hard to fathom for some this is one compromise that will prove to be very beneficial to those who dare accept this venture. This sacrifice of individuality would be returned in terms of financial as well as social aspects. Having a more associated community style society can ensure the safety of its inhabitants and well as the progression of status of life as well. Families would be able to place full trust in those with whom they reside and reap benefits such as carpooling or community transportation for children. This self sustaining society would them be able to easily come to a consensus over issues such as energy consumption, thus leading to a renewable energy community where they are not only able to sustain themselves but make a profit that can be used to further aid the community.

The impact of a renewable community may be felt even deeper if some families decided to make their work revolve around it. There will be opportunities for some to take up positions as inspectors for safety as well as maintenance. Since the workers would be so closely involved with their home environment this would allow for them to be more diligent in their jobs as they could feel the direct impact of mistakes as well as the freedom in that it is not just a job to make money but rather something you are a part of to keep your family and the community safe and healthy. This type of community would make the work environment less formal but would boost accuracy as well as open the door for adaptations that lead to advancements in the technology usage in the community. As seen in other groups such as Grupo Fenix while the technology can be designed to work accurately it's best implementation is usually derived from the necessity of the community and the adaptation of the technology to meet those necessities. Through a series of compromises the community will not completely deny itself from becoming a society of individuals but instead advance together and once again rekindle the flame that brought together the colonists that started this United States of America.

The design of the renewable energy community would allow for financial, economical as well as environmental advantages but there are less obvious factors. The ability of the community to depend on its inhabitants will be a crucial factor in the successful establishment of a renewable energy community. For example if the community became self sufficient enough they can reap the benefits that similar communities such as the ones in Australia have already achieved. This has allowed their communities the ability of shared resources in terms of kitchen and laundry facilities, vehicles and tools. They have also established a network in which the community as a whole ensures the safe propagation of their way of life and encourages the endorsement of the community lifestyle to others who may dwell where such a lifestyle was never seen as an option. Through their efforts they have established a system that maintains their way of life while simultaneous expanding the ways in which their community benefits society whether it be from a good environment to raise children or finding ways to recycle items in the community. However a community can only be built as well as its creators allow. The problem that then arises is that an engineer's design is based on set sights that are often too narrow.

(QE)Science as we know it today has been structured on paradigms and their evolutions. As a result of paradigms it sometimes occurs that there is paradigm induced blindness hindering the progression of science. An article called the "Catch-22 of engineering sustainable development" suggests that current paradigms of development are still hindering engineers. Another aspect is that the vision of engineers is too limited. Since most people live under one hundred years this seems to be the scope of view when addressing problems. However that which is not noticeable in a single human lifetime often has a greater impact on the global society. This time span dilemma is a key issue that engineers must face when undergoing any tasks with global implications. Concerning a sustainable renewable energy community, there are two factors that the article suggests to be constants and thus must always be addressed if one is to establish a sustainable community. They are ensuring that the basic necessities of the people are met as well as the foresight to avoid any threats to the community that may hinder its sustainability.

The ability to analyze the current community and spot potential threats will be critical to sustaining the community. In a study done it was realized that for environmental stability pollutions emissions need to be reduced by a factor of 10-50 but by the time this was noted it was only possible to reduce emissions by a factor of 2-3. To ensure the success of a our community potential problems should be analyzed before hand coupled with and implementation from which the people of the community can voice the concerns and further shed light of future obstacles to prolonged efficiency of the community

The success of the community cannot be gauged solely upon the creation but by the design of the engineers. They play a key role in ability of the community to become self sufficient and as such should be extra critical of the future implications of their actions. A combined effort with the inhabitants of the community will allow them to address problems that arise as well as observe the unpredicted before they become hazardous to maintenance of the community.

The ability of the community to not only sustain itself but to also perpetuate and grow will be a key aspect in gauging the success of this venture. This idea of a renewable energy community should not just be a fad that lives for a couple of years only to die out from a lack of interest. Switzerland is a land where there are citizens that are members of a commune. However the number of communes is falling due to the fact that some no longer are viable and were left with the choice of merging with their neighbors. Overall there are about 2900 communes ranging in size from a mere one hundred inhabitants to the ten thousands. For the smaller communes the people have more of a direct impact with the ability to voice their opinions on issues and electing administrators. The larger communes have similar input but though less personal ways such as voting booths.

In the 1800's UK communes failed because of lack of capital as well as the utopian design of equality. When the design was altered such that profits from trade went proportionally to purchases the communes began to thrive. The key aspects that can be drawn form these examples to ensure a sustainable commune are that they are kept within the limits of reason and executed with care towards the financial distributions as well as proportionality of rewards to amount of work contributed. The commune needs to provide adequate incentive to invite people to live there as well as continued benefits that would ensure that the rate of growth is always positive. Many have tried and many have failed at the idea of a utopia like commune in which all the world problems were solved but the reality is that all these types of communes failed because they did not live up to their promise. Thus the renewable energy community must be kept efficient and beneficial to the inhabitants.

(QE)A key aspect will be the money that this community has and how wisely it is used. While most renewable energy sources currently available would eventually reach a point where it becomes profitable it is the elongated investment that hinders most from engaging in these energies. To combat this it is proposed that there be a tourism aspect associated with the renewable energy community. Through sponsored events held in the community they could both promote awareness of the advantages of the way of life of the inhabitants as well as those pertaining to renewable energy. Another way to aid the community financially would be to make some parts of it into places where tourists can come to vacation or simply experience something different. The profits from this tourism would ideally be spread out evenly but this would head down the path that leads to failure in other communities. Instead the issue of proportionality will be used to decide which inhabitants or aspects of the community to which the finances will be delineated.

The prospect of living in a community would provide several benefits to those who occupy it but also carry some disadvantages. The close nit community would have to endure any discrepancies that arise in the community and solve them together. This group consensus would be necessary to make decisions that would affect the community however reaching such an agreement would prove difficult depending on the situation. The combining of different people from different walks of life is bound to create some sort of tension that may cause discord that would undermine the very structure of the community.

While this community will not be a utopia, the ideality that we will try to achieve will be close in comparison. While the people will bring with them more internal issues such as racial, or class issues those are aspects that will be difficult to change and only attainable with time. The more external aspects would be privacy as well as the guarantee that everyone in the community is doing their part to successfully sustain it. This may be achieved through the implementation of monthly or possibly weekly community meeting. These would allow the community members to voice their experiences and address any issues that arise while also acting as a checkup to ensure that those who have roles that affect the entire community are doing them.

In the incident that something does arise that creates a disturbance there will be a community manager. Their role will be not as a governor but rather as a supervisor for any issue that may arise. Thus he will serve as a mechanism to ensure social stability between the people. Their final actions would require approval from a random sampling of the community. This position may grow to be one that rotates in that different people of the community may take up this role from time to time fostering the social growth of the community since they will become more interactive ad interconnected with different aspects of each other's lives.

This renewable energy community is filled with paths to adaptation. Many will have to face the reality of how much of a direct impact their actions will have on themselves and the community. It would make the people more socially aware as well as more environmentally aware. Through compromise a successful community can be established that would become self reliant. While doing this however it is also important that they not segregate themselves from the rest of the world but instead spread the ideas and ways of life that foster in the community. Hopefully this would result in more people taking an interest in the applications of renewable energies and the ways in which they can improve one's way of life.

A commune would be successful only if it integrated current societal aspects with those achieved through living in a community without making the people have to sacrifice their individuality. The people would be able to retain their privacy and keep their personal lives but be able to embrace the diversity of the community. This mentality hopes to achieve a more social society where people are more able to discuss their problems and work together to more easily achieve their goals versus a cycle of anger and hate that hinders the progression of societies today.

Chapter III: Procedure

(AK)Once we decided on doing an analysis of a small community of twenty-five homes we needed to decide what renewable technology we would focus on. Our initial research suggested that geothermal would be too impractical and we decided against a 150 foot tall wind tower in the middle of our town. This left us with one main candidate; solar energy.

Solar is a mature technology and a very abundant energy source. Our research suggested the technology has sufficiently matured so that even in the New England area, it would be feasible and cost effective to have a solar installation. Solar also has the option to let you choose between heat or electricity production. With solar prices expected to drop to competitive levels soon, its main downside is that it is not a consistent source of energy.

We wanted our community to be self-sufficient, or at the very least, very independent from the electrical grid, and oil. Since solar is inoperable at night and cloudy days we decided to add a biomass generator. The generator would supply supplemental electricity to the community and since it is a combustive process it also creates a lot of excess heat which can be used by the community as well. Later in the project we learned of an emerging new technology which uses solar energy to create hydrogen. One part of the process converts methane into hydrogen. Since the main product of biomass is methane, we believe it will create a nice addition to our system. The hydrogen would then be stored for use during peak hours either as fuel, or in conjunction with a fuel cell.

(AK) Having decided upon what technologies to use, the next step was to determine what the demand for heat and electricity would be. Since heating is the primary energy expense of a home we focused on that. We first determined the heating requirement of a home in El Paso Texas and Pittsfield Massachusetts. "Comfortable homes are maintained around the year at 20 to 25^oC (68-77^oF). During the colder months a certain amount of heat must be added to stay within this range; this defines the heating requirement of the dwelling."(pg. 22) One parameter used to help estimate this is called degree days. Degree days are the difference between the average daily temperature and a baseline of 18^oC (65^oF). For example, if the average daily temperature was 15^oC then the degree day for that day would be 18^oC-15^oC = 3 heating degree days. If the average daily temperature were higher then the baseline, then that would be a cooling degree day, however this report will only deal with heating degree days because research suggests that solar cooling systems have an unsatisfactory effect, suppliers, and installation. Nevertheless, attention should be paid to reducing the amount of solar radiation that hits the house, while still allowing an ample breeze to exist. This is especially true of El Paso which has nearly as many cooling degree days as heating degree days. The calculations for heating requirement are shown in appendix A.

Solar panels that collect heat are a good way to reduce heating bills. Water circulating thru the solar collectors heats up, and flows to the thermal mass where it deposits its excess heat. During cool times the thermal mass releases its heat into the household.

Initially, we wanted the solar panels to provide 80% of the homes heating requirement, but the sizes of these systems are rather large. In the north the system would be roughly the same size of the house. Even in El Paso, in order to provide 80% of the yearly heating a water tank would have to be about ½ the size of the house. Appendix A shows how large the water tank used for solar heating would have to be to supply a percentage of the heat required. If space is available to build a large storage tank, then more heating can be supplied, otherwise these systems should not be made to provide more than 50% of a homes heating requirement.

The next step is to determine how much area is needed for the solar panels. This is calculated in Appendix B Even in Pittsfield, the maximum size is about 2/3rds the area of the home's floor area (158 m^2 average).

Figure 19 below shows a system well suited for the water system. The panels are connected to an anti-freeze loop. This helps prevent freezing, especially in the north. Via a heat exchanger, the anti-freeze passes its heat onto the water storage. From there it can be used to help preheat water. It can also be pumped thru the walls or floor of the house for heating.

The solar panel area needed, especially for El Paso, is not very large and any size should be able to fit onto a roof. The main problem lies with the size of the water storage. For single family homes a large storage facility could be impractical, however Figure 20 shows a concept design for a community storage tank. This allows for a long term storage facility without the extra cost and unsightliness of a large water tank storage shed attached to the house.

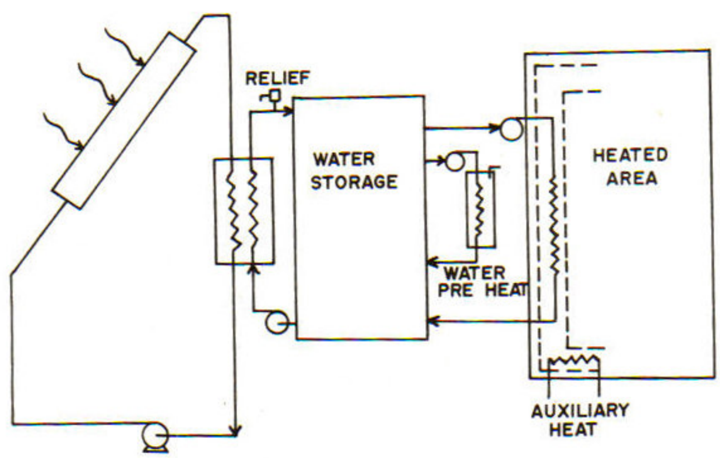


Figure 19: Dual-liquid system with heat exchanger and solar assisted, domestic hot water.

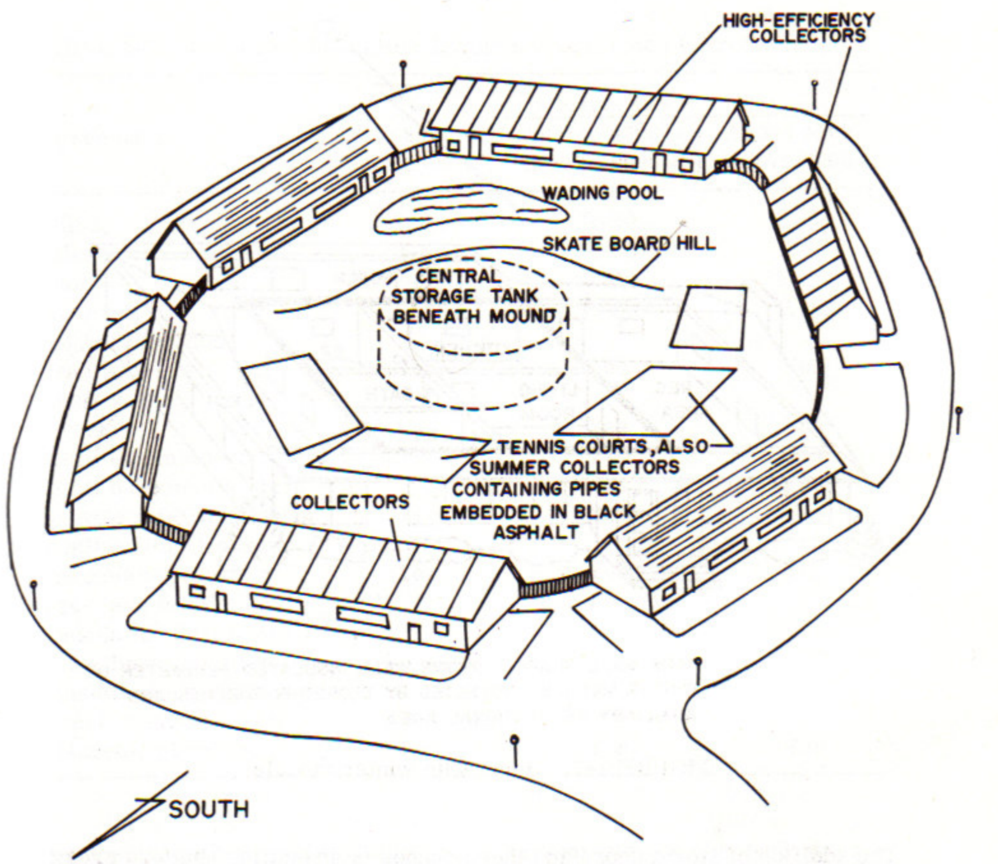


Figure 20: Multi-unit complex sharing a central storage facility. Units with roof collectors have short term storage tanks. Surplus heat is directed to the central storage tank.

Radiantec[33] offers a system almost identical to the one stated above, except there is no long term storage tank, for $5568.80. Appendix C shows a cost breakdown of their solar water heater.

The next step was to determine the size and production capabilities of the biomass system. Then the methane to hydrogen converter was analyzed. Any miscellaneous items, such as piping were then accounted for. Once all these were calculated, the final cost of our renewable energy system could be tabulated.

Chapter IV: Results

(AK)From Appendix A it was calculated that the yearly heating requirement for El Paso, Texas was 29 GJ/year and for Pittsfield, Massachusetts it was 80 GJ/year for the average sized household. Since we will be using a multi-family home, this is reduced to 17GJ/year for El Paso, and 47GJ/year for Pittsfield.

For Solar heating the size of the thermal mass and the area of the solar panels needed are shown in Tables 8 & 9, the calculations of which are shown in Appendix A & B:

Table 8: Size of a cubic water tank needed to supply a %heat requirement

%Heat supplied	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
Cube side(m)									
El Paso, TX	2.6	3.2	3.7	4.1	4.4	4.6	4.9	5.1	5.3
Pittsfield, MA	3.6	4.5	5.2	5.7	6.2	6.5	6.9	7.2	7.5

Table 9: Area of solar panels needed to supply a % heat requirement

	El Paso, TX	Pittsfield, MA
%heat supplied	Area(m^2)	Area(m^2)
10	0.63	2.94
20	1.31	6.13
30	2.62	12.25
40	3.93	18.38
50	6.29	29.40
60	8.39	39.20
70	11.53	53.90
80	15.73	73.50
90	22.02	102.90

A Small Community with Integrated Renewable Energy Sources

(AK)After all our research and planning we decided upon a community which integrates several different renewable energy resources to create something much greater than the individual parts. See Figure 22 for a schematic. Passive and active solar techniques such as sun tempering, green houses, trombe walls, photovoltaic cells and solar panels produce heat and electricity. To create a base electrical supply and to take over at night or during cloudy days, biomass will be integrated into the community. The excess heat from the combustion process will also be used in conjunction with solar for heating. Finally, in order to maximize efficiency, a solar converter will turn the biomass methane into the more potent hydrogen, which can then be stored for times of need and burned in the same microturbine generator as the biogas.

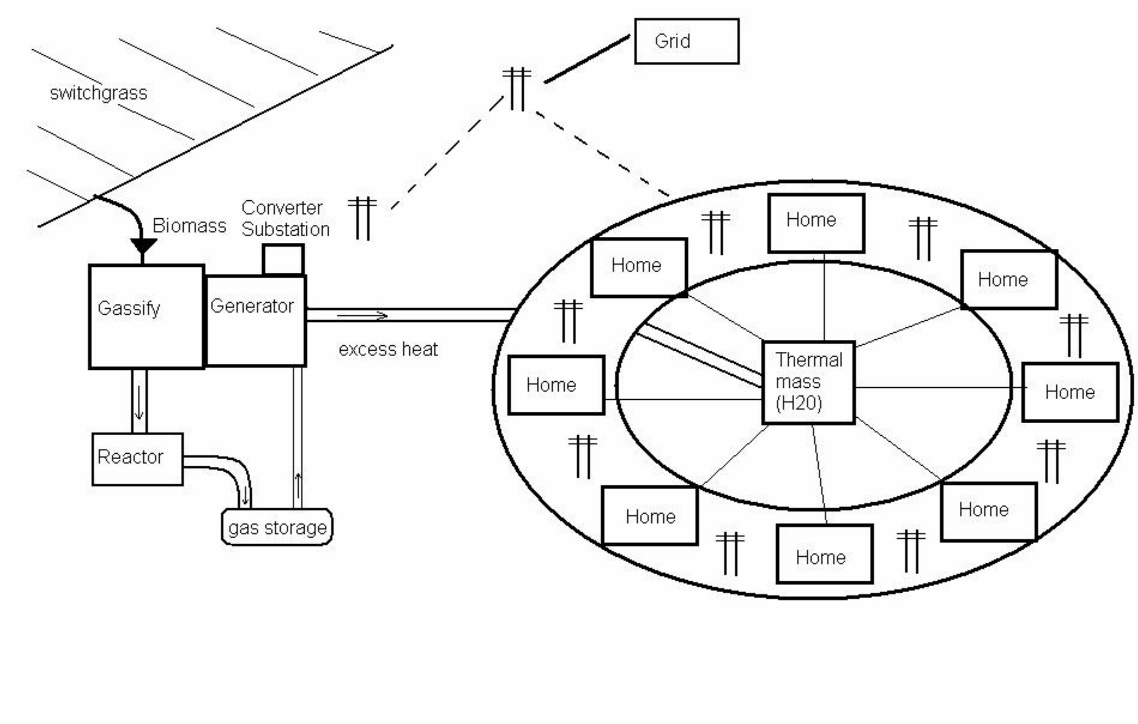


Figure 21: Community Schematic

Cost Analysis

(AK) The plan is to have a community with a central storage mass that will supply 50% heating for all the homes which means the necessary cubic water thermal mass would have to be 4.4 meters a side in El Paso, Texas and 6.2 meters a side in Pittsfield, Massachusetts. Appendix D goes into detail about the cost of the solar heating. For the complete system of the central storage tank, solar panels and equipment, and all the underground piping for all the homes, the total for El Paso was $107,000 which is $4,300 per household and $341,000 for Pittsfield which is $13,600 per household. This leads to a payback period of roughly 3 years for El Paso and 9 years for Pittsfield.

Then there is the cost of the photovoltaic cells. A_1.5kW grid system costs about $17,000 including installation(without rebates)[39] and is enough to power a "Green Kitchen which includes running your fridge, microwave, dishwasher (3 uses per week), oven/grill, stove, toaster and kitchen lights. It will also run the rest of your lights, your TV, video, stereo and radio"[39]. This constitutes the solar expenses.

(RJ)A complete biomass system may run around $11,000 per household for a complete system, as demonstrated in Biomass Integration on page 66 and in Appendix H. For a community of 25 households, a 65kW generator would supply 2.6kW per home, in addition to the 1.5kW supplied by photovoltaic cells. The total peak available per household of about 3.1kW is far in excess of the average household energy needs of about 1.1kW, and should be enough to handle peak energy needs. Extra power can be sold back to the grid to hasten the return on investment.

(AK) The biomass micro-turbine also generates 78kW of the thermal energy, which is 2,460 GJ/year. This heat can be used in conjunction with the solar heating to supply the additional 50% of heating need. If we assume 75% losses between the heat exchanger and dissipation through the piping it will provide an additional 615GJ yearly which is just slightly more than what the Pittsfield complex needs to achieve 100% heating supplied from biomass and solar.

One final note, since solar hydrogen generators are a burgeoning technology there are no cost estimates available. For this reason, all cost estimates are performed assuming the hydrogen module is not part of the system. As the technology matures, efficiency increases, and the cost becomes available a complete cost analysis can be performed. Thus the cost analysis is for present day technologies which can be implemented now.

Chapter V: Analysis of Results

In the hybrid solar/biomass/hydrogen system we have designed, electricity and heat are generated from renewable energy sources, namely solar and biomass energy. The system was designed for a small community of 25 average households clustered into five 5-family complexes. The system is efficient and cost effective enough to be attractive to a new community interested in integrating energy independence into the development design.

Our system is designed specifically for the Northeast or Southwest. Relative to each other, in the Northeast electricity costs more, land is more expensive, and the solar intensity is lower, but biomass is readily available. In the Southwest, electricity costs less; the area has higher solar intensity, and cheaper land, but may require irrigation to grow biomass crops.

The renewable energy system can be constructed now, because all of the components are already available. These are also mature technologies which have proven themselves to be reliable and effective. Our system is for people who want the independence and environmental friendliness of renewable energy resources

Is the system feasible? The hybrid photovoltaic/passive solar/biomass system is a cost effective option for new towns that properly plan ahead. With installation costs for a complete 1.5kW photovoltaic system running around $17,000, a 2.6kW biomass system running around $11,000, and a solar heating system running around $4,000-$13,000 the initial investment is not that high, only about 1/10th the cost of the average house. This system will cover all the electrical and heating needs of a home for all but the highest electrical loads and coldest days. The investment return time is around 13-16 years for the entire system, which is shorter than the life expectancy of the system. Additionally our system was a 50/50 split between solar and biomass. By tailoring the setup for the location one can achieve even better cost effectiveness. In the north the system should incorporate more biomass since the major cost was due to the large solar installation. In the South, more attention should be paid to a solar installation since the sun is plentiful and water for irrigation is not.

In the end a renewable system can only be effective if the specific location and technologies are well understood so that the optimum plans can be implemented.

Chapter VI: Conclusions and Recommendations

Societal Impact

(QE)The implementation of a renewable energy resource community will not come cheap in terms of financial impact as well as the societal impact. For a renewable resource community to be successful it must not deviate to far from current lifestyles, while still offering its unique benefits. In this way people will feel comfortable and benefit instead of feeling alienated. One deviation from the norm was our choice of multi-family housing in order to benefit from its particular advantages These were significantly lower costs of heating and cooling as compared to single family housing. Since these were the number one sources of energy consumption in the household, reducing the amount of energy required would result in significantly lower energy costs.

In terms of energy this would be beneficial to the solar community, but the societal aspect must also be considered. Currently single family houses are the most prevalent source of housing in the United States. The US family has grown to enjoy the individuality that single family households allow. Multi family housing would lead to compromises in this individuality that has become an integral part of the American way of life. However this may be more suitable for lower income families that are normally forced to live in apartments, making the transition easier.

Though the transition may be difficult for single family households it may prove to be beneficial financially as well as foster a more communicative society. This would lead America on a path back to its roots in a time where a community would rely on each other for sustenance.

(AK) Since the Renaissance, few people would dispute mankind's great advancements. However, in one respect humanity has been stuck in the Dark Ages. We as a race have been progressively losing contact with our environment. At one time, our whole life was a harmonic synthesis with the environment, taking what was needed, and replenishing what was lost.

With the advent of cheap energy we have become decadent and lazy, spending little time to figure out how to harmonize with our surroundings. If you need heat, burn some oil, if it's too hot, turn on the air conditioning. In the past, without access to oil or electricity our ancestors devised methods to have a somewhat steady temperature without the constant need to input energy. Just by reorienting the home, changing the home's shape, or by adding some insulation many of the temperature fluctuations could be reduced drastically. Only recently has there been a trend back towards this "smart" home design.

Homes that are harmonious with the environment create happier home owners for several reasons. As stated above, homes with radiant heating are far more comfortable than homes with radiators or other convection heating devices. Many people enjoy the sense of independence gained from having an alternative energy resource home. They are no longer subject to the whim of the power companies or for example, foreign Arabian nations. There is also great satisfaction in having a significantly lower electrical and heating bill. Finally, there is a subconscious happiness gained from knowing that your home is clean, safe, and beneficial to the environment. For these reasons, it is no wonder that renewable energy homes have such a high "greatly satisfied" rating.

(RJ)Integrated, condo-style housing will force people to be more cooperative and tolerant, or else risk eviction from the community. Similarly, consideration for the community by the individual must be important. Communication to resolve personal conflicts is imperative to avoid disharmony.

Residents must be accommodating of their neighbor's pursuit of happiness, even when such pursuits are strange and unfamiliar. Residents pursuing happiness must be considerate of their neighbors so neither disrupts either's quest for happiness.

As such close-quarters living becomes more commonplace in rural areas, I would expect people with similar interests to converge, creating communities where individual pursuits of happiness mesh well with the collective.

This convergence will likely foster more interaction between neighbors and within the community. As people generally like to avoid confrontation and desire acceptance within a community, I would expect such interaction to be mostly positive, especially when the residents chose to live together. Contrast community interaction with the isolation of suburban living, where neighbors are friends initially because they live nearby, and not for any shared interest. People are social, and love to bond with others we perceive as similar; suburban living is not conducive to such bonding.

For example, consider a rural community that begins to draw residents who love to ride mountain bikes. Bikers are almost universally passionate about their sport, and bonding between people who ride begins immediately after they discover riding as a common interest. Mountain biking also requires land to ride on, and in some cases, stunts and dirt jumps to be built. In a community of gardeners or wildlife watchers, putting mounds of dirt in the fields and cutting trails through the woods would certainly invite strife. But in a community of bikers, they all understand and can enjoy the structures and trails. Indeed, biking residents will probably grow closer as they ride together.

I think large-scale adaptation of close-quarters living will result in a shift from the current suburban sprawl and its associated problems to more compact, efficient, and friendly communities that foster social interaction within and between complexes. Again using the biking community as an example, and given the similarities between mountain biking and motorcycle dirt biking, I would anticipate there would be communication and friendly ties between two such communities.

In conclusion, the convergence of residents who share similar interests on communities that have close-quarters housing has positive potential. The camaraderie and friendship that residents may develop between themselves and other communities with similar interests will be beneficial to society. Networks of close-knit communities that share common interests is opposite to the soul-draining isolation of suburban sprawl, and will benefit American society as a whole when people can connect and identify with each other.

(RJ)As the fossil fuel – derived energy begins to run out in the foreseeable future, humanity must turn to alternative energy sources to keep its society running. In order to make up for the fantastic energy density of fossil fuel, and given the low efficiencies of technology such as solar photovoltaics, energy to power the next generation of society must come from a variety of sources. Dominant alternative energy sources vary with geographic location: from a sun-drenched desert, to the geothermal hotspot of Iceland, to the intense wave-energy potential of the Scottish Islands. The renewable energy supply of the future will be pieced together from solar, wind, water, geothermal, and biological sources.

The prototype community developed in this project is a blueprint for an approach to meeting energy demands in the future. The community relies heavily on solar energy – an abundant resource in the Southwestern United States – for electricity, as well as temperature control. Thermal masses absorb energy from the sun during the day, and dispense radiant energy to the community at night, or whenever it is needed. Photovoltaics convert solar energy directly into electricity to power the community. Base-load electrical power is provided by a generator running on gasified biomass to ensure the electric supply is consistent and available. Excess solar electricity is used to electrolyze water to produce hydrogen, which is stored for combustion in the same generator to help keep power available.

In order for alternative renewable energy sources to become widely exploited, they must consistently and reliably supply enough electricity so that living standards can at least remain constant. In the United States, which consumes vast amounts of energy, the transition to renewable energy will be difficult enough because of its massive power consumption; social rejection of renewable energy because of an image of unreliability or inferiority will make the transition impossible.

Entrenched industries and distribution channels should be adapted as cost-effectively as possible to speed the acceptance of renewable power sources. Photovoltaics can be adopted by the semi-conductor industry as their manufacture moves into the micro- and nano-scale domain. The gasified and pyrolized liquid products derived from biomass can be distributed and stored similar to home natural gas and heating oil. Radiant heat greatly increases the comfort of the home living environment, and is considered a step up in living standards. By making alternative energy production attractive to the commercial sector, and desirable to the consumer sector, the transition away from fossil energy will be much smoother.

Recommendations for the Future

(AK)Right away we decided that we would get optimal performance by combining the different renewable technologies. In this way we were able to play to their strengths and reduce their weaknesses. For our project we decided on a blend of solar and biomass with a hint of hydrogen technology to supply all our heating and electrical needs, but future projects could optimize different combinations of renewable energy types. In our project wind, geothermal, and tidal were largely untouched. We suggest an investigation to study how well these other technologies can be integrated with each other.

Since our project is a largely independent community it can easily be adapted to form the foundation for an undersea or space community. From there the new project would focus on the location specifics and the optimal energy generating technologies.

Our project started from scratch, so it was desirable to keep our community small. Future projects could look at the impact of renewable energy resources on larger communities, even cities. How many wind turbines would it take to power New York?

Finally, our project designed a town to be built for renewable energy sources, but in lieu of the coming energy hardships a more relevant topic would be to determine what it takes to convert an existing town to renewable energy.

Renewable energy resources offer a wide variety of project topics. Not just between the different types such as wind and biomass, but within individual topics such as solar which includes photovoltaics, solar heating, parabolic solar mirrors, and solar sterling engines.

Final Concept Design of Community

The following design concept depicts what the Northeast complex would look like. All components are drawn to scale.

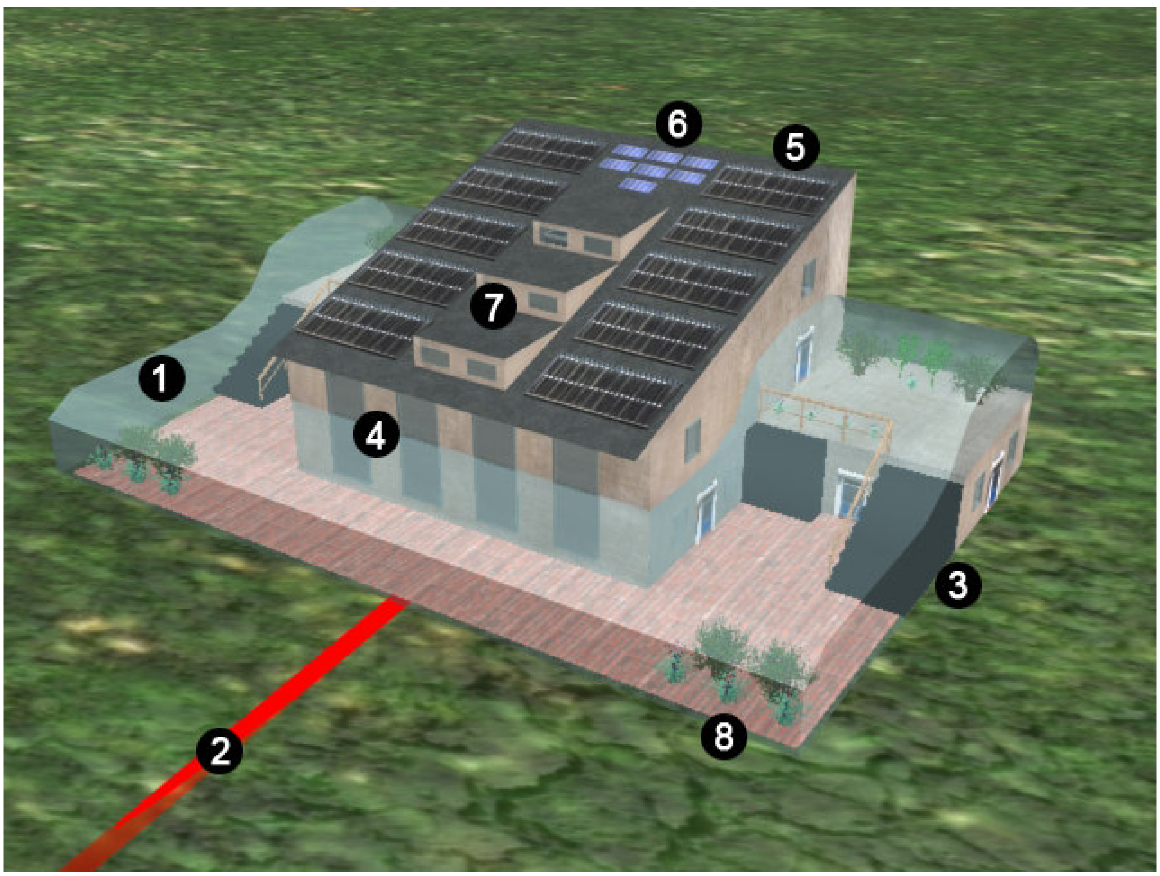


Figure 22: Five family smart home concept design

1. Large communal greenhouse that creates a supply of warm air, allows plants to be grown year-round, and fosters a sense of community.

2. Heating pipe that exchanges hot water between the home complex and the central mass.
3. Large thermal masses(in this case, in the form of a staircase) to regulate temperature fluctuations.
4. Large South facing windows for sun tempering and daylighting.
5. Solar panels(black) used for heating water to heat the house and generate hot water. Excess heat is pumped to the central storage mass. Note: Northeast requires 10 panels per complex, Southwest only requires 2 panels per complex.
6. Photovoltaic cells(blue) generate electricity.
7. Celestory windows allow for daylighting and ventilation.
8. Plants create clean air, food supplies, and general pleasure year-round.

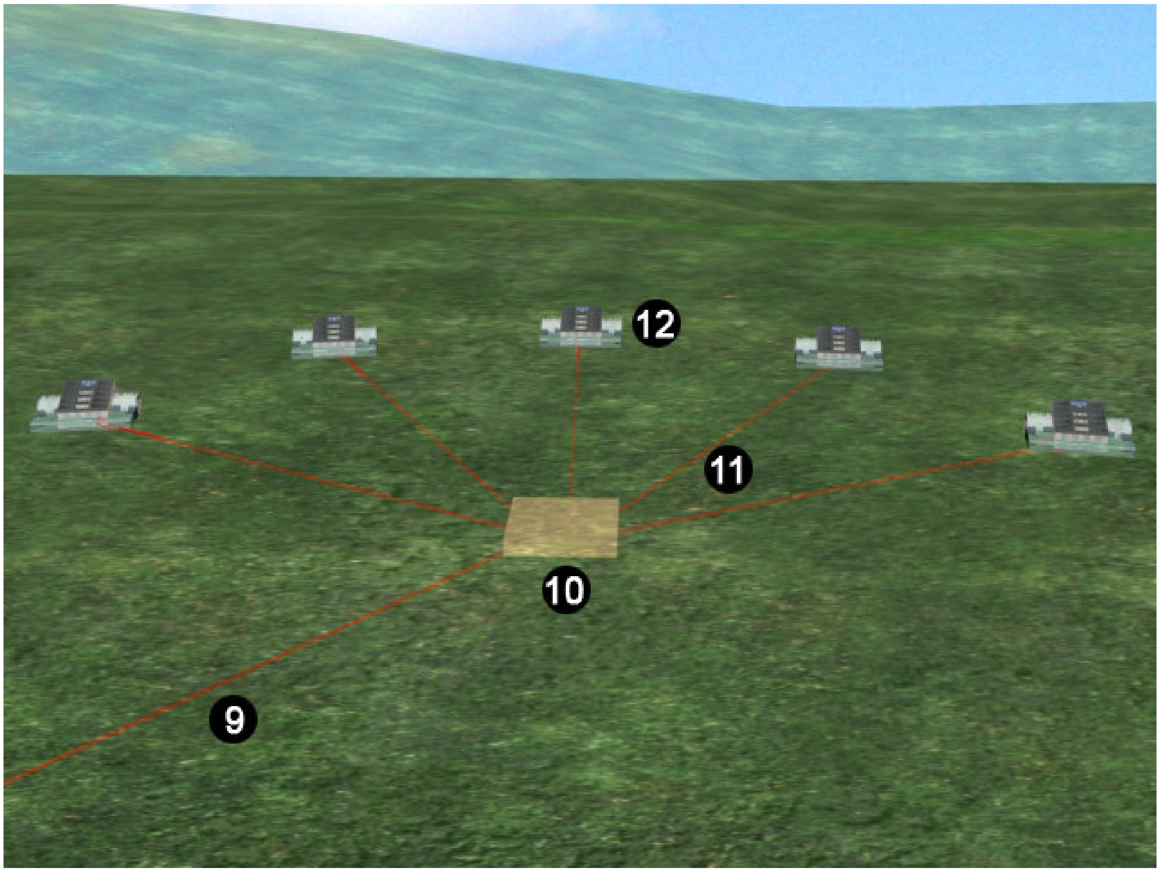


Figure 23: Community setup

9. Underground hot water pipeline that connects the central thermal mass to the biomass generator.
10. Underground central thermal mass.
11. Underground hot water pipelines that connect the central thermal mass to the housing complexes
12. Five-family housing complex

The last components which are not shown are the gasifier, microturbine, storage silo, and switchgrass fields for the biomass system. Lastly the solar hydrogen generator and gas tank are not shown as well.

Appendices

Appendix A: Estimating Heating Requirements

(AK)[30]

Table 10: Assumed insulation values, and general location information

	Insulation							
	Ceilings	Walls	Floor	Basement	Avg. winter temp. (^oC)	Degree Days	Elevation(m)	Latitude
El Paso, TX	R-22	R-12	R-12	-	11	1500	1134	31°45'
Pittsfield, MA	R-30	R-12	R-12	R-8	0	4210	317	42°45'

Estimating Heat Losses by Conduction

$Q = K_A*U*A*\Delta T$ where:

Q = rate of heat loss

K_A = factor to adjust for required units of Q

U = heat transfer coefficient for surface being assessed.

$U = 1/R_T$ where R_T = total thermal resistance

A = Area of surface being assessed

ΔT = difference between inside and outside design temperature

Estimating Heat Losses by Infiltration

$Q = F*K_f*V* \Delta T$

Q = rate of heat loss

F = factor to adjust for the required units of Q

V = volume of room

K_f = Factor depending on room arrangement (# of windows, etc) Table 2-2, pg30

ΔT = difference between inside and outside design temperature.

Infiltration is the loss of heat thru cracks in window panes, opening doors, and drafts. Since specific design details of the homes are not known, a quick heat requirement estimate will be made for Q in Watts.

Normal winter design temperatures:

El Paso = -12°C

Pittsfield = -28°C

$Q = K_I*A*(18-T)$ pg. 40,

Q = heat losses

K_I = 2.8 for poorly insulated buildings

= 1.4 for well insulated buildings
A = floor area in m^2
T = normal winter design temperature

The average US home has 1700 sq. ft of floor space which is:
$A = 1700\ ft^2 * (0.3048m)^2 / 1ft^2$
$A = 158m^2$

Assuming good insulation:
Heat losses for El Paso:

$Q_{EP} = 1.4*158m^2*(18 – (-12^oC))$
$= 6,634\ W$

Heat losses for Pittsfield

$Q_P = 1.4*158m^2*(18 – (-28^oC)$
$= 10,172\ W$

To get the heat loss in terms of degree days (pg. 31)

Heat loss(W)/(18-outside design temperature(Celsius))

<u>For El Paso:</u>
6,634J/s/(18-(-12)) *3600s/hr*24hr/day= 1.91*10^7 J/DD

<u>For Pittsfield:</u>
10,172/(18-(-28))*3600s/hr*24hr/day = 1.91*10^7J/DD

This system will use sensible heat storage. "Sensible heat storage occurs when the storage medium experiences a rise in temperature following contact with the heated fluid from solar collectors." (pg. 83). The equation is:

$\mathbf{\Delta Q = ms\Delta T}$ where
ΔQ = stored heat
m = mass of storage medium
s = specific heat of storage medium
ΔT = useful temperature rise

<u>For El Paso:</u>

Heating requirement = $1.91*10^7$ J/DD *1500DD
= $2.865*10^{10}$ J yearly

80% heating supplied is $2.865*10^{10}J*0.8 = 2.292*10^{10}$ J

Allowing for 20% losses:
$2.292*10^{10}J/0.80 = 2.865*10^{10}J$ storage capacity needed

Assuming that the maximum temperature of the storage tank is 60°C and that a useful minimum is 30°C gives:
$\Delta T = 60\text{-}30^{o}C = 30^{o}C$

Specific heat of water is 4180J/kg*°C

$m = \Delta Q/(s^* \Delta T) = 2.865*10^{10}J/(4180J/(kg\text{-}^{o}C)*30^{o}C)$
$= 2.285*10^{5}kg = 2.285*10^{5}liters = 228.5m^{3}$
This is equivalent to a 6.06m per side cube.

<u>For Pittsfield:</u>

Heating requirement $= 1.91*10^{7}J/DD*4210DD$
$= 8.04*10^{10}$ J yearly

$m = \Delta Q/(s^* \Delta T) = 8.04*10^{10}J/(4180J/(kg\text{-}^{o}C)*30^{o}C)$
$= 6.41*10^{5}kg = 6.41*10^{5}liters = 641m^{3}$
This is equivalent to an 8.6m per side cube.

Since we will be using a 5 family household instead of a single family the heat requirement is less. From Appendix E we know that a single family house used 801gal of oil for heating and that a single family from a 5-family home used 466gal.

New Heating Requirement = Old Heating Requirement* 466gal/801gal

El Paso's New Heating Requirement:
29GJ*466/801 = 17GJ per household
or 85GJ per 5-family complex

Pittsfield's New Heating Requirement:
80GJ*0.582 = 47GJ
or 235GJ per 5-family complex

This leads to:

Table 8: Size of a cubic water tank needed to supply a %heat requirement

%Heat supplied	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
Cube side(m)									
El Paso, TX	2.6	3.2	3.7	4.1	4.4	4.6	4.9	5.1	5.3
Pittsfield, MA	3.6	4.5	5.2	5.7	6.2	6.5	6.9	7.2	7.5

Appendix B: Sizing the Solar Panel Array

(AK)[30]

In order to determine the area of the solar panels needed the Huck-Winn method was used. This method plots f against H_TA/L. Where:

f = fraction of load supplied by the solar panels (using figure 1)
$\bar{H}_T$ = average total monthly solar radiation falling on a tilted collector surface
A = collector area, max = 112m^2 (1200ft^2)
L = total heating load for January(Table D-18, page 401).
H_T is calculated by $H_T = H_H*R$
R = estimated tilt ratio and is calculated by using K_c, the sunshine factor,
the tilt angle of the panels and Appendix Table D-11(pg 366).
H_H = monthly average daily total radiation on a horizontal surface

For site latitude of 21^o-45^o the optimum tilt angle of the solar panels is site latitude + 10^o.[31]
El Paso panel tilt = 42^o Pittsfield tilt = 53^o

<u>El Paso Solar Panel Area Calculation:</u>

H_H = 14.17 MJ/(m^2*day) for January
K_c = 0.686 for January
For a latitude of 32^o with a tilt of 42^o and a K_c of 0.686, Table D-11 estimates R to be:
R = 1.58

H_T = 14.17 MJ/(m^2*day)*1.58
H_T = 22.4 MJ/(m^2*day)
$\bar{H}_T$ = 22.4 MJ/(m^2*day)* 31days/January
$\bar{H}_T$ = 694MJ/(m^2*Jan.)

January Heating load is:
L = (load/DD)*(total DD in January)
= 19.1 MJ/DD * 381DD (this was calculated in the previous report)
= 7277 MJ/January

Rearranging the equation:
A = (Huck-Winn value from Figure 1)*L/ $\bar{H}_T$

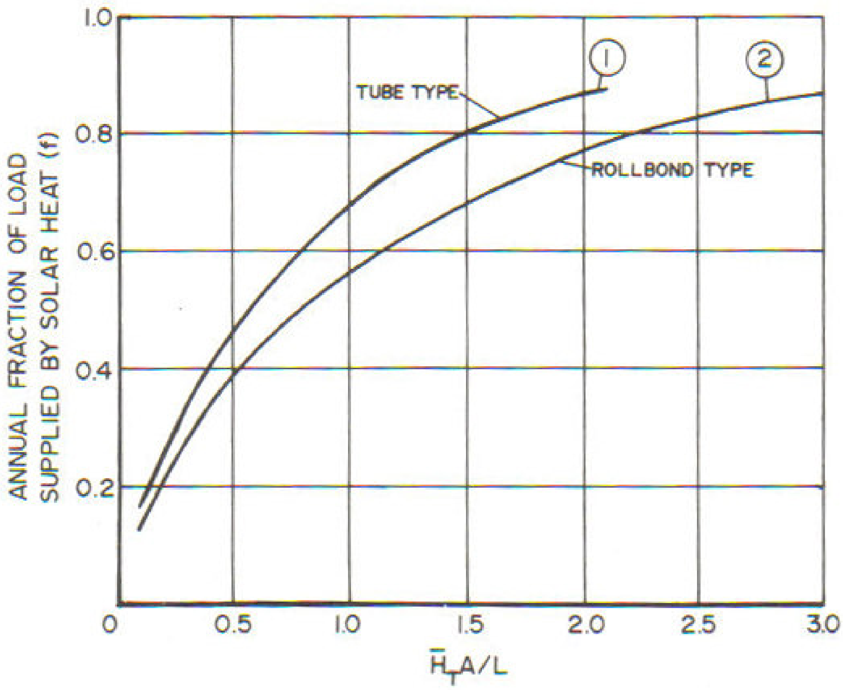


Figure 24: Design curves for liquid-type collectors, Huck-Winn method. Pg 111(fig 6-6)

<u>Pittsfield Solar Panel Area Calculation:</u>

Some of the data for Pittsfield is not available, so they will be estimated using the closest available cities of Boston, MA and Schenectady, NY.

H_H = 5.64 MJ/(m^2*day) for January
K_c = 0.408 for January
For a latitude of 43^o with a tilt of 53^o and a K_c of 0.408, Table D-11 estimates R to be:
R = 1.66

H_T = 5.64 MJ/(m^2*day)*1.66
H_T = 9.36 MJ/(m^2*day)
~~H_T~~ = 9.36 MJ/(m^2*day)* 31days/January
~~H_T~~ = 290MJ/(m^2*Jan.)

January Heating load is:
L = (load/DD)*(total DD in January)
= 19.1 MJ/DD * 744DD (this was calculated in the previous report)
= 14210 MJ/January

Using a tube type collector, the panel area needed to supply a percent of the heating need is compiled in Table 9.

Table 9: Area of solar panels needed to supply a % heat requirement

	El Paso, TX	Pittsfield, MA
%heat supplied	Area(m^2)	Area(m^2)
10	0.63	2.94
20	1.31	6.13
30	2.62	12.25
40	3.93	18.38
50	6.29	29.40
60	8.39	39.20
70	11.53	53.90
80	15.73	73.50
90	22.02	102.90

Appendix C: Solar Heating Installation Cost Breakdown

(AK)

Components Required for Solar Option II [33]
2005 Prices

5 - 4'x 8' Solar Collectors. . . . . …………….	$2550.00
Mounting Clips . . . . ……………..	$110.00
2 - 80 Gallon Storage Tanks with Integral Heat Exchanger .	$1500.00
Plumbing Mechanical Package. . . . . ……….	$349.00
Pump . . . . ………………..	$285.00
Solar Controller . . . . ……………….	$96.75
Digital Temperature Display. . . . . …………	$96.75
Heat Dump. . . . . ……………….	$213.30
Quality Tempering Valve. . . . . ………..	$110.00
Thermostatic Override. . . . . …………..	$96.00
Misc. Components (sensors, struts) . . . . ………	$180.00
Total . . . . …………………….	$5586.80

Appendix D: Central Water Tank and Infrastructure Cost Analysis

(AK)[30]Assuming the thermal storage has a height of 5m, this gives a thermal mass volume:

El Paso: 4.4^3 * 25 homes = 2130 m^3 = 5 x 20.6 x 20.6m (h*w*d)

Pittsfield: 6.2^3*25 homes = 6000 m^3 = 5 x 35 x 35m

The storage container design is essentially a tank created out of concrete blocks, with good insulation to minimize heat loss, and some sort of lining to prevent leaks. One concrete block is 190x190x390mm and usually costs between $0.60 and $0.90[35, 36].

Surface area of El Paso thermal container is $(4*5*20.6 + 2*20.6*20.6)m^2 = 1260m^2$

Surface area of Pittsfield thermal container is $(4*5*35 + 2*35*35)m^2 = 3150m^2$

Concrete block surface area is $0.19*0.39 = 0.0741m^2$

El Paso needs about $1260m^2/0.0741m^2$ = 17000 blocks *$0.90/block = **$15,300**

Pittsfield needs about $3150m^2/0.0741m^2$ = 42500 blocks *$0.90/block = **$38,000**

An insulation cost estimate for the central storage tank was performed using contractors.com[37]. The roof used unfaced R-30 10” insulation, the floor used unfaced R-19 6-1/4” insulation, and the walls used unfaced R-13 3-1/2” insulation.

The estimate for El Paso was **$19,700**

The estimate for Pittsfield was **$51,000**

The solar heaters described in the last report went for $5600, add in a few hundred for extra piping and pumps to connect this system to the central storage tank, so roughly $6000/system

Because of the higher temperatures and volume of sunlight El Paso only needs 2 systems per 5-family complex which gives:

5 5-family complexes*2 solar systems/complex*$6000/solar system = **$60,000**

Pittsfield requires the solar panel area of two systems in order to reach 50% heat supplied per household. So an additional $3500 per household is needed which gives.

$150,000 + $3,500*25 = **$240,000**

Another cost inquiry was about the underground piping used to connect the houses to the central storage tank. E-Z Lay pipes[38] seem to be what we would need. It's insulated and would allow a two way flow between the house and the main storage tank. It is $5.95/ft, which isn't too expensive. Estimate it at 200ft to connect a complex and 1000ft to connect to the biogas generator:

(200ft/home*5complexes+1000ft)*$5.95/ft = **$12,000**

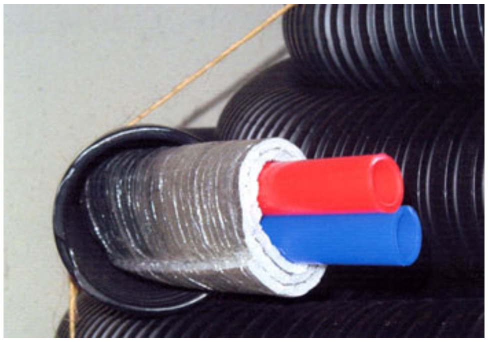


Figure 25: E-Z Lay Pipes

Running total for El Paso = $107,000

107,000/25homes = $4,300 per household

Running total for Pittsfield = $341,000

$341,000/25homes = $13,600 per household

Payback period for El Paso is roughly 3 years

Payback period for Pittsfield is roughly 9 years.

The complete system of solar, photovoltaic, and biomass will cover all the energy needs of the household. Yearly energy cost averages $4300[55], but since no other source to verify this was found, $2500/year will be used.

Total Cost of System per household:

El Paso: $17,000 PV + $4,300 solar + $11,000biomass = $32,300

Payback = $32,300/$2500/year = **13 years**

Pittsfield: $17,000 + $13,600 solar + $11,000biomass = $41,600

Payback = $41,600/$2,500/year = **16.5 years**

Appendix E: Household Energy Use Breakdown

(QE)

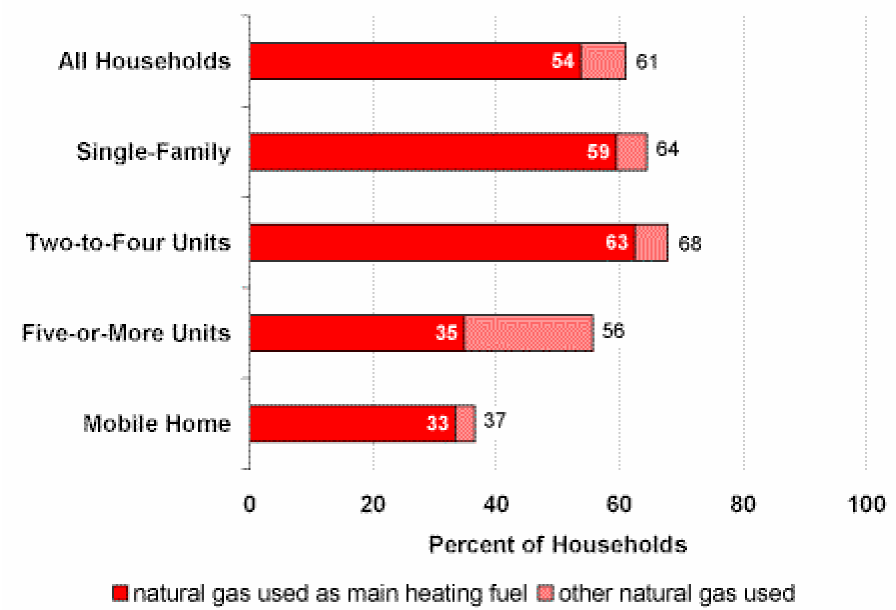


Figure 26: Percent of Households That Use Natural Gas by Type of Housing Unit, 1997

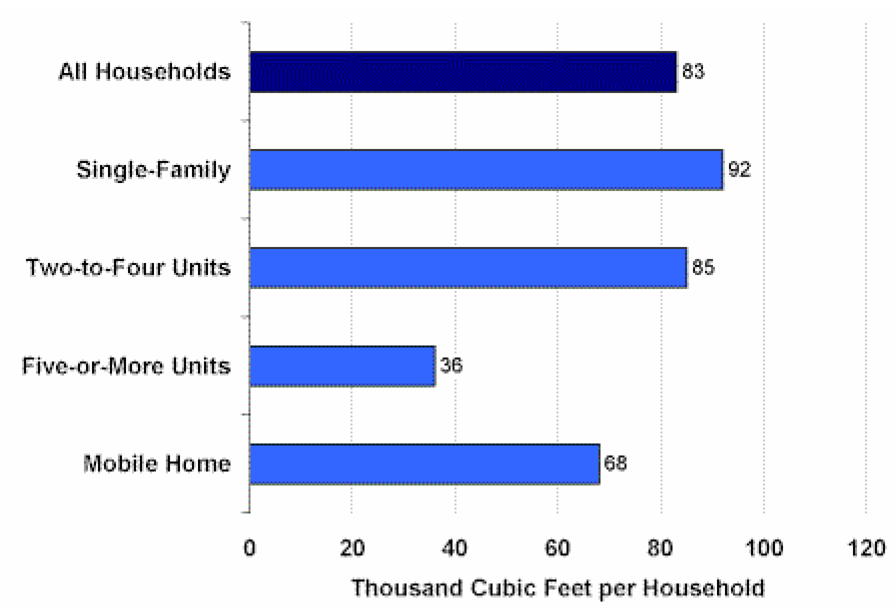


Figure 27: Natural Gas Consumption per Household by Type of Housing Unit, 1997

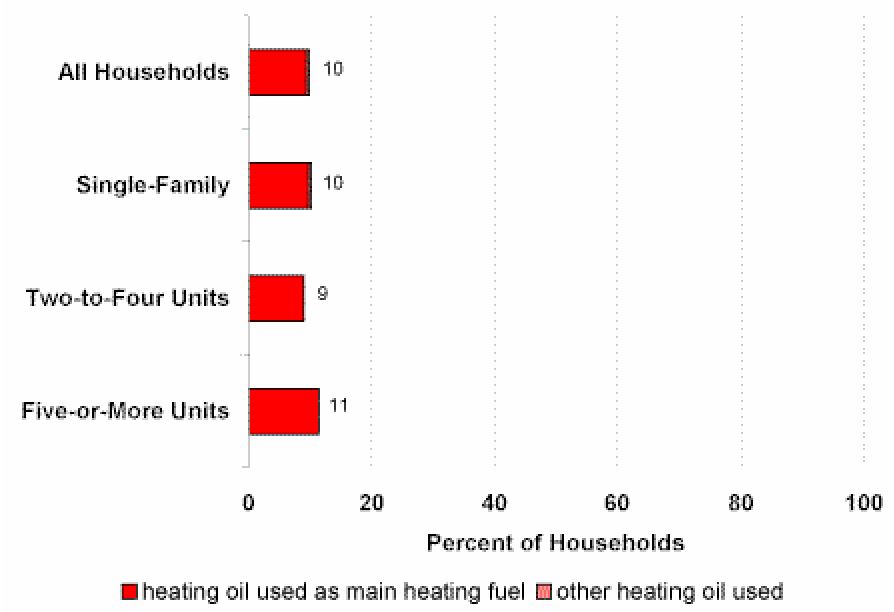


Figure 28: Percent of Households That Use Heating Oil by Type of Housing Unit, 1997

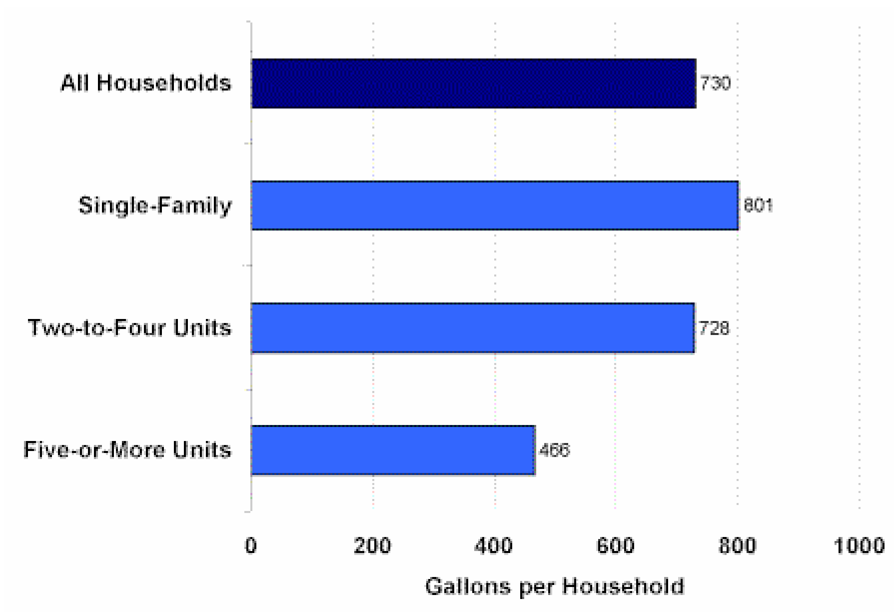


Figure 29: Heating Oil Consumption per Household by Type of Housing Unit, 1997

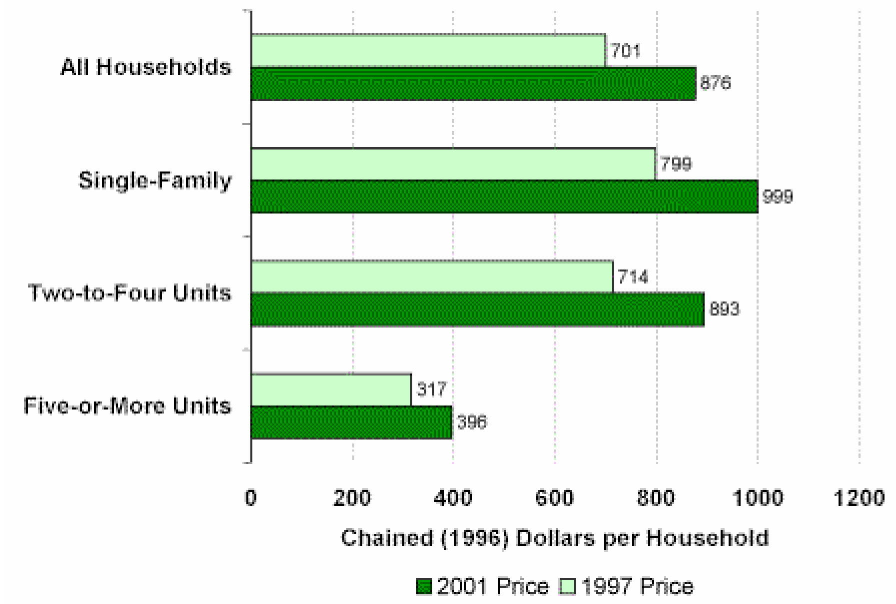
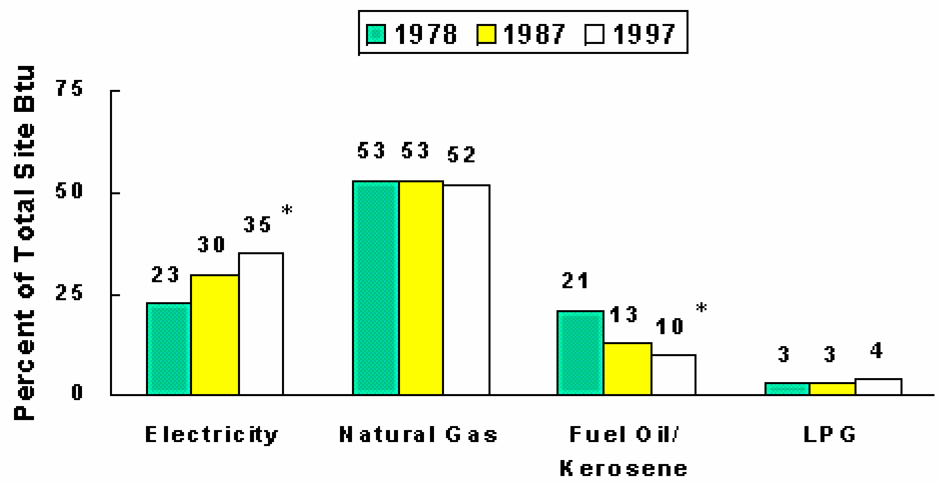


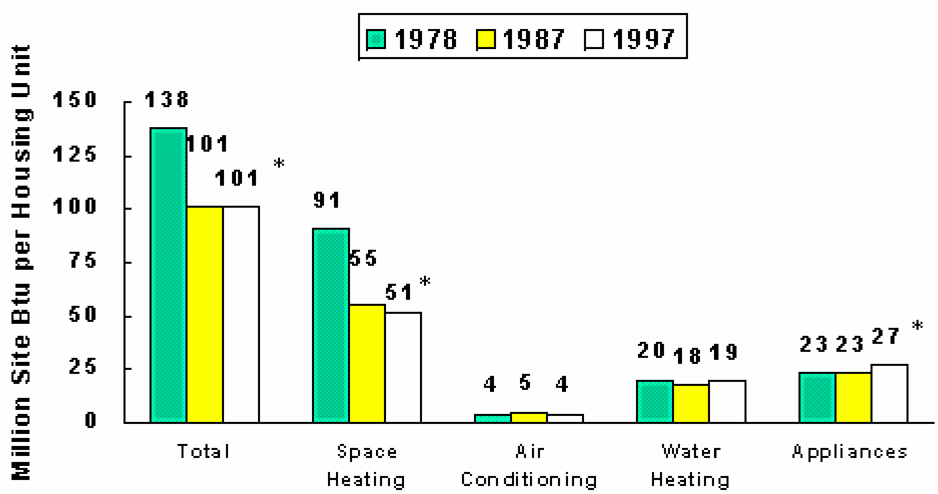
Figure 30: Heating Oil Expenditures per Household in 1997 by Type of Housing Unit

Appendix F: Energy Consumption by Sector and Type



* The difference between the 1978 and 1997 estimates is statistically significant at the 95-percent confidence level.
Sources: Energy Information Administration; 1978, 1987, and 1997 Residential Energy Consumption Surveys.

Figure 31: Percent of Total U.S. Residential Site Energy Consumption



* The difference between the 1978 and 1997 estimates is statistically significant at the 95-percent confidence level.
Sources: Energy Information Administration; 1978, 1987, and 1997 Residential Energy Consumption Surveys.

Figure 32: Site Energy Consumption per U.S. Housing Unit by Total and End Use

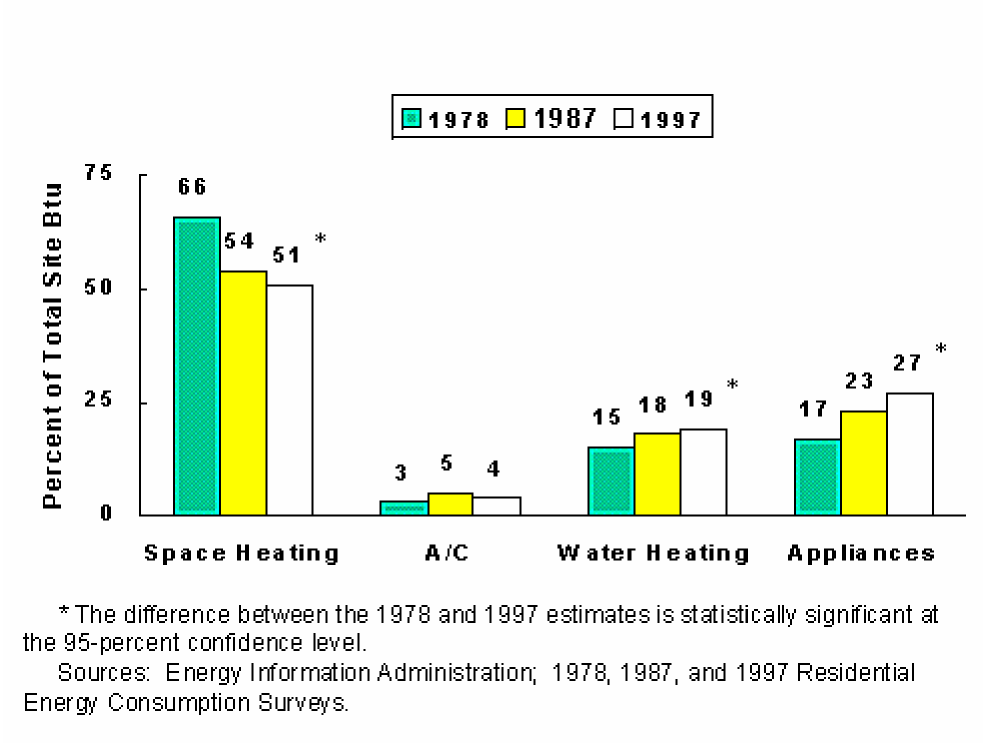


Figure 33: Percent of Total U.S. Residential Site Energy Consumption by End Use

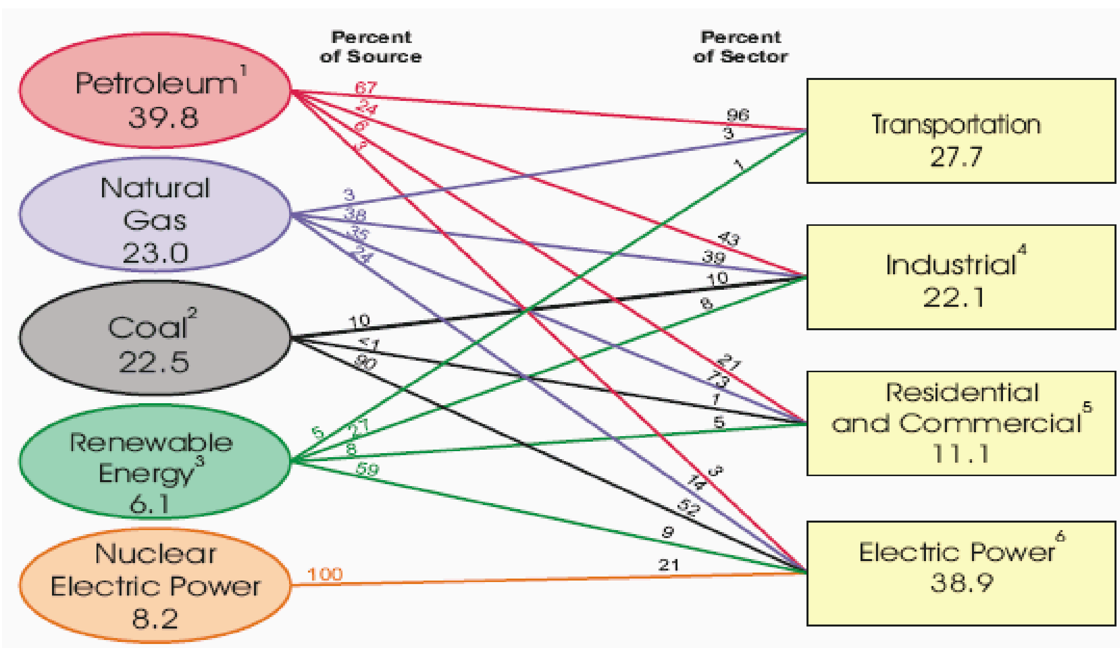


Figure 34: Energy Consumption by Sector

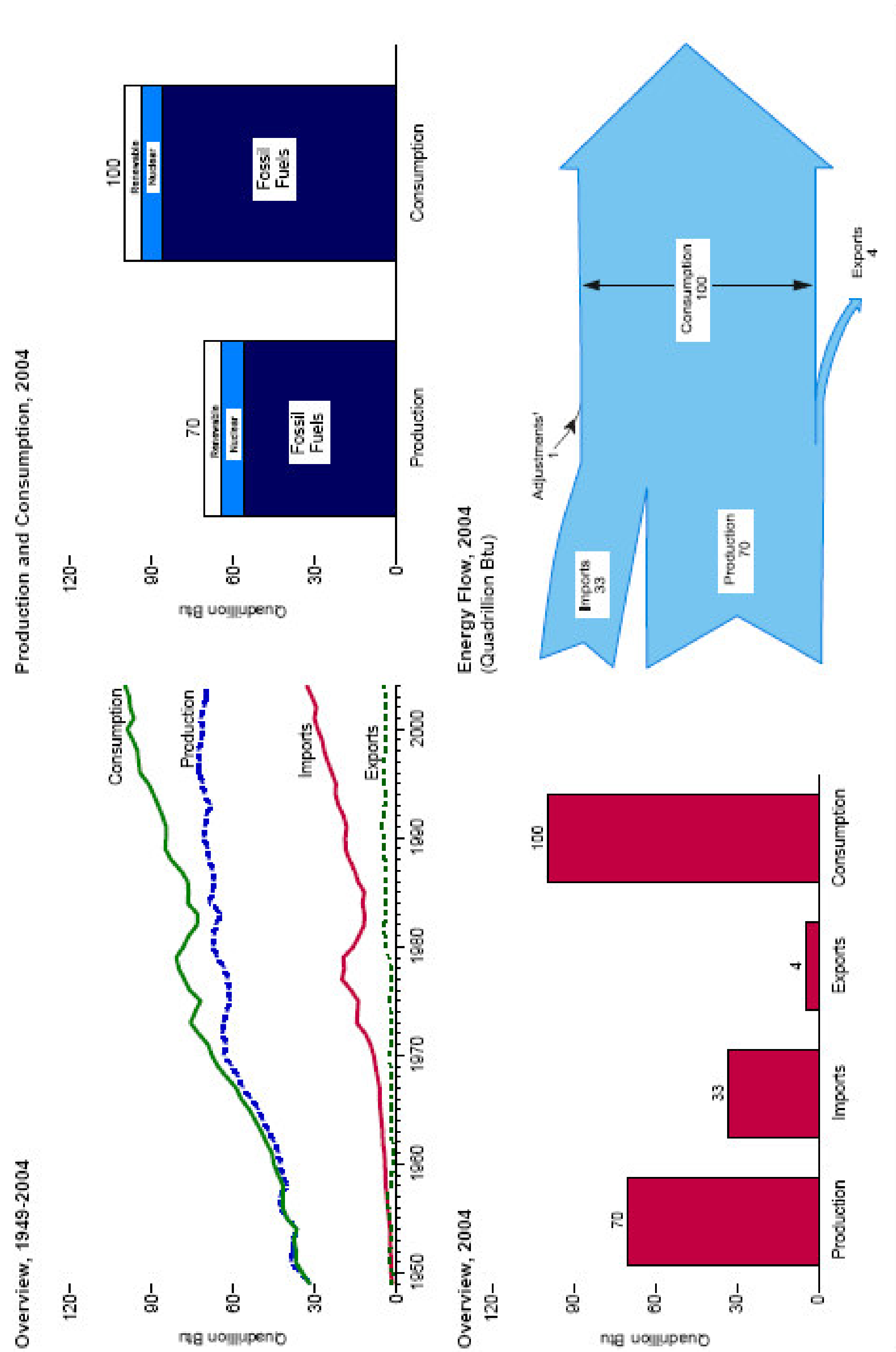


Figure 35: Energy Overview

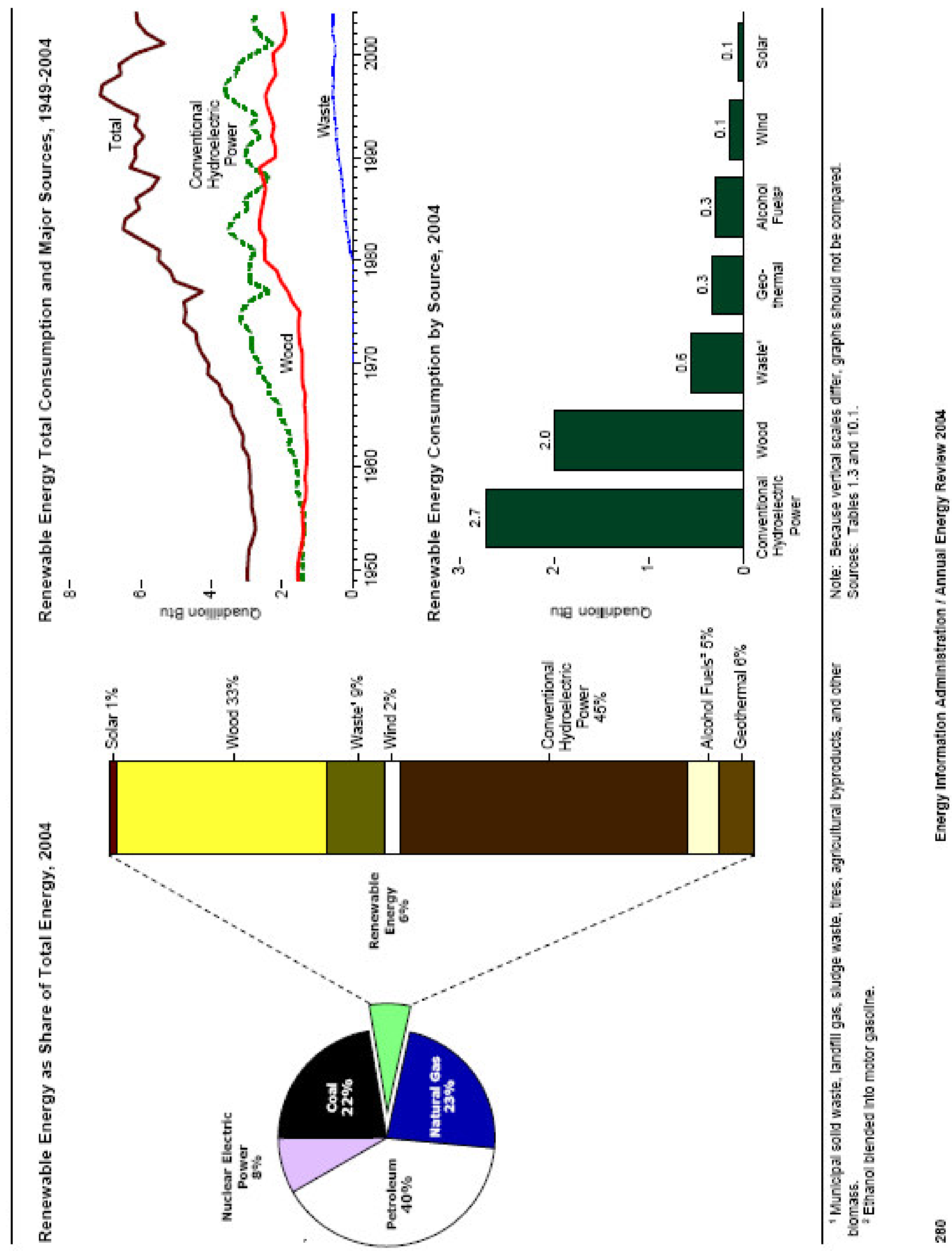


Figure 36: Renewable Energy Consumption by Major Sources

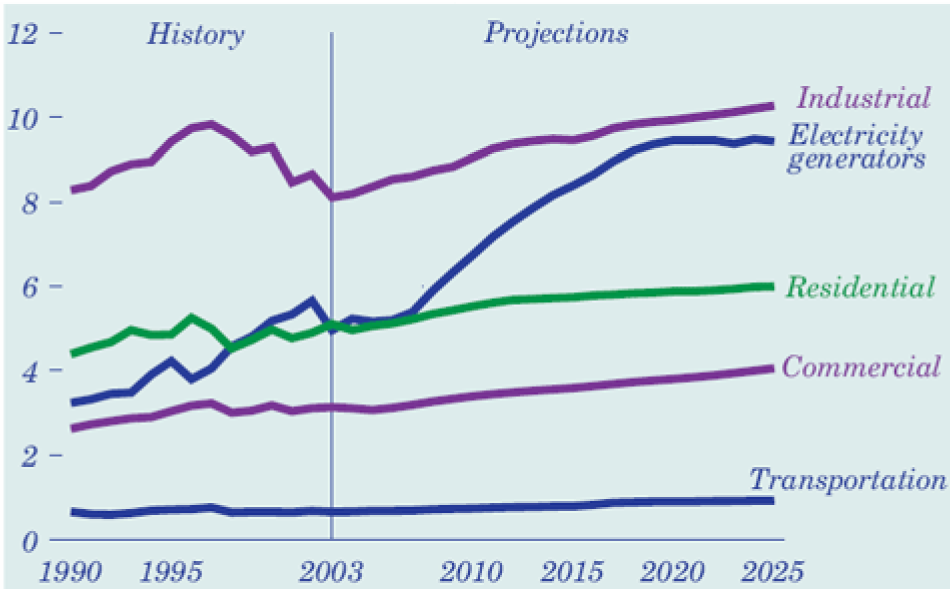


Figure 37: Natural gas consumption by sector, 1990-2025(trillion cubic feet)

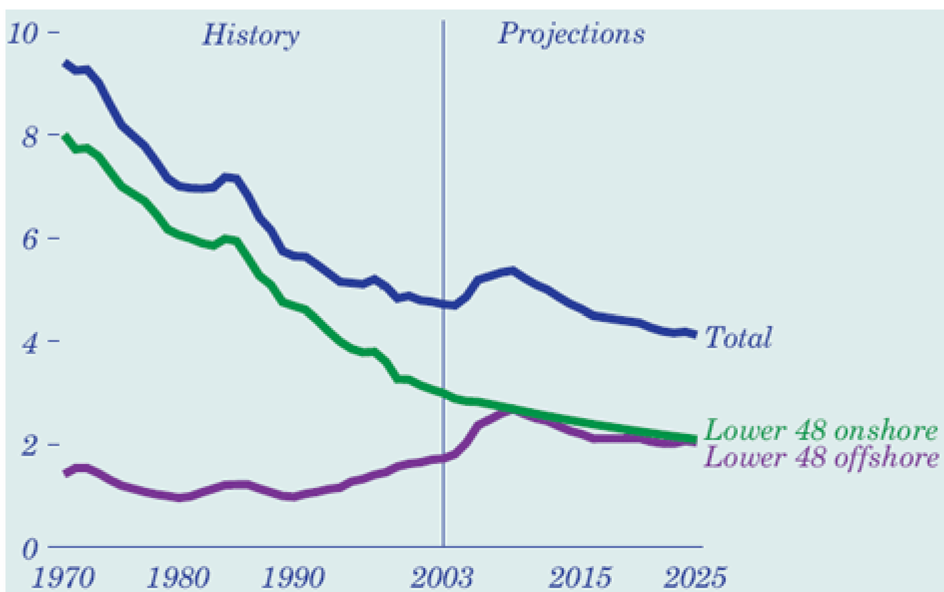


Figure 38: Lower 48 crude oil production by source, 1970-2025 (million barrels per day)

Wellhead price is the cost of gas as it comes from the well excluding cleaning, compression, transportation, and distribution charges.

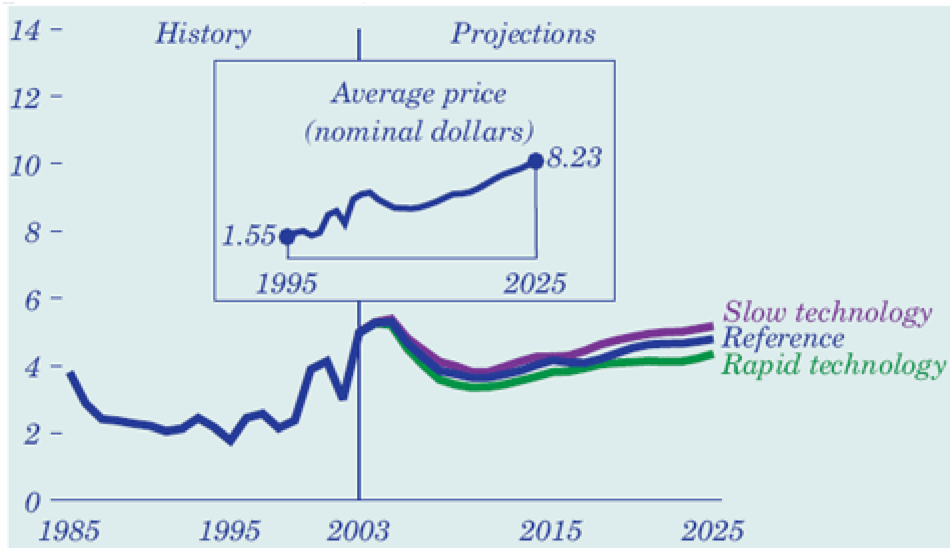


Figure 39: Lower 48 natural gas wellhead prices in three cases, 1985-2025(2003 dollars per thousand cubic feet)

Appendix G: Northeast Energy Maps

(QE)

Figure 40: EIA Renewable energy potential map of Northeast

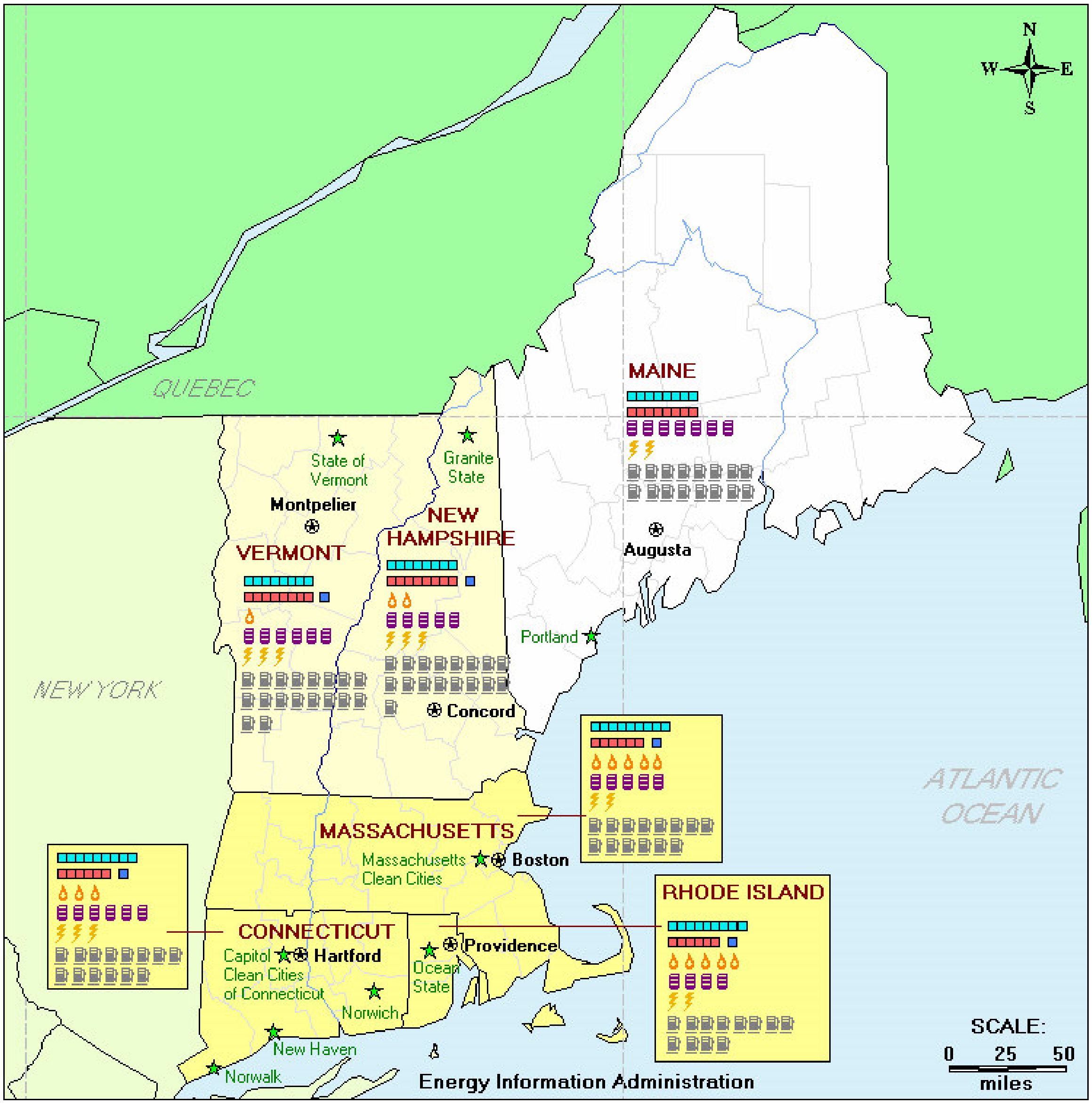
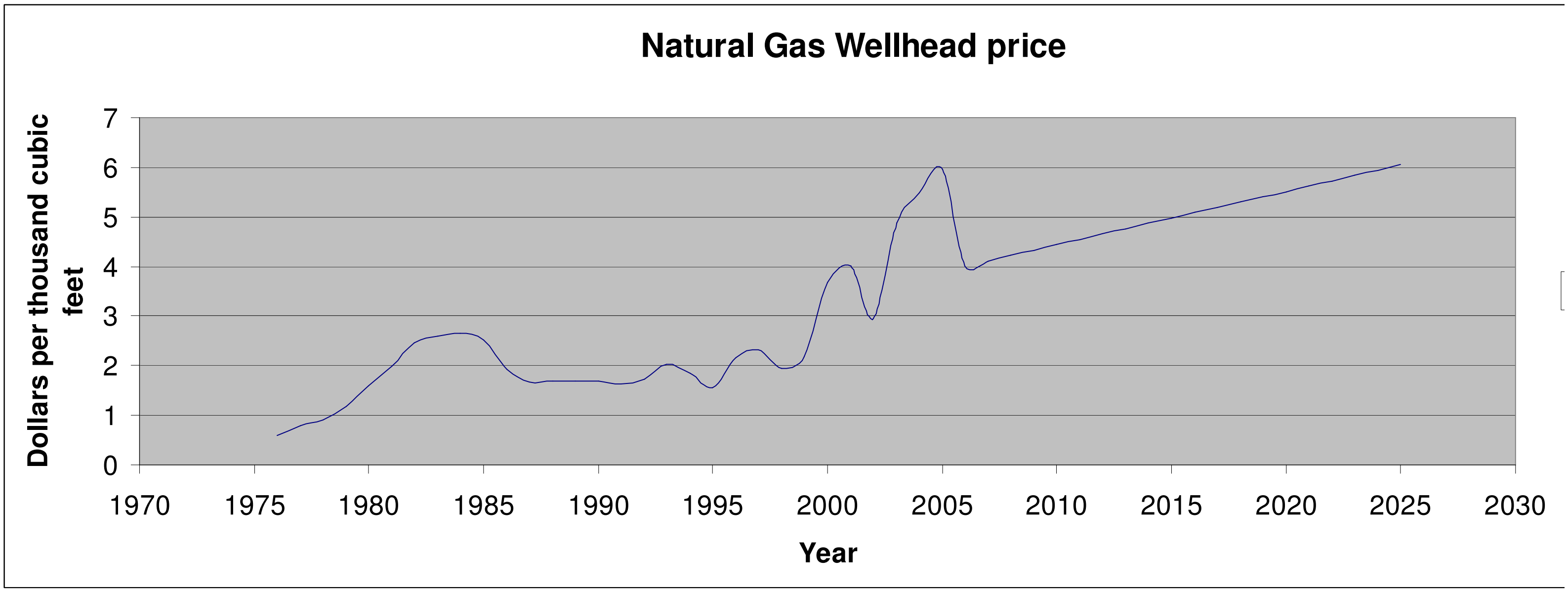
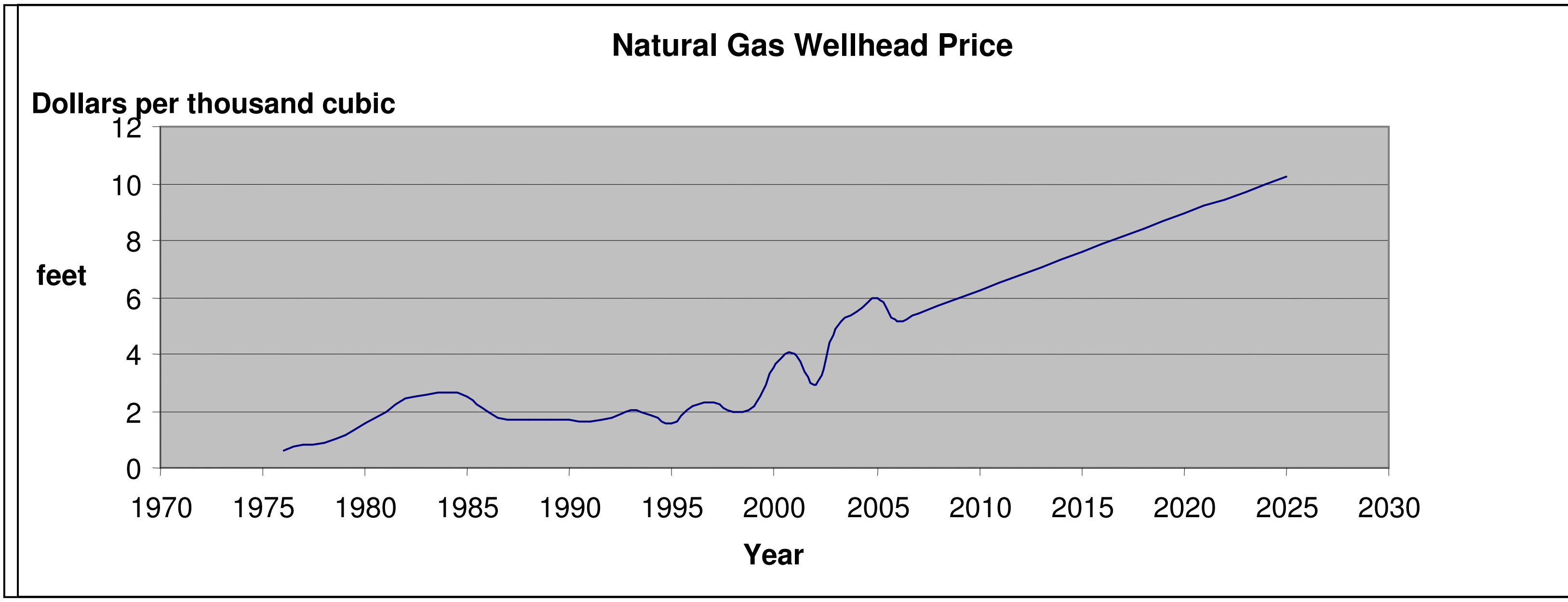


Figure 41: EIA energy map of Northeast



Data for above 2005-2025 was forecast using data from 1975 to 2005.



Data for above 2005-2025 was forecast using data from 1990 to 2005.

Calculations:
1,141kWh/month*1.3(typical rate)*12months/year = 17,800kWh/year

17,800kWh/year*20years*$0.091/kWh = $32,400 savings over the life of the solar panel warranty

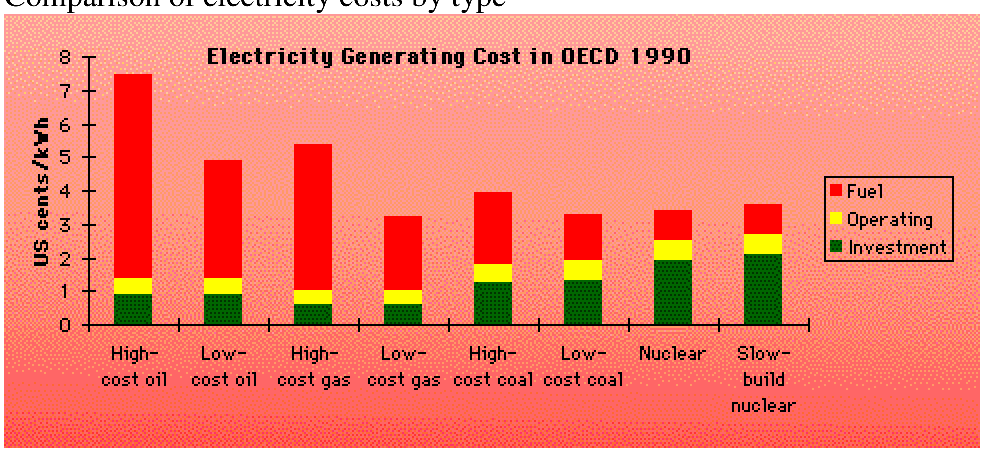
$50,000/20years/ (17,800kWh/year) = $0.14/kWh

Other Calculations:

Cost per kWh of a photo voltaic system.
GT9000 system: $50,000/(11400kWh/year*20years) = $0.22/kWh
GT3000 system: $16,000/(2626kWh/year*20years) = $0.30/kWh
GT1200 system: $7,800/(1518kWh/year*20years) = $0.26/kWh

Energy per unit of fuel:
Each such fission typically releases about 200 MeV, or 3.2×10^{-11} Joule, (contrasting with 4 ev or 6.5×10^{-19} J per molecule of carbon dioxide released in the combustion of carbon).[4]

Comparison of electricity costs by type[15]



Waste production of coal versus nuclear energy

Appendix H: Biomass Calculations

(RJ)Following is the cost estimates and analysis for the gasification system running on a microturbine generator.

- Gasifier system $700-3500/kW
- Generator: $800-1500/kW
- Undeveloped land in the Northeast/Berkshire region: ~$450/acre (from a real estate quote of $77 000 for 176 acres of undeveloped land in upstate NY, close to the Massachusetts border)
- Hiring a tractor to periodically harvest the grass: $50+/hr (from personal experience)

The acreage required for the switchgrass is about 142 acres, leaving about 1.4 acres left per household on a 176 acre site. This is a good starting point because a land quote is already available. To provide 1kW of electrical power, 2.17 acres of land is needed (1/0.46kW/acre = 2.17 acre/kW).

A = 2.17 acres/kW	= Acreage required per kW
A_c = $450/acre	= Approximate cost per acre in the Northeast
G = $700-3500/kW	= Cost range for gasification system
T = $800-1500/kW	= Cost range for turbine system
H = $50/kW	= Estimate for once-a-year harvest labor

$Cost_{low} = (A*A_c) + G + T + H$ = $2527/kW = Low range capital cost for complete gasification generation system

$Cost_{high}$ = \$6027/kW = High range for complete system

For a 65kW system, the total cost range is \$164,225 – 391,755.

Per household, the total cost range is \$6,569 – 15,670.

Average estimate, per household, in the Northeast is \$11,120.

Average cost of electricity in the Northeast, August 2005: \$0.135[53]

Average annual cost of electricity in the Northeast: (7,142kWh/yr * \$0.135/kWh) = \$964/yr

Estimated Return on Investment (ROI): \$11,120/\$964/yr = 11.5 years.

However, the ROI estimate does not factor in revenue generated by selling excess power to the grid. The generator need not necessarily run 24/7, which would reduce fuel demands and therefore cost. If it did run constantly, however, excess power could be sold back to the grid, generating some revenue when the community is not using maximum power.

Biomass heat generation:

78kJ/s*3600s/hr*24hr/day*365days/year*0.25 losses = 615GJ/year

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