Rising Energy Costs &
The Economics of Solar Hydronic Heating

A Feasibility Study for OMNI Development Corp.

1 Mashapaug Street
Providence, Rhode Island

"I'd put my money on the sun and solar energy. What a source of power"

- Thomas Edison, March 1936

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Table of Contents

List of Figures

List of Tables

List of Appendices

Abstract

The costs of natural gas and oil have gone up significantly in the last five years due to increased demand and declining spare capacity. In the first decade of the 21st century many of the world's largest oil and gas fields are showing signs of peak production, causing significant speculation that the price of these fuels will continue rising.

At this same point advances in alternative energy systems have made tremendous progress in efficiency and affordability. Of all the major energy consuming sectors buildings offer the greatest opportunity to reduce demand. Heating and hot water in particular consume the most energy within buildings, averaging 56% of total annual demand. A new solar thermal system offers developers and building owners the opportunity to substantially reduce conventional energy use for these two applications in a cost-effective manner. The system combines radiant floor heating, solar thermal collectors, and phase change thermal energy storage material.

This thesis assesses the status of today's energy market and the additional up front costs, government incentives, and payback period that would apply to this new system's installation at 1 Mashapaug St, Providence, RI. OMNI Development Corp. is considering redeveloping this property into low-income veteran housing. Currently it is an unoccupied 14,240 sq. foot mill building in poor condition. According to Bill Thomas, the design engineer of the solar system, the building meets all the criteria to be fully redeveloped with this technology.

A cost and performance analysis shows the system will offset roughly 37.5% of the building's total heating and hot water load on an annual basis. At $1.82 per Therm of natural gas, the price in December 2005, the system will pay for itself within 12.7 years through energy cost savings. However, natural gas prices are expected to continue rising, making the payback of this investment even quicker.

Introduction

Recent advances in solar energy technology suitable for building implementation are considerable. As energy prices have increased significantly over the past 5 years a new interest has developed among consumers and developers to invest in energy efficient and renewable energy systems. Focusing these investments on space heating and hot water technologies may offer the quickest returns. According to the U.S. Department of Energy (DOE) these two utilities account for 56% of the average residential energy bill.

OMNI Development Corp. of Providence, RI is currently working with the U.S. Department of Housing and Urban Development (HUD) to appropriately transform an old 14,240 sq. ft mill into low-income veteran housing. The redevelopment proposal is for 1 Mashapaug St, Providence, RI and is evaluated for a new solar heating and hot water system installation.

Entities within the state of Rhode Island have recently engaged in discussion regarding the effects of rising fuel costs on the low-income. State and federal funding now exists to assist these households with rising heating bills during winter months. The Rhode Island Renewable Energy Fund (RIREF) specifies a portion of its grants must be applied to low-income housing. Additionally, state and federal tax incentives to install renewable energy and energy efficient upgrades are available to all homeowners and businesses.

Substantial data on the economics for clean energy technologies such as solar hot water, photovoltaic (PV) and wind turbines are readily available. In 2003 the U.S. Department of Energy's (DOE) Solar Program funded a report titled, "PV in Commercial Buildings – Mapping the Breakeven Turnkey Value of Commercial PV Systems in the

U.S.[1]" In addition the National Renewable Energy Laboratories (NREL), a group within the DOE, offers PVWatts[2], a free software program that calculates the payback of specific PV installations. Information regarding the return on small wind power investments can be found in Berkeley National Laboratory's report, "Building a Market for Small Wind: the Break-Even Turnkey Costs of Residential Wind Systems in the U.S.[3]" Solar hot water data is available from NREL such as "Solar Water Heating.[4]" However, a cost analysis method for a new combined solar space heating and hot water system has not been completed. The focus of this report is to assess today's energy market and the additional up front costs, government incentives, and payback period that would apply to this new system's installation at 1 Mashapaug St, Providence, RI.

OMNI Development Corp. and Mashapaug Solar Proposal

OMNI Development Corporation of Providence, RI is a non-profit organization specializing in revitalization efforts and affordable housing. Joseph Caffey, president of OMNI, articulates its mission as such,

> "Omni Development Corporation is a non-profit community planning and housing development corporation charged with the renaissance of communities through the development of residential, commercial, and economic development real estate.[5]"

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1 Christy Herig (NREL), Susan Gouchoe (NC Solar Center), Richard Perez (ASRC) and Tom Hoff (Clean Power Research). National Renewable Energy Laboratory. ASES Solar 2003 Conference. 2003. (7 pp.)
2 http://rredc.nrel.gov/solar/codes_algs/PVWATTS/
3 Jennifer L. Edwards, Ryan Wiser, Mark Bolinger, and Trudy Forsyth, "Building a market for small wind: The break-even turnkey cost of residential wind systems in the United States" (March 1, 2004). Lawrence Berkeley National Laboratory. Paper LBNL-54865.
4 www.nrel.gov/docs/legosti/fy96/17459.pdf
5 http://www.omnidevelopmentcorp.com/home.cfm

At present OMNI is considering the redevelopment of an historic mill located at 1 Mashapaug St. in Providence, RI shown in Figure 1. The building stands 3 stories high and measures a total floor space of 14,240 sq. feet. As of now the mill is unoccupied, boarded, and in poor physical condition. For the past 30 years the U.S. Environmental Protection Agency (EPA) has registered the property as a brownfield, a site that may be contaminated by low levels of hazardous waste or pollution but has the potential to be reused after appropriate remediation efforts.

Figure 1: Photo of old mill building at 1 Mashapaug Street from south side

Although there is limited information on the building's past, it is known the mill was erected in 1882 and has a history of light manufacturing and commercial use. It was first home to John & Thomas Hope Company, later to become incorporated as John Hope & Sons. The company is credited with inventing the first pantograph, a device used for engraving and printing. They continued operations there through 1937 when the Koffler Trunk Company moved in and conducted business through the 1960s. It is assumed the building has remained vacant since.

OMNI is now working alongside the U.S. Department of Housing and Urban Development (HUD) in attempts to appropriately renovate the building for low-income veteran housing. However, this is not the first time Mashapaug's redevelopment has been proposed. In May of 2001 Federal Housing Associates (FHA) made a redevelopment proposal, including a substantial addition to the structure [Appendix 1], but the project was never approved. Fortunately for OMNI, FHA conducted an environmental assessment of the brownfield property, finding evidence of lead paint and coal use [Appendix 2].

FHA's remediation proposal [Appendix 3] included placing a geotexile fabric barrier over all exposed soil surfaces and covering it with a minimum 1 ft. layer of granular fill. The textile would provide both a physical and visual barrier for any future excavation to discover. It was estimated 1,330 cubic yards of fill would be necessary for the 36,000 sq. feet of exposed soil. At $9 per cubic yard of fill and $1.50 per sq. yard of textile the total remediation cost was estimated to be $17,970 and expected to be sufficient for DEM standards.

In collaboration with an OMNI employee, Matt Willse, the Mashapaug redevelopment was evaluated as a prospect for a new solar heating and hot water installation. The system was first designed, developed, and operated with the expertise of Bill Thomas, a leading solar and energy efficiency mechanical engineer at Arden Engineering in Pawtucket, RI. For the purposes of this study, the system he developed that is being analyzed for Mashapaug is referred to as 'Soltron'. Thomas has assisted extensively with this report by specifying the most effective design for this building. He has been to Mashapaug numerous times and confirms the building meets all the criteria to be redeveloped with solar thermal technology, having the potential to be a 'standout project'. Major considerations include direct southern exposure to the sun from the rooftop, and strong building insulation characteristics which will be met by redevelopment standards.

The proposed solar thermal design installed on Mashapaug offers OMNI a tremendous opportunity to save on energy costs in addition to setting the precedent for low energy buildings in New England. However, in order for any professional developer to invest alternative energy systems it is crucial to understand the underlying economics. As such the conventional oil and gas industry and the markets for these fuels are addressed first.

BACKGROUND

Energy Supply Background

As an active solar hot water and space heating installation, the payback on this system will be contingent on the price of heating oil and natural gas through the coming years. According to the Rhode Island State Energy Office (RISEO) 46% of the state's residential sector heats with natural gas and 42% with heating oil[6], a refined petroleum fuel that fluctuates in price proportional to conventional crude as Figure 2 shows.

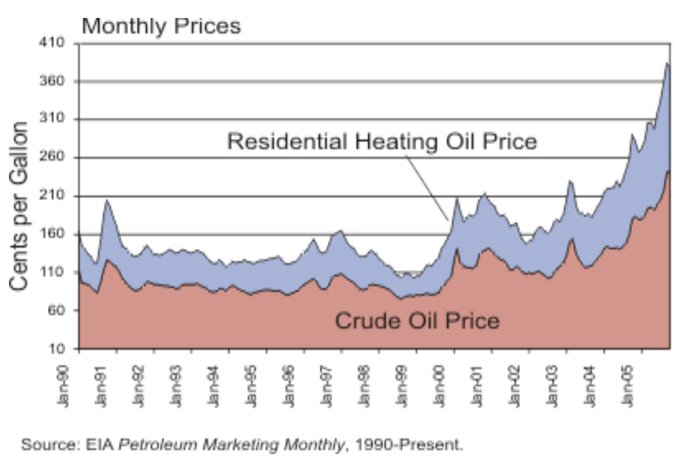

Figure 2: The correlation in price between heating oil and crude oil. Source

For the purposes of this report oil and natural gas markets are analyzed according to supply, demand, and price through the year 2025, a time frame well within the life of the proposed solar

[6] www.riseo.state.ri.gov

technology. The majority of energy data and statistics analyzed are referenced from the Energy Information Administration (EIA) and the International Energy Agency (IEA). These two groups are widely respected as publishing the most current and accurate energy data. The EIA is the statistical agency within the U.S. Department of Energy and is the nation's premier source of information, producing detailed global energy market reports on a weekly basis. The IEA acts as the energy advisor to its 26 member countries. It provides information on energy supplies, demand, technology, and policy and is known worldwide for its objectivity[7].

During the fall of 2005 energy markets experienced the highest spike in prices of recent history. On August 31st, 2005 oil topped $70 per barrel[8] while natural gas ran above $16 per million British thermal units (MMBTUs) at wellhead[9]. These price surges represented a 250% price increase for oil and 400% increase for natural gas over the previous 5-year period. In August of 2000 oil sold for $20 per barrel and natural gas for $4.43 per MMBtu[10]. At the onset of the 2005-2006 winter there was substantial concern over the high increases these markets would impose on home heating bills[11]. For the first time

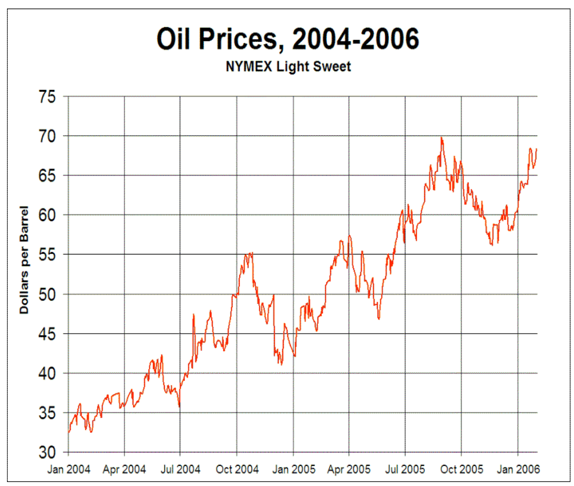

Figure 3: Market value for barrel of oil 2004-2006. Source: NYMEX

[7] http://www.iea.org/Textbase/about/index.htm
[8] Federal Energy Regulatory Commission, "Winter 2005-2006 Natural Gas Market Update", January 19, 2006
[9] Ibid
[10] www.ksg.harvard.edu/cbg/Conferences/economic_policy/EnergyPolicyTables.pdf
[11] Stone, Brad "How to Beat the Big Energy Chill" Newsweek, November 2005

since the oil crises of the 1970s mainstream press, policy makers and investment bankers engaged in lengthy discussion on the vulnerability of the United States' energy infrastructure and the need for alternative energy sources[12].

The steep spike in energy prices, shown in Figure 3, is attributed to 2005's devastating hurricane season, followed by increased speculation in the energy markets. Hurricane Katrina followed by Rita whipped through the Gulf crippling a significant portion of the oil and gas industry's ability to produce, refine, and transport energy supplies to market.

Although the 2005 hurricane season was a short-term series of natural disaster events it signaled an alarming lack of spare capacity within the energy supply chain. When the Gulf's oil and gas infrastructure was damaged and shut-in there was little extra supply the world market could contribute. Over the last five years the balance between oil and natural gas supply and demand has become increasingly tighter across all markets.

Oil Outlook

Currently, in 2006, the world consumes nearly 85 million barrels per day (mbd) of conventional crude oil[13] with economic growth predicted to increase demand at 2% annually over the next two decades[14]. The EIA estimates world demand will reach 119 mbd by 2025 if business-as-usual continues[15], but substantial speculation is questioning where these additional supplies will come from. The aftermath of Hurricanes Katrina and Rita demonstrated the extremely tight balance between production capacity and demand. Currently every oil-producing nation, with exception to Saudi Arabia, is pumping at full

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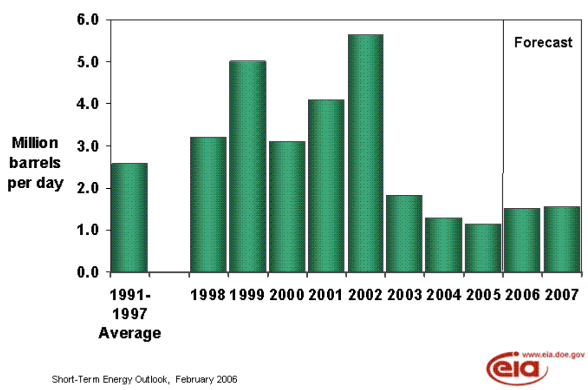
[12] Ibid
[13] EIA, Short-Term Energy and Summer Fuels Outlook, April 11th, 2006
[14] EIA, "International Energy Outlook 2005", World Oil Markets, July 2005
[15] EIA, "International Energy Outlook 2005", World Oil Demand, July 2005

capacity[16]. On October 27, 2005 the *New York Times* reported in an article titled *Doubts Raised on Saudi Vow for More Oil*, "Saudi Arabia's capacity now stands at about 11 million barrels a day. The Saudis pump about 9.5 million barrels, leaving a cushion of about 1.5 million barrels, mostly of heavier grades not very usable in the West. There is virtually no other global spare capacity.[17]" Figure 4 shows the sharp decline in spare capacity since 2002.

Figure 4 shows spare capacity in the global oil market. In 2005 it was just above 1 mbd
Source: EIA



The EIA categorizes the 'world's largest oil producers' as those nations that supply over 2 mbd to market. Of these 14 countries, half are members of the Organization of Petroleum Exporting Countries (OPEC).[18] According to the EIA's '*Short-Term Energy Outlook – April 2006'*, Saudi Arabia is the only OPEC member with any spare capacity, but measures only 1.1 – 1.6 mbd (1.9% of current daily consumption)[19].

The remaining non-OPEC members of the 'world's largest oil producers' include the U.S., Russia, Mexico, China, Canada, Norway and the United Kingdom. Of these 7 nations only Russia, Norway, and Mexico remain net exporters to the global market all three of which are or will soon be facing a decline from current production [Appendix 4].

[16] EIA, "Persian Gulf Oil and Gas Exports Fact Sheet", September 2004
[17] Gerth, Jeff, New York Times, "Doubts Raised on Saudi Vow for More Oil," October 27, 2005
[18] EIA, "Non-OPEC Fact Sheet", June 2005
[19] EIA, "Short-Term Energy Outlook", Table 3a. OPEC Oil Production, April 2006

Of all OPEC and non-OPEC members Saudi Arabia is the largest producer and lists the highest proven reserves. Historically, Saudi Arabia has played a critical role as the market supply regulator. The International Energy Agency anticipates the Saudi's will have to double its current production of 9 mbd by 2030, in order to meet projected growth demand[20]. Matthew Simmons, an oil industry investment banker, explains his views on the situation,

> "For years, every important energy supply model has assumed that Saudi Arabian oil is so plentiful and can be produced so inexpensively that its supply is expandable to any realistic demand level the world might need, at least through 2030. Many widely respected supply model (such as those used by United States government energy planners and the International Energy Agency) assume that Saudi Arabia will be producing as much as 20 to 25 million barrels of oil a day within the next two to three decades. In reality, the kingdom's demonstrated production capacity in 2004 was on the order of 10 million barrels a day – in other words, one-half of the estimate."[21]

As the 'easy-to-produce' supplies of conventional oil become scarcer, and fewer new discoveries replace them, the energy industry is looking to unconventional oil. The most commonly talked about sources include the tar sands of Alberta, Canada and oil shale of the western United States. However, these solutions are far from perfect and will have little effect on a world oil market.

Although the Alberta tar sands are estimated to contain 1.6 trillion barrels of oil equivalent[22], "half of which may be recoverable," the production rate of these sources is severely limited. According to Canada's National Energy Board in report titled

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[20] IEA, World Energy Outlook 2006, Reference Scenario
[21] Simmons, Matthew "Twilight in the Desert" pg. xiii
[22] Alberta Dept. of Energy, Alberta's Oil Sands, December 8th, 2004

Canada's Oil Sands: Opportunities and Challenges to 2015, the sands offered a production of 1 mbd in 2004, and are only expected to reach a mere 2.2 mbd by 2015[23]. In addition the energy input of producing every barrel of synthetic oil requires 1,000 cubic feet of natural gas[24], a cleaner energy source also facing supply constraints.

Similar challenges face the United States oil shale reserves, which are estimated to contain over 1 trillion barrels of oil equivalent[25]. The time frames, energy inputs and environmental consequences of developing the synthetic oil industry leave it having little impact on the global oil market. A study prepared for the National Energy Technology Laboratory of the U.S. Department of Energy by RAND Corp, a nonprofit consultancy firm, writes, "…we assume oil shale production is yielding 3 million barrels (crude oil equivalent) per day. …this production rate will unlikely be reached until at least 30 years hence."[26]

Substantially more evidence exists showing the supply of this finite resource is tightening and its price tag will continue rising. As global oil production starts declining, which many experts argue lies within this decade, the economic case for an aggressive pursuit and development of alternative energy infrastructure will be even clearer than today. As time gets closer and closer to that point natural gas supplies will undoubtedly become even more vital to the global energy infrastructure.

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[23] National Energy Board [Canada], Energy Market Assessment, "Canada's Oil Sands, Opportunities and Challenges to 2015" May 2004, pg. 46
[24] Crookshank, George; CFO of OPTI Canada Inc, http://www.energybulletin.net/1191.html
[25] Foy, Paul, Denver Post, "Oil Riches Just Out of Reach" October 3, 2005
[26] RAND Corporation, "Oil Shale Development in the United States Prospects and Policy Issues," [Prepared for the National Energy Technology Laboratory of the U.S. Department of Energy] 2005, pg. 47

Natural Gas Outlook

Natural Gas is widely recognized as the highest quality fossil fuel for heating, electricity generation, and industrial processes because it burns cleaner, safer, and more efficiently than oil or coal. Over the past decade many large energy consumers, particularly power plants, have converted their systems to natural gas to meet stricter environmental regulations and increase efficiency. For example between 1999 and 2002 the US built an additional 144,000 megawatts (MW) of electricity generation capacity, 138,000 MW of which was powered by natural gas[27]. As a result of this increased demand many industry experts are speculating on the future supplies and price to the same degree as oil.

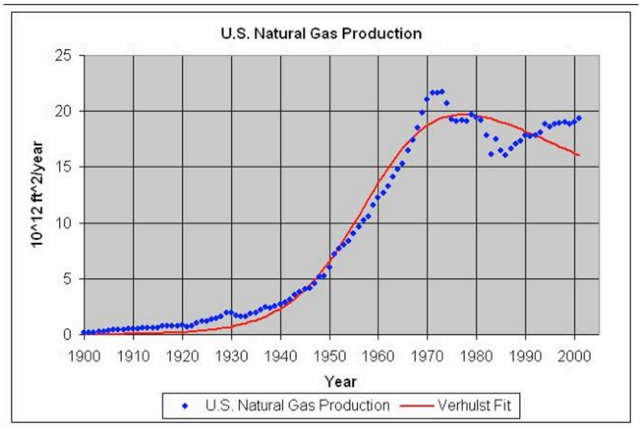

Figure 5 Depicts the declining production of US natural gas. Source: EIA

The market for natural gas is unique from oil because it can't be easily stored or transported by rail, automobile or vessel. In order to get the gas from source to user it must be distributed through pipeline networks, leaving markets primarily regional. Although new natural gas discoveries around the globe are significantly more frequent than oil, the transmission infrastructure hinders an internationally balanced market.

[27] MFS, "North American Natural Gas: Data Show Supply Problems" http://www.mnforsustain.org/natural_gas_supply_in_decline_youngquist_duncan_1203.htm

Figure 5 shows the domestic production of natural gas within the US has declined since 1972[28]. In 2004 the US depended on natural gas for roughly 22% of its energy needs, consuming 22.3 trillion cubic feet (Tcf)[29], 19% of which was imported[30]. Canada is the largest exporting nation to the US accounting for 3.9 Tcf in 2005, but they too are facing declining natural gas supplies[31].

The US and Canada have an extensive network of trans-border natural gas pipelines, which the US has become increasingly dependent on to meet its gas needs. In January 2006 Canada's proven reserves registered 56.6 Tcf [32]. However, estimates suggest they will only be able to export 2.5 Tcf to the US by 2025, which will be consuming 31.1 Tcf per year by that point[33]. From an extremely conservative outlook, if US production stays consistent at its current rate of 18.2 Tcf[34] through increased drilling and new discovery and Canada can meet its expected export quota, an additional 10.4 Tcf will still be needed to meet 2025's demand. While Mexico, the only other bordering nation, has significant oil reserves they lack natural gas resources and have maintained a net importing relationship with the US[35]. In order to meet these future demands liquefied natural gas (LNG) technology will have to play an increasing role.

LNG is a complex transportation infrastructure that offers the delivery of natural gas overseas. In regions of spare natural gas capacity, such as Russia and the Middle East, natural gas is chilled to minus 260°F, bringing it to a liquid state. At this point its volume condenses to roughly 1/600th of its gaseous state making it affordable to transport

[28] EIA, "US Natural Gas Markets, Recent Trends and Prospects for the Future"
[29] EIA, Country Analysis Briefs, United States, Natural Gas, November 2005
[30] EIA, Country Analysis Briefs, United States, Natural Gas, November 2005
[31] EIA, Country Analysis Briefs, Canada, Natural Gas, April 2006
[32] EIA, Country Analysis Briefs, Canada, Natural Gas, April 2006
[33] EIA, Country Analysis Briefs, United States, Natural Gas, November 2005
[34] EIA, "Short-Term Energy Outlook" April 2006, Table 8a
[35] EIA, Country Analysis Briefs, Mexico, Natural Gas, December 2005

via specially designed LNG tankers[36]. When the tanker arrives at its destination terminal the LNG is re-gasified and distributed to users through an existing pipeline network.

LNG technology has been operating since 1959 and is primarily used by island nations, such as Japan with no domestic supplies, and those that don't have established pipeline infrastructure. However, the infrastructure required for these deliveries are extremely capital intensive and environmentally controversial. In 2005 the US received only .63 Tcf via LNG[37]. By 2025 LNG import capacity is estimated to be 5.8 Tcf[38].

Officials have attributed the remaining supply of will be made up by unconventional natural gas supplies[39]. Similar to unconventional oil, these supplies are expected to come from the coalbeds and oil shales of the Western US. However, significant skepticism exists that these production projections are feasible.

It's clear the markets for both oil and natural gas have the potential to be increasingly volatile in the coming decades. Policy makers across the nation will be faced with difficult choices of how to allocate these scare resources while reducing overall demand. When examining the situation it is important to recognize what the consumption use splits are for these fuels in order to make effective decisions. Overall the energy US buildings consume for space heating and hot water is substantial, and technologies that help alleviate this demand may prove extremely wise investments.

[36] ConocoPhillips, Liquified Natural Gas (LNG)
[37] EIA, "Short-Term Energy Outlook" Table 8a, April 2006
[38]EIA, Country Analysis Briefs, United States, Natural Gas, November 2005
[39]EIA, "Annual Energy Outlook 2006" Natural Gas Demand

Building Heating & Hot Water Energy Use

The 81 million buildings in the US consume more energy than any other sector, including transportation and industry[40]. In 2005 54% of the nation's total natural gas consumption and 8% of its oil was attributed to buildings[41]. Emerging technologies are addressing many of the energy intensive uses within buildings including lighting, appliances, air conditioners and refrigerators with increased efficiency. Information on these applications is available from the Building Technologies Program at the DOE's office of Energy Efficiency & Renewable Energy[42]. The solar technology of topic is designed specifically to offset two of the most energy intensive uses in buildings, heating and hot water. Of the total energy consumed in this sector, 39.1% was used for space heating and 12.9% for hot water, a combined 52%[43].

There are many uses of oil and gas that have no practical alternatives. Heavy manufacturing, transportation, petrochemicals and medicines are just some of the many applications that are utterly dependent on these precious resources. As these fuels become scarcer in the coming decades these industries may have little choice but to pay the higher premium. Evolving technology for solar space heating and hot water production offers an alternative to curb building energy demand though.

The range of domestic hot water and room temperatures make them particularly applicable to solar thermal technology. The average building operates at 65°F and supplies hot water at 120°F. Commercially available and affordable technology is increasingly being used to collect and store solar thermal energy for these purposes. The

[40] http://www.eere.energy.gov/buildings/tech/index.html
[41] EERE, Building Energy Data Book 2005, Tables 1.1.7 & 1.1.8
[42] http://www.eere.energy.gov/buildings/tech/index.html
[43] EERE, Building Energy Data Book 2005, Tables 1.1.4

vast majority of the nation's developers and homeowners are unaware and unfamiliar with the developments in this industry. However, leading engineers of alternative energy and energy conservation technologies are demonstrating and proving the potential of these applications through systems solar thermal systems.

Solar Heating & Hot Water Technology

As a heating and hot water system the core design of the system, referred to in this report as 'Soltron', combines three thoroughly proven technologies: radiant heating, solar thermal collectors, and thermal energy storage. Figure 6 is a schematic of Soltron's first installation. When solar radiation beams from the sun a water/antifreeze solution is pumped through the solar collectors (Figure 6: top center, dark grey) and heated to temperatures ranging from 130°F to 245°F. The heated solution is then directed for one of three purposes. First, it can be transferred to the hot water tank (Figure 6: center, yellow) and used to heat the domestic hot water. Second, it can be pumped through the building's radiant heating panels (Figure 6: ceiling, orange) for indoor space heating. Lastly, if more heat is generated from the collectors than is used on demand it can be retained in the building's thermal energy storage unit (Figure 6: lower right box, orange).

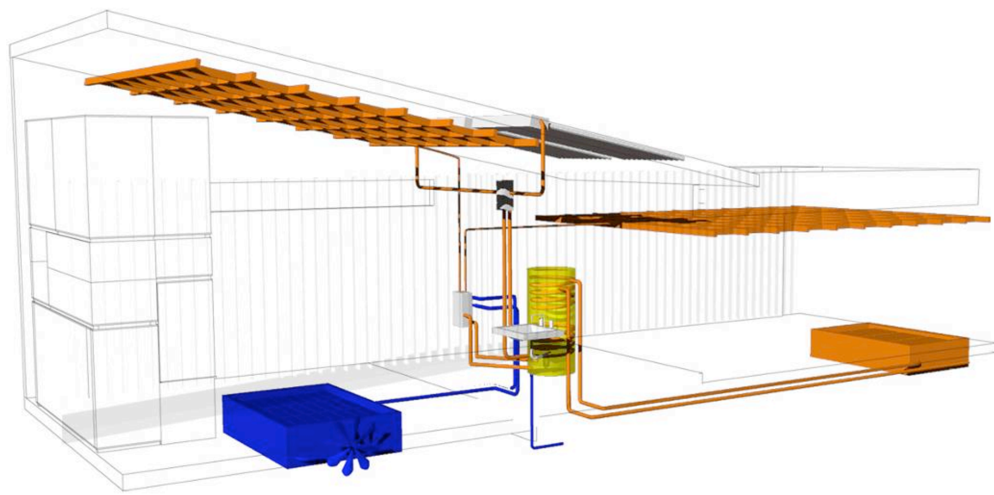

Figure 6 A schematic of the Soltron system in RISD Solar. The dark grey panels in the top center represent the solar collectors. The orange ceilings represent the radiant heating system. The orange box in the lower is the thermal energy storage unit and yellow tank stores domestic hot water. Source: Daniel Craven, Rhode Island School of Design, Department of Architecture

RISD Solar

The Figure 6 schematic shows Soltron's first installation *Rhode Island School of Design's* RISD Solar[44] project, which participated of the U.S. Department of Energy's 2005 Solar Decathlon[45]. The event challenged international collegiate teams to design, build, and operate an 800 sq. foot solar powered house on the National Mall. For first two weeks of October 18 universities demonstrated the latest in solar design and technology to representatives from the *National Renewable Energy Laboratories* (NREL) and thousands of visitors from the public. On November 2, 2005 the team testified before the *U.S. House subcommittee on Energy* in regards to Soltron's design and the possibility of its technology transfer into the building industry[46].

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44 solar.risd.edu/
45 http://www.eere.energy.gov/solar_decathlon/
46 http://www.house.gov/science/press/109/109-153.htm

Radiant Heating

Radiant floor heat is the fasting growing sector within the heating ventilation and cooling (HVAC) industry because it is highly efficient and offers a higher quality of comfort[47]. Currently the market is growing at an average rate of 19% per year[48].

The thermal comfort one feels standing in the sun on a cool day is an example of radiant heat. The sun's radiant energy does not heat the air directly; rather it heats objects of mass. This is why one might feel cool standing in the shade but warm in the sun, even when ambient air temperatures are exactly the same. Solar radiation transfers heat from the sun to bodies through electromagnetic radiation such as infrared radiation and light[49]. Radiant heating systems work in a similar fashion, emitting heat to cooler surfaces and objects surrounding them.

Radiant floors, illustrated in Figure 7, use entire flooring areas to distribute heat within a building. This allows for a consistently even heat delivery and eliminates drafts and 'hot spots' associated with conventional baseboard or dedicated vents systems. Occupants are quick to acknowledge the increased thermal comfort of the warm-feet, cool-head environment and enjoy the relative silence of its operation compared to forced air systems. Radiant heated floors are ideal for apartment dwellings because they are easily zoned by room and allow residents to place their furniture however they choose.

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[47] Watson, Richard & Chapman, Kirby "Radiant Heating and Cooling Handbook" McGraw-Hill Professional, 2002
[48] Mader, Robert "Hydronics Sellers Cautiously Optimistic" Contractor Mag, Januarya 25, 2005 < http://www.ncsu.edu/news/dailyclips/0105/012505.htm>
[49] Thomas, Randall, "Environmental Design, Second Edition" Routledge, New York, NY, 1999, pg. 11

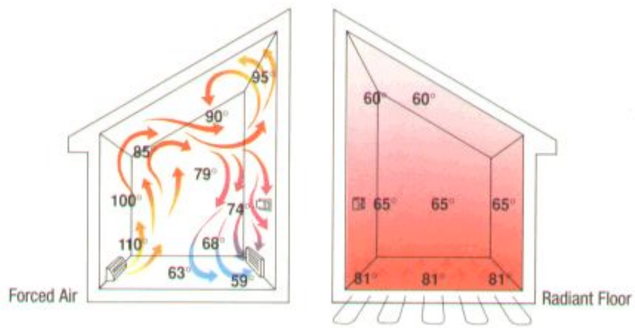

Figure 7 Contrasts the drafts of a forced air heating system versus the consistent temperatures of radiant heating

There are three general types of radiant floor systems, air, electric, and hydronic. Each of the three designs has a different means of generating and transferring the heat. Air floors are the least popular because the capacity of air to hold heat per unit of volume is roughly 1/4 that of water[50]. Thus 4 times more air than water is required to be forced through the flooring system to distribute an equal amount of heat. This increased volume requires a greater primary heat source and heavier fan equipment, resulting in higher levels of energy consumption and upfront mechanical costs. Electric radiant floor systems are highly effective at heating buildings, but are the most expensive to install and operate[51]. These installations are most common within upscale residential homes where the perceived comfort benefits of a radiant floor in spaces such as bathrooms and kitchens outweigh additional costs. Distributing heat via hot water or hydronics is the most cost effective and efficient means in new radiant floor installations[52]. Water has a high heat capacity and can be pumped throughout a network of floor pipes in a relatively energy efficient and silent method.

Hydronic floors are becoming the choice of more and more homeowners seeking radiant floor heating because of decreasing costs. The initial installation costs of these systems are dropping to become cost competitive with traditional forced air and

[50] http://www.exploratorium.edu/climate/glossary/heat-capacity.html
[51] http://www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12590
[52] Ibid

baseboard heaters, averaging between $4-$6 per sq ft[53]. This is occurring as advances in the necessary materials and technology allow the mechanical engineering and plumbing specialists to implement the system in a more timely and efficient manner.

The greatest development in the field has been the evolution of Crosslink PolyEthylene (PEX) piping in the plumbing supply industry, which is replacing traditional rigid copper piping at increasing rates. PEX is currently the most flexible and versatile piping available and can easily be bent around corners or other obstacles where traditional copper pipes require angled fittings. Using PEX for radiant floors significantly decreases the amount of time and materials installers need to weave pipes across a surface. Since fittings are the most common source of leaks in pipes PEX offers a more reliable system as well.

Solar Thermal Collectors

The greatest efficiency of the hydronic radiant heat comes from its ability to utilize solar energy as a heat source. Currently there are two technologies that heat water using solar energy, both of which are classified as solar collectors. Simply stated, collectors convert the sun's radiant energy into heat, which is then transferred to water. They have traditionally been used for domestic hot water and swimming pool heating, however as the use of hydronic radiant floors becomes more standard solar collectors are gaining an increased market share.

Flat plate collectors are the original and most common form of collectors. As the name suggests, they consist of a flat plate black absorber with internal adjacent tubes running through them. Solar radiation heats the absorber, which in turn heats the water

[53] Ibid

or water based solution running through the tubes. Generally these collectors heat water to approximately 180°F in ideal conditions[54]. However, in windier and colder climates much of the heat absorbed in flat plate collectors is lost to the external environment through conduction, causing the efficiencies to drop significantly[55]. As a result flat plate collectors are recommended primarily for domestic hot water and pool heating in consistently moderate to warm climates such as the American southwest.

A newer solar collector technology known as evacuated tubes can raise water temperatures between 150°F and 350°F year round, making them ideal for annual use in more seasonal regions such as New England[56]. These collectors encase the absorber within a clear exterior vacuum-sealed tube. As solar radiation penetrates the exterior tube the encased absorber converts it to heat, which can't pass back through the vacuum. The heat transfer of evacuated tubes functions somewhat differently from the flat plates in that water never comes in direct contact with the absorber. Rather, the absorber contains a heatpipe. As the fluid in the heatpipe warms its buoyancy increases causing it to rise. As it reaches the top of the pipe its heat transfers to water flowing perpendicularly across, cooling the fluid back down and maintaining a continuous cycle.

Thermal Energy Storage

In order to design an effective solar heating and hot water system that maximizes the potential of solar energy gain it is critical to have an efficient means to store excess heat for later use. This is due to the fact that the sun is not always shining when the demand for heat and hot water is greatest and vice versa. The vast majority of existing

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[54] http://www1.eere.energy.gov/solar/sh_basics_collectors.html
[55] http://www1.eere.energy.gov/solar/sh_basics_collectors.html#flatplate
[56] http://www.eere.energy.gov/buildings/info/components/waterheating/solarhot.html

solar hydronic heating installations utilize the sensible heat of water for thermal energy storage (TES).

While water has proven effective to some degree the IEA has acknowledged the need for better TES systems. Known as *Task 32* and documented in the handbook titled "Thermal energy storage for solar and low energy buildings," the concerned IEA taskforce addressed the following questions[57]:

> 1. Can we enhance existing water storage techniques for solar houses?
> 2. Can we beat water as a storage solution for a solar house in terms of performances?
> 3. Can we reach a factor 2 or 3 in the density of storage using chemical solutions?
> 4. Can we use a combined solar and chemical heat pump to lead to a higher solar fraction…?

The different storage technologies the group is currently investigating include chemical reactions, phase change materials, and water stores. The final report of the taskforce is due for release December 2006.

The most promising TES technology may be the recent commercialization of phase change materials (PCM). This technology stores thermal energy as latent heat in materials, offering more consistent temperatures in less volume and weight per unit of storage capacity. Latent heat is defined as the thermal energy released or absorbed during a change of state, in contrast to sensible heat released or absorbed during change of temperature**.** According to research done by the *Centre for Sustainable Engineering* based in the UK, "PCMs store 5 to 14 times more heat per unit volume than sensible storage materials."[58]

Until recently PCMs have been widely tested and researched by scientists and engineers, but were unavailable for commercial use. While the potential TES

[57] http://www.baseconsultants.com/IEA32/
[58] http://www.engsc.ac.uk/er/sustainable/index.asp

applications of the materials were well documented the challenge of consistently manufacturing the chemical compounds to change phase at a specific temperature proved extremely difficult. "In solar energy applications, sensible heat storage is more common, but there is active research in improved latent storage materials. Unfortunately, few inorganic or organic materials have yet been brought to a stage of practical application[59]. Although these compounds are fairly inexpensive, the packaging and processing necessary to get consistent and reliable performance from them is complicated and costly.[60]" However, as of January 2006 a new company based in the UK under the name of *EPS, LTD* now offers a line of 37 phase change compounds, ranging in phase change temperatures from minus 45F – +273F[61].

Implications

As a result of modern developments in the three core technologies combined in Soltron, the feasibility of efficiently utilizing solar thermal energy for space heating and hot water has never been greater. Evacuated solar tube collectors allow installations in seasonal climates to generate heat year round. The growing market share of hydronic radiant floors has created economies of scale and lowered first time installation costs to become competitive with traditional systems. Finally, the recent commercialization of Phase Change Material allows heat to be stored in a relatively cost and space efficient method that was previously unavailable.

[59] Phase Change Materials for Solar Heat Storage, US Department of Energy, Office of Energy Efficiency and Renewable Energy Reference Briefs, 2003.
[60] PCM Hot Water Storage: Enhancement of solar thermal energy storage performance using sodium thiosulfate pentahydrate of a conventional solar water-heating system
[61] http://www.epsltd.co.uk/

The challenge facing the industry of solar engineers now is finding suitable projects to install these systems. Currently, retrofitting existing buildings is cost prohibitive due to design constraints and mechanical space. If, however, the system is specified in the early planning stages of a new building or redevelopment project the installation is considerably more doable and cost effective. In addition, an extremely attractive federal income tax credit is now available which reduces the initial costs of the overall system and offers a quicker payback for the invested developer.

Renewable Energy Tax Incentives

The *Energy Policy Act of 2005,* created by the US Congress, increased federal income tax credits for solar energy projects. The program allows investors and owners of approved solar energy technologies to deduct varying percentages of a system's total cost from their overall federal tax burden. A publication produced in conjunction with the Solar Energy Industries Association (SEIA), titled *Federal Tax Incentives for Solar Energy*, highlights the eligibility of these tax benefits.

The federal tax incentives define two categories of installations, commercial and residential. The proposed installation at 1 Mashapaug St. constitutes a commercial tax credit, as it is an apartment dwelling greater than a duplex that will be owned and operated by OMNI Development Corp. The tax incentives available for commercial use are intended for larger projects and offer an unlimited credit compared to the $2,000 cap on residential.

Under the *Energy Policy Act of 2005* the incentive reads, "The commercial solar tax credit is 30% of the "tax credit basis" that a company has invested in "eligible property" that is "put into service" during 2006 and 2007. It is 10% of tax credit basis for property put into service in other years. A tax credit is a dollar for dollar reduction of an entity's Federal tax burden.[62]" Therefore OMNI Development Corp. will be able to claim a 30% tax credit of the total solar project's cost, including materials and installation, if the system is complete and operating by the end of 2007. SEIA recognizes the tax credit timeline between 2006-2007 is not a sufficient window to "substantially grow manufacturing or installations" and is seeking "to extend the tax credits for the next decade"[63].

Eligible Property

The SEIA report summarizes eligibility of solar thermal equipment[64]:

To qualify for the credit, equipment must be an integral part of the solar heating or cooling system. All equipment associated with a solar thermal system is eligible property for the credit except that which is designed for the use of non-solar power (e.g. a natural gas furnace that is used to augment the solar thermal system). However, pipes and ducts that are used to convey steam, hot water or heat from a furnace or hot water heater qualify for the credit if solar energy is the source of more than 75% of the steam, hot water or heat carried through them in the year the pipes and ducts are put into service. The test is done by looking at solar energy as a percentage of total energy used to generate the steam, hot water, or heat conveyed by the pipes and ducts.

There must be an allocation. Thus, for example, if 10% other energy is used in the year the pipes and ducts are first put into service, then the solar tax credit can be calculated on 90% of their cost. However, a dip in the solar energy use below

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[62] SEIA, Federal Tax Incentives for Solar Energy, January 27th, 2006, pg. 11
[63] SEIA, Federal Tax Incentives for Solar Energy, January 27th, 2006, pg. 4
[64] SEIA, Federal Tax Incentives for Solar Energy, January 27th, 2006, pg. 11-12

90% in any of the next four years would lead to the IRS' recapturing the tax credit claimed.

The credit available on the expenditures for the evacuated solar collectors and PCM thermal energy storage, including installation labor costs, will be fully applicable because these are directly associated with the solar thermal system. If the project is sized to meet 75% of the total annual heating and hot water demand with solar energy the radiant floor installation and domestic hot water plumbing costs will also be applicable for the 30% tax incentive. As this quota is not met by the specified soltron design it may be possible to claim the system provides 75% of the energy consumed for domestic hot water, allowing at least the hot water plumbing to be deductible.

Placed in Service

As noted before, the 30% commercial tax incentive is offered for projects "placed in service" between the years 2006 and 2007, after which a 10% incentive is available. The SEIA report summarizes the time guidelines as such[65]:

· The equipment must have been delivered and physical construction or installation on site must have been completed, although contractor personnel can still be at the site in support of startup and maintenance and completion of minor tasks like painting and attending to punchlist items.

· The taxpayer must have taken legal title and control of the equipment.

· The taxpayer must have the licenses and permits needed to operate it.

· Pre-operational tests must have demonstrated that the equipment can serve its intended function. (Other testing to determine whether the equipment can operate at the design capacity and to identify and eliminate defects can occur after the equipment is in service.) Testing is more important at projects that are integrated and assembled on site under contract as opposed to where an integrated device is merely purchased "off the shelf." Equipment bought off the shelf is usually

[65] SEIA, Federal Tax Incentives for Solar Energy, January 27th, 2006, pg. 13

assumed to be in workable condition.

OMNI Development Corp. will have to move fairly quickly in redeveloping the site and installing the solar thermal system to receive the full potential of tax benefits. If a decision is made to go ahead with the project developers should give time priority towards this purchase and installation. The system must be in operable condition by the end of 2007, however this does not mean the building must be occupied by tenants at this point in time.

If the project is not finished by 2007, OMNI can receive a 30% tax credit in the amount of the equipment purchased and installed before that point, and 10% for everything afterwards[66]. For example, if the purchase and installation of the evacuated tube collectors were completed by this deadline but the PCM thermal energy storage was not, OMNI would be eligible for 30% of the solar collectors cost and 10% of the PCM cost.

Ownership Structure of Project

Due to OMNI's status as a non-profit corporation they do not pay federal income tax and therefore must establish a partnership in order to use the available federal income tax credit. The SEIA report states, "Any owner that cannot use credits on a solar project because of an inadequate tax burden should explore either selling the project to and leasing it back from another company that can use the credits -- in which case the original owner could share in the tax incentives indirectly in the form of reduced rent -- or else

[66] SEIA, Federal Tax Incentives for Solar Energy, January 27th, 2006, pg. 22

bringing in an equity investor that can use the credits as a partner.[67]" In either scenario OMNI will need to get another entity with a sufficient federal tax burden to utilize the tax benefits. SEIA recommends that non-profit developers seek the consultation of experienced tax specialists to assist with the structuring of these deals. Due to the potential size of the commercial solar federal tax credits beneficiaries are allowed 20 years to carry the credit forward[68]. An employee of OMNI has suggested *National Equity Fund, Inc.*[69] may be an appropriate project partner as they have worked together in the past.

Accelerated Depreciation of Installation

In addition to the federal tax credit, OMNI's project partner would benefit financially from an accelerated depreciation of solar installations. According to IRS Publication 946 certain 'energy property' is depreciable within 5 years, and in some instances 50% is depreciable within the first year[70]. The publication identifies 'energy property' to include, "Equipment that uses solar energy to generate electricity, to heat or cool a structure, to provide hot water for use in a structure, or to provide solar process heat.[71]"

The total depreciation basis equals the original cost of the solar installation minus 50% of the federal tax credit. Therefore, if the Mashapaug installation cost $100,000, was completed before 2008, and OMNI's partner used the full 30% federal tax credit, they would be eligible to depreciate the system on the basis of $85,000 [100,000 –

[67] SEIA, Federal Tax Incentives for Solar Energy, January 27th, 2006, pg. 22
[68] SEIA, Federal Tax Incentives for Solar Energy, January 27th, 2006, pg. 25
[69] http://www.nefinc.org/
[70] Internal Revenue Service, 2005 Publication 946, pg. 17, www.irs.gov/pub/irs-pdf/p946.pdf
[71] Internal Revenue Service, 2005 Publication 946, pg. 17, www.irs.gov/pub/irs-pdf/p946.pdf

50%(100,000 x 30%)] over the course of 5 years. Similar to the federal tax credit and partnership structure a certified tax analyst should be consulted for maximum benefit from these federal incentives. According to the SEIA report, "For businesses, when combined with incentives for accelerated depreciation of solar equipment, these [federal income tax] credits help reduce the capital cost of new solar energy equipment by up to 60%.[72]"

Rhode Island Tax Incentives

The Rhode Island State Energy Office (RISEO) maintains a list of state energy programs and incentives on its website. Currently, Rhode Island has limited tax incentives for commercial solar heating and hot water systems. A 25% state tax incentive is available to residential installations and can be carried over to subsequent years[73], but no incentives are available for commercial purposes. The only established Rhode Island state tax incentive applicable to a commercial solar thermal system is an exemption from the state's 7% sales tax [74].

Rhode Island Renewable Energy Fund

The Rhode Island Renewable Energy Fund (RIREF) offers grants and assistance for renewable energy projects, however its current language generally restricts it to systems generating electricity such as wind turbines and photovoltaics. Erich Stevens is the manager of *People's Power and Light*, advertised on their website as 'Rhode Island's

[72] SEIA, Federal Tax Incentives for Solar Energy, January 27th, 2006, pg. 5
[73] RISEO, Renewable Energy Incentives, http://www.riseo.state.ri.us/programs.html
[74] http://www.taxadmin.org/fta/rate/sales.html

non-profit energy consumers' alliance'[75]. He is familiar with the RIREF and believes they will be very interested in the Mashapaug project. Erich suggested submitting a one to two page unsolicited proposal and highlighting the fact that this is a low-income housing project. A letter from Rhode Island Housing[76] acknowledging the redevelopment proposal is 'approved' as a low-income housing project should be included. According to Erich, the RIREF language includes clauses of dedication for low-income households and specifically for heating, but the fund has been presented with few projects to meet this criteria.

Soltron Breakdown

In order to estimate the costs, payback, and performance of a solar heating and hot water system a number of variables must be evaluated. The most important criteria is determining how efficient the building is at retaining heat. Once this is evaluated with local climate condition data the building's heat loss can be quantified. Heat loss is then used to estimate the amount of space heating necessary to maintain room temperature, which in combination with hot water demand determines the building's total heat load. At this point the size of the space heating system can be gauged and an appropriate solar collector installation is specified according to local levels of solar radiation.

[75] People's Power & Light, <http://www.ripower.org/PPL_index.htm>
[76] Rhode Island Housing, <http://www.rihousing.com/>

Heat Loss

Heat loss is the flow of heat from the contained space within a building to the outdoor environment. It occurs inevitably whenever outside temperatures are lower than the indoor temperature in accordance with the 2nd law of thermodynamics. The heat loss a building suffers depends on its design characteristics and local climate. Well-insulated buildings with low heat loss are known to have strong building envelopes. The thickness and insulative properties of the materials used in the building's exterior walls and roof, in addition to the quality of its windows and doors are all factors in the efficiency of the building envelope. Figure 8 shows the typical percentages of heat loss in a building.

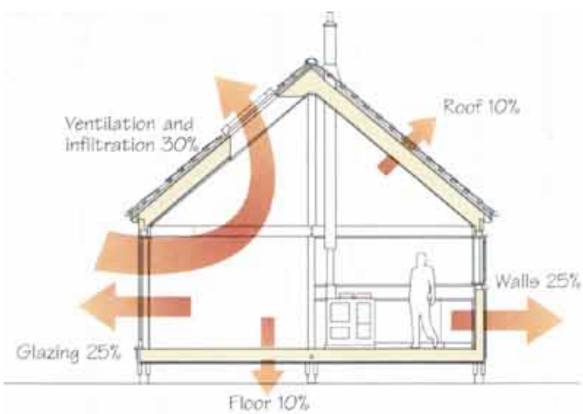

Figure 8 shows the typical heat loss percentages through different parts of a building.
Source: EERE

The National Renewable Energy Laboratories (NREL) publishes a series of data on climatic conditions for locations across the country. The '*Solar Radiation Data Manual for Flat Plate and Concentrating Collectors'* records monthly average temperatures and solar radiation levels over the course of 30 years from 1961-1990[77]. The selected locations of data collection include Providence, RI, providing valuable information for designing Mashapaug's solar heating and hot water system [Appendix 5].

[77] NREL, Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors, <http://rredc.nrel.gov/solar/pubs/redbook/>

Determining Mashapaug's heat loss is estimated using the average climatic conditions reported in NREL's Providence, RI data sheet. Heat is measured in BTUs, the unit of energy necessary to raise 1 lb of water 1°F. A building loses heat proportional to the difference between indoor and outdoor temperature, the greater the difference the quicker the heat dissipates. Thus a building set at room temperature (65°F) will lose two times more BTUs when it is 30°F colder outside versus 15°F.

Engineers use heating degree-days (HDD) to estimate indoor/outdoor temperature differentials for building heat loss assessments. An HDD equals the difference between each day's outdoor mean temperature and room temperature. For example, if the outdoor temperature averaged 30°F for a given day the HDD would be 35 (65°F -30°F). Using 30 years of data NREL has compiled the average number of heating degree-days per month for Providence, RI[78], shown in Table 1.

Table 1 Heating Degree Days per Month in Providence, RI. Source: NREL

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
HDD, Base 65°F	1,150	988	857	527	247	31	0	7	90	358	630	997	5,882

Once the number of heating degree-days per month is known the building's heat loss per HDD can be applied. Heat loss degree-days (HLDD) are measured as BTUs [lost] per Day per 1°F change in Temperature or in BTUs/Day/1°FΔT. The HLDD varies depending on the quality of the building envelope; those with stronger envelopes will have a lower HLDD and are thus more energy efficient.

[78] NREL, Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors, http://rredc.nrel.gov/solar/pubs/redbook/ (Degree Days Base 18.3°C x 1.8 = Degree Days Base 65 °F)

Gauging Mashapaug's precise heat loss requires a sound background in building science and engineering. As this project is proposed to be a standout building in energy efficiency it is assumed its redevelopment will incorporate advanced insulation techniques with high performance windows and doors. Combined, these priorities will limit the infiltration of outside air and conductive heat loss.

Bill Thomas has stated on the Mashapaug project, "I am willing to bet with proper insulation techniques, and proper windows, you can get the heat loss in that building down to less than 250,000 BTUH [Btu per hour] on a design degree-day[79] [0°F] (6,000,000 Btu/Day).[80]" This figure equates to a HLDD of approximately 92,300 Btu/Day/1°FΔT for the entire building, dividing the design 6,000,000 Btu/Day by the 65°F ΔT.

USA Solar is a company that specializes in the consultation, design and installation of solar hydronic heating systems[81]. It is owned and managed by Peter Biondo in Sedona, AZ. Biondo frequents many solar conferences around the country offering workshops in solar heating. In his Workshop Guidebook he compares the heat loss of buildings with varying energy efficiencies (heat loss) in Btu/hr/1°F/sq. ft floor area, shown in Table 2, allowing those less skilled in the art of building science and engineering to better estimate heat loss[82].

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[79] Design Degree-Day: Coldest day of year for which the heating system in designed, 0°F in Providence, RI

[80] Bill Thomas, Arden Engineering mechanical engineer, personal correspondence, 2/24/06

[81] USA Solar, Peter Biondo, http://www.usasolar.net/index.htm

[82] USA Solar, Peter Biondo, Solar and Radiant Heating Systems Workshop Guidebook, Heat Loss Comparisons, pg. 3

Table 2 Heat Loss Estimates per Sq. Foot of Buildings. Source: USA Solar

Energy Efficiency Performance per Square Foot Floor Area	
Super Insulated	.20 - .25 Btu / hour / 1°F ΔT / 1 sq ft floor area
Average Insulated	.26 - .30 Btu / hour / 1°F ΔT / 1 sq ft floor area
Low Efficient	.31 - .35 Btu / hour / 1°F ΔT / 1 sq ft floor area
Poor or Designer	.36 - .40 Btu / hour / 1°F ΔT / 1 sq ft floor area

According to Bill Thomas's assessment, the 14,240 sq. ft Mashapaug redevelopment should operate with a heat loss of approximately .27 Btu/hr/1°FΔT/1sq.ft, a performance Peter Biondo would rate as 'Average Insulated'. This rating seems appropriate for the site, given it is a 19th century mill building foundation and structure that will be redeveloped with 21st century windows, doors, roofing and insulation.

Heating Load

Once the building's heat loss degree-day and its climate's monthly heating degree-days are known the building's monthly heat load can be evaluated. The heat load is the amount of heat, measured in BTUs, needed to maintain room temperature within the building for a given period of time. For each month of the year the heat load is calculated by multiplying the Heat Loss Degree-Day (92,300 Btu/Day/1°FΔT) by the number of Heating Degree-Days.

Hot Water Load

Mashapaug's domestic hot water will also require a significant input of energy. OMNI's redevelopment proposal calls for, "an apartment dwelling suitable for 40 residents[83]". At a domestic hot water (DHW) consumption rate of 20 gallons per day[84], the average use will be 24,000 gallons/month. The temperature of the incoming municipal water averages 55°F over the course of the year[85] and must be heated to 120°F, requiring a ΔT of 65°F. At 8.33 Btu/gallon/1°F ΔT for water, Mashapaug's monthly DHW will average approximately 13,000,000 Btu.

Combined Heating and Hot Water Load

The total monthly heat loads for the building can now be calculated by adding the monthly space heating load and the domestic hot water load together. This data, shown in Table 3, is critical for determining the energy necessary for heating and hot water and also for evaluating the performance and returns on any proposed solar thermal installation.

[83] Matthew Willse, OMNI Development Corp., personal correspondence, 3/18/06
[84] http://www.absn.com/akwarm/AkWarmUpdate.cfm
[85] Fred Crosby, Providence Water, personal correspondence, 2/27/06

Table 3 Mashapaug's Total Heat Load per Month Breakdown

	HDD Base 65°F	HLDD (Btu/Day/1°FΔT)	Space Heat Load (Btu)	DHW Load (Btu)	Total Heat Load (Btu)
January	1,150	92,300	106,145,000	13,000,000	119,145,000
February	988	92,300	91,192,400	13,000,000	104,192,400
March	857	92,300	79,101,100	13,000,000	92,101,100
April	527	92,300	48,642,100	13,000,000	61,642,100
May	247	92,300	22,798,100	13,000,000	35,798,100
June	31	92,300	2,861,300	13,000,000	15,861,300
July	0	92,300	0	13,000,000	13,000,000
August	7	92,300	646,100	13,000,000	13,646,100
September	90	92,300	8,307,000	13,000,000	21,307,000
October	358	92,300	33,043,400	13,000,000	46,043,400
November	630	92,300	58,149,000	13,000,000	71,149,000
December	997	92,300	92,023,100	13,000,000	105,023,100

Solar Gain Factors

The solar radiation available for thermal energy collection varies from region to region according to latitude and climate conditions such as temperature and cloud cover. Therefore, NREL's '*Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors*'[86] is necessary to evaluate the expected performance of solar thermal installations. Although Mashapaug's system is specified to use evacuated tube collectors,

[86] NREL Data manual produced in 1994, before evacuated tube collectors were commercially available

not flat-plate or concentrating, the data in this manual contains all the essential information.

The NREL manual lists average monthly solar radiation in kWh/m^2/day, which must be multiplied by 317.2 to convert it into BTUs per sq. ft[87]. To maximize the solar radiation gain in winter months, when the building's heat load is greatest, the collectors should be fixed facing south at an angled tilt equaling latitude (42°) + 15°. The additional 15° is to compensate for the sun's path tracking lower in the sky during winter months. The proper NREL data to use in evaluating Mashapaug's solar thermal system is under the section titled 'Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt' for 'Latitude + 15'.

Before the solar gain can be calculated the total aperture[88] of the collector array must be determined. After reviewing the dimensions and southern exposure of Mashapaug's 4300 sq. foot roof [Appendix 7] Bill Thomas estimated 400 evacuated tube collectors would maximize potential solar gain[89]. Additional collectors could be placed in other locations, but this would raise the price of the project significantly.

The 400 tubes are specified as Sunda Seido 5- 16 tube collectors. Sunda is a Chinese company affiliated with the Beijing Solar Energy Research Institute, the 'largest and most highly acclaimed in the country' according to their website[90]. The company is known in the solar industry as a premier supplier for quality, efficiency and affordability.

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[87] NREL, Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors, Unit Conversion Factors, http://rredc.nrel.gov/solar/pubs/redbook/HTML/conversn.html
[88] Aperture: Area in which solar radiation enters the collector
[89] Bill Thomas, Arden Engineering mechanical engineer, personal correspondence, 2/24/06
[90] http://www.sundasolar.com/

Mashapaug will use 25 manifolds of the Seido 5 -16, which house 16 tubes each. The net aperture per manifold amounts to 38.75 sq. ft[91], totaling an array area of 968.75 sq. ft. Assuming an annual average efficiency of 65%[92] from the evacuated tube collectors, the net solar gain of the entire installation is estimated on a monthly basis in Table 4 and correlated against the monthly heat load in Figure 9.

Table 4 Mashapaug's Monthly Solar Gain with Soltron Design

	Solar Radiation (Btu/sq ft/day)	Collector Aperture (sq ft)	Average Collector Efficiency	Total Solar Gain (Btu/Array/Month)	Total Building Heat Load (Btu)
January (31 days)	1142	968.75	65%	22,292,197	119,145,000
February (28 days)	1332	968.75	65%	23,484,825	104,192,400
March (31 days)	1459	968.75	65%	28,480,136	92,101,100
April (30 days)	1459	968.75	65%	27,561,422	61,642,100
May (31 days)	1491	968.75	65%	29,104,786	35,798,100
June (30 days)	1491	968.75	65%	28,165,922	15,861,300
July (31 days)	1523	968.75	65%	29,729,436	13,000,000
August (31 days)	1523	968.75	65%	29,729,436	13,646,100
September (30 days)	1491	968.75	65%	28,165,922	21,307,000
October (31 days)	1396	968.75	65%	27,250,356	46,043,400
November (30 days)	1047	968.75	65%	19,778,484	71,149,000
December (31 days)	983	968.75	65%	19,188,467	105,023,100

[91] Sunda net aperture
[92] Solartechnik Prüfung Forschung SPF (Switzerland), Solar Collector Factsheet SPF-Nr. C690, 11/25/05

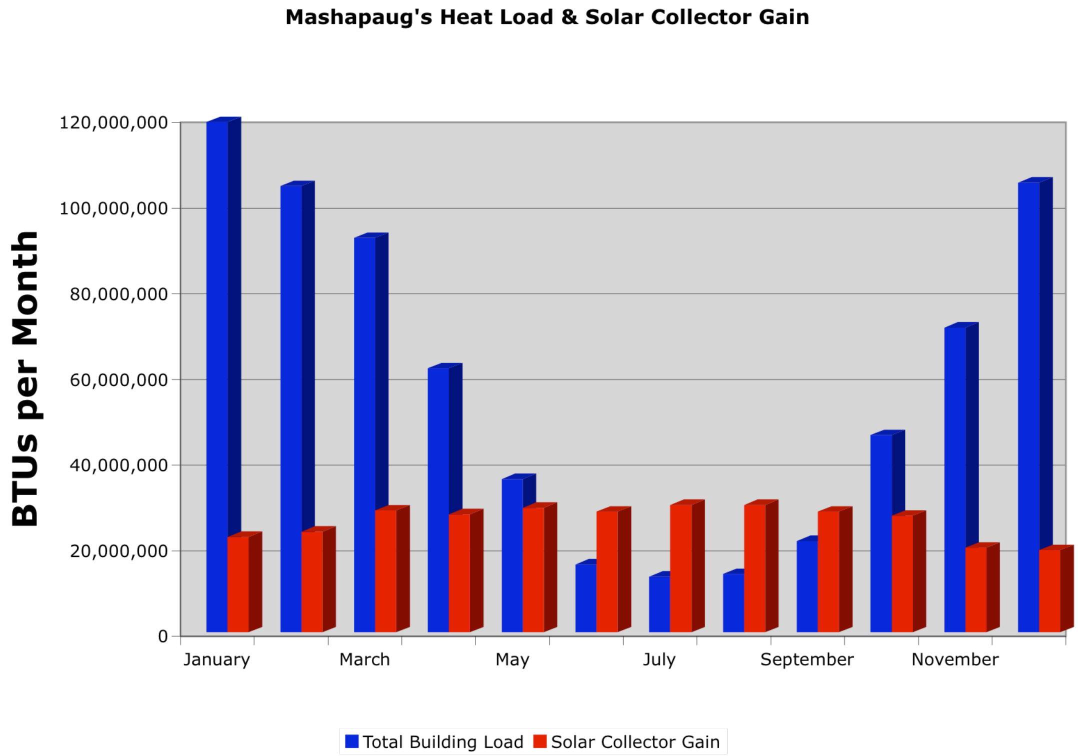

Figure 9 Shows Mashapaug's Monthly Total Heat Load Compared to Soltron's Solar Gain

Solar Savings

The amount of energy the solar collectors contribute to the total building heat load is known as the solar savings, and is shown on a monthly basis for Mashapaug in Figure 10. This is one of the most important criteria for estimating the performance and economics of any solar energy system. Solar Savings is generally calculated as a percentage, which can later be extrapolated into dollar savings according to energy prices.

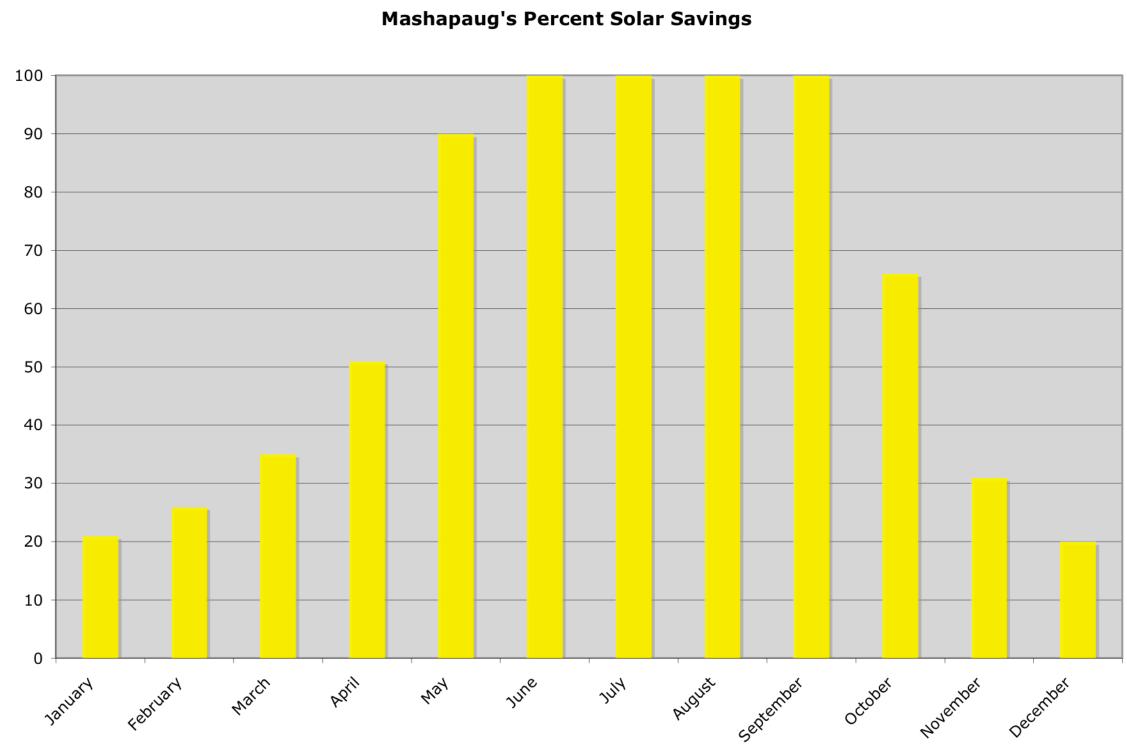

Figure 10 Represents the Solar Savings Soltron will deliver to Mashapaug as a Percentage of Total Heat Load

It is important to note that the maximum percentage savings for any given month cannot exceed 100%. BTUs generated during summer months in excess of the building's heat load are not designed to be stored for later long-term use according to the specification of Mashapaug's design. However, as the cost of PCM thermal energy storage comes down and energy prices rise, retaining the extra heat generated during summer months for long-term use will become more economical.

Building Heat Load Energy Expenditures

Increasingly the heating fuel choice of new buildings throughout the northeast has been natural gas. In 2004 73% of all new residences were constructed to heat with natural gas, while only 23% opted for oil heat and the remaining 4% for electric[93]. This represents a substantial shift in trends from 30 years prior when only 15% of new houses chose natural gas[94]. Accordingly, it is assumed that OMNI would use natural gas to as the primary fuel for space heating and hot water at Mashapaug.

As previously reported the natural gas industry is facing severe supply issues coupled with an ever-growing demand from new buildings and power plants. The construction of new LNG terminals may offer some relief to the market, but these will most likely only offset a decreasing supply in region at best. 2005 witnessed record high prices, and avoided a total supply and price crisis only by a mild winter[95]. It is important to understand the trends governing the natural gas market in order to fully appreciate the potential a solar heating and hot water system may have on fuel cost savings.

In an effort to best analyze the economics of Mashapaug's proposed solar system, it is conservatively correlated with a consistent natural gas price from December 2005. At this point the cost of delivered gas was $1.82 per Therm[96] (100,000 Btu). Applying the monthly heat loads of the building to the cost per Therm of natural gas gives an accurate estimate of the heating and hot water energy costs of a 100% conventional natural gas system. Just as the efficiency of the solar collectors was considered, the average 80% efficiency[97] of new boilers to convert natural gas into heat is too. Figure 11 graphs the monthly energy expenditures for heating and hot water in Mashapaug. At a consistent price of $1.82 per Therm OMNI would pay approximately $16,000 a year for natural gas.

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[93] US Census Bureau, Manufacturing Mining and Construction Statistics, Type of Heating Fuel Used in New One-Family Houses Completed, pg. 2
[94] US Census Bureau, Manufacturing Mining and Construction Statistics, Type of Heating Fuel Used in New One-Family Houses Completed, pg. 2
[95] Stone, Brad "How to Beat the Big Energy Chill" Newsweek, November 2005
[96] EIA, Short-term Energy Outlook, Monthly Price Data, Regional Natural Gas Prices, New England, Commercial
[97] http://www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12530

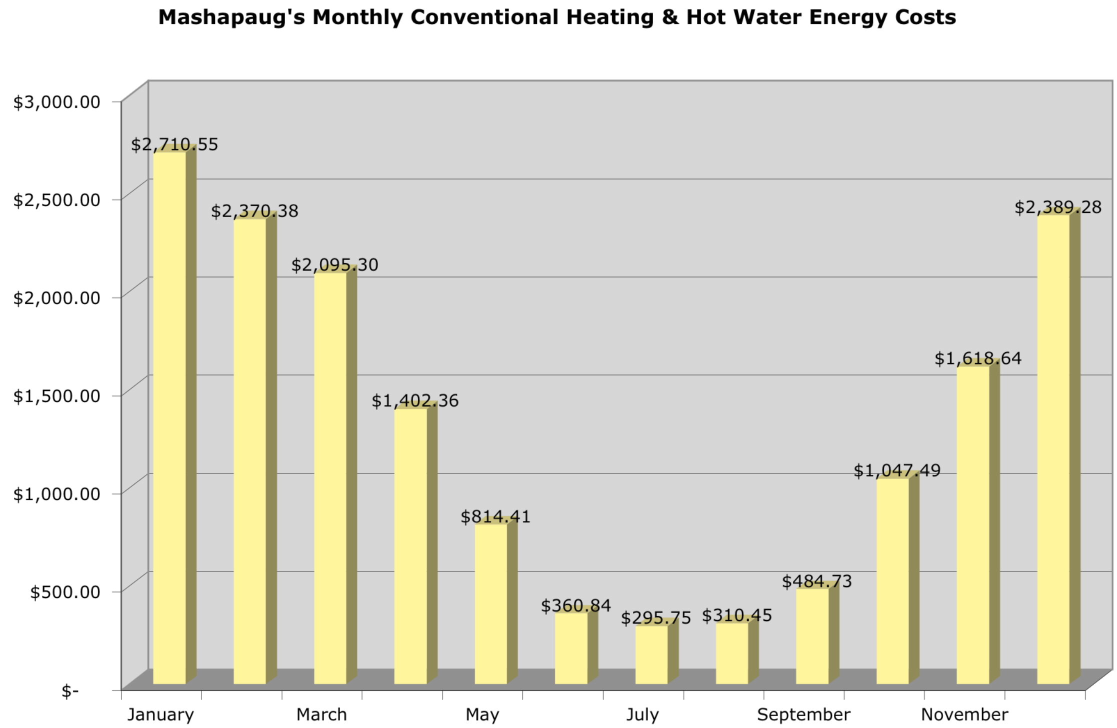

Figure 11 Mashapaug's Total Monthly Heat Load Converted into Dollars Figures at $1.82 per Therm Natural Gas without Soltron Installation

Solar Energy Dollar Savings

Using the same methodology for energy expenditures, the solar energy savings is converted into dollar savings in Figure 12. The monthly savings are greatest in the spring and fall when the solar radiation in Providence, RI is strong and enough heating degree-days exist to utilize all the BTUs generated from the collectors. During the summer months the savings decreases because the BTUs are used only for domestic hot water. However, on an annual basis the savings are considerable, amounting to $5,937 per year assuming a stable price of $1.82 per Therm natural gas. As natural gas prices rise in the coming years throughout the northeast the savings will increase in proportion.

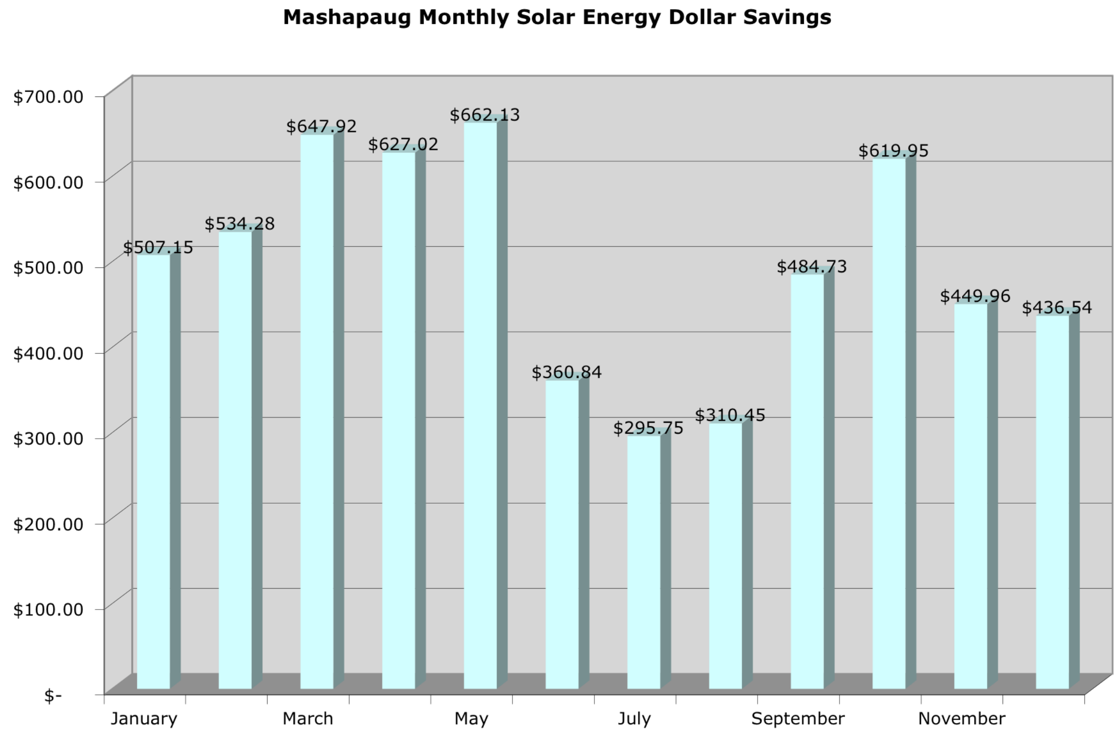

Figure 12 Monthly Energy Savings Soltron will provide Mashapaug at $1.82 per Therm Natural Gas

Solar Installation Costs & Payback

Although the proposed solar thermal system for would offset a considerable amount of the energy Mashapaug consumed, ASHRAE requires that all commercial buildings with solar installations be engineered with full-scale 'backup' systems. In the event of an extended winter period with minimal solar radiation the boiler needs a capacity to provide the building with all of its space heating and hot water needs. Thus, although the building would have alternative thermal energy capacity, no savings will be generated from a reduced boiler facility.

The solar installation will be an additional up front development cost to OMNI and its partners that will pay itself back solely through energy savings. The additional costs are broken down into two categories, materials and installation. Quotes were taken from authorized dealers of the proper materials and installation costs were conservatively estimated according to the skills and time required for each task.

Materials

- **Evacuated Tube Solar Collectors**
  - 25 *Sunda Seido 5-16s*
  - Authorized Dealer: Phoenix Energy Supply, Auburn, NY
  - Total: $31,266 (shipping included)

- **Phase Change Material TES**
  - 2.5 Million Btu storage capacity
  - Phase change temperature: 136°F
  - 490 cubic ft, *Plus Ice E58*
  - Authorized Dealer: EPS Ltd, Yaxley, UK
  - Total: $38,346 (shipping included)

- **Thermal Storage Tank for PCM**
  - 530 cubic ft
  - Authorized Dealer: EPS Ltd, Yaxley, UK
  - Total: $24,926 (shipping included)

- **Solar – Radiant Floor & DHW Tie-In Fittings**
  - Valves, couplings, manifolds, sensors, pipes
  - Total: $5,000 (estimate)

Installation

- **Solar Collector Flat Roof Installation**
  - 2 man hrs per collector unit, 25 units
  - $50 per hour
  - Total: $2,500 (estimate)

- **PCM & Thermal Storage Tank Installation**
  - 5 man hrs
  - $100 per hour
  - Total: $500 (estimate)

- **Solar – Radiant Floor & DHW Tie-In Installation**
  - 50 man hrs
  - $100 per hour
  - Total: $5,000 (estimate)

Total Solar Materials & Installation: $107,538

Solar Payback Period

- Total Materials & Installation: $107,538
- Federal Income Tax Credit (30%): $32,261
- Net Solar Cost: $75,277
- Annual Energy Savings: $5,937
- Annual Solar Savings: 37.5%
- Simple Payback: 12.7 years

After all costs of material and installation labor are considered, OMNI can anticipate a simple payback on their investment in 13 years or less, and an approximate solar savings of 37.5%. Due to Soltron's limited moving parts (hydronic pumps) it won't be subject to heavy wear and tear. It is assumed it will require minimal maintenance over the course of its estimated 25-year lifespan. In this timeframe, after the system has paid for itself, OMNI can expect an additional savings of six figures in energy expenditures over the course of the system's life.

Discussion

Currently the U.S. Congress is intensely scrutinizing the energy industry for price gouging gasoline while enjoying record high profits[98]. However, rising fuel costs is the most effective catalyst for popular mentality shift towards energy conservation and alternatives. Until these higher prices initiated conversation, the average American was largely unacquainted with the limits facing oil and gas supplies, or even conscious of 'America's addiction to oil' in the words of President Bush. Today on the other hand, few can dismiss the circumstances as insignificant or refute the need for alternatives.

Many are aware of President Bush's recent campaign towards domestic ethanol production, a hydrogen fuel economy, and his discussion of raising the Corporate Average Fuel Economy (CAFE) standards for the nation's automakers. These issues are often reported on in the media as methods to reduce American dependence on 'foreign oil'. The transportation sector is a highly sophisticated, energy intensive network that needs addressing from the top on down. However, the magnitude and scope of these

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[98] FIALKA, J. J. "House Backs Bills On Gas Gouging, Refinery Permits" Wall Street Journal. May 4, 2006

programs will take decades to develop before any results will be realized. Unfortunately, the energy ‘crisis’ needs solutions to be implemented now, not 10 years from now. Americans need to witness and be exposed to the workings of alternative energy sources before any industry growth will occur. The solar energy savings of Soltron offer just that.

Implementing Soltron technology offers far greater rewards than the calculated energy dollar savings at 1 Mashapaug St. From a macro perspective this project represents the ability for a relatively small non-profit corporation to lead the local building industry in the use of alternative energy. A building in Providence, RI that’s offsetting over 1/3 of its natural gas demand in a cost effective method will set the precedent for many more to come. While the overall energy conservation this single project could contribute to the grander energy issues is negligible, a successful development example that local policy leaders could reference would be invaluable.

Although Soltron’s model is proposed for a building being completely redeveloped in this report, retrofits of existing buildings are extremely possible without heavy renovation. Modular hydronic radiant floor systems, which cover and convert existing floors for heat delivery relatively easily, are readily available. Similarly, equipping domestic hot water systems with solar collectors has been in practice for decades. Therefore the macro vision of this system includes its implementation into the millions of buildings already developed throughout the country. In Rhode Island alone this would offer noteworthy reductions in oil and gas consumption.

In 2005 19 billion cubic feet of natural gas was delivered to Rhode Island's residential sector[99], primarily for heating and hot water. Hypothetically, if one out of every four residencies in state had or could create adequate southern exposure to properly install Soltron, 4.75 billion cubic feet could be offset by solar. However, extrapolating Mashapaug's 37.5% annual solar savings rate would yield a more accurate estimate, leaving 1.8 billion cubic feet to be conserved, or 9.5% of the total residential sector's demand. This isn't to say it wouldn't be an extremely capital intensive goal, but it's and should be considered as such. Prices of material and labor per installation would surely fall dramatically with economies of this scale.

Regions throughout the west, southwest, and greater northeast are prime prospects for Soltron systems. Although Figure 13 only portrays the payback period of solar hot water, the information can be used to evaluate available solar energy around the country as well. Darker areas on the map with quicker paybacks for solar hot water correlate directly with regions of higher solar radiation. Accordingly, California appears to receive the highest levels in the country, making Soltron's foreseeable solar savings percentage even greater out there. The potential is large, considering California's residential sector consumed over 508 billion cubic feet of gas in 2005[100].

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[99] http://tonto.eia.doe.gov/dnav/ng/ng_cons_sum_dcu_SRI_a.htm
[100] http://tonto.eia.doe.gov/dnav/ng/ng_cons_sum_dcu_SCA_a.htm

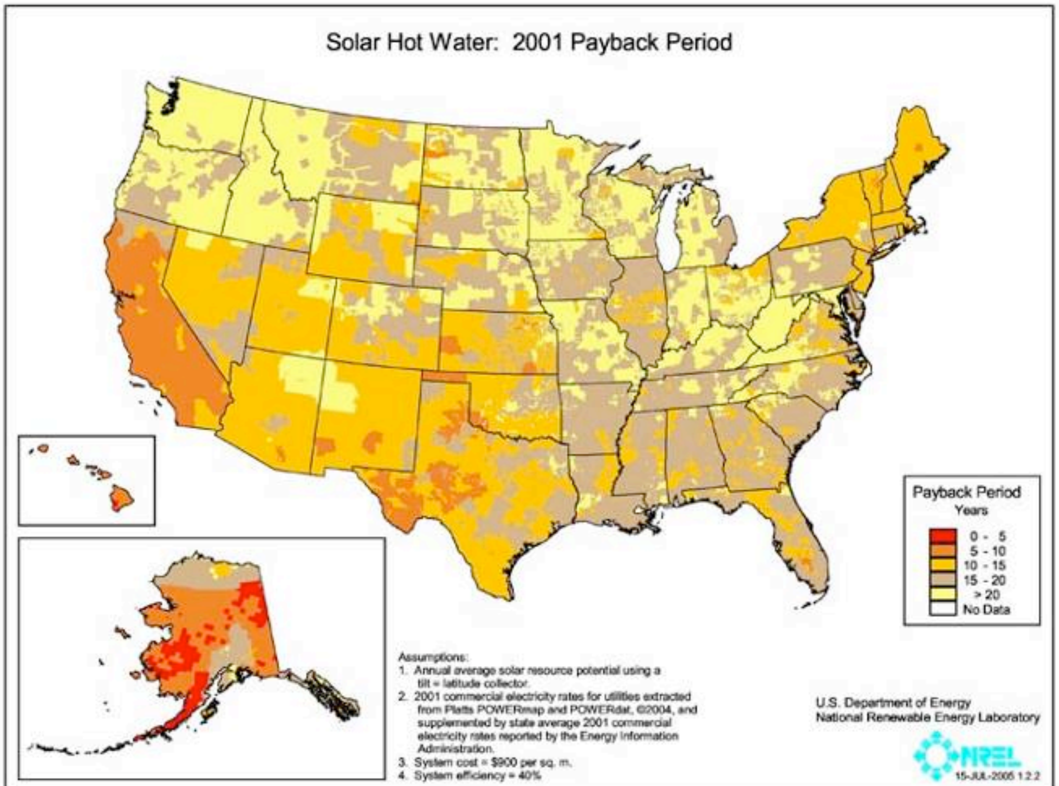

Figure 13 Solar Hot Water Payback gives insight into Soltron Performance around country. Source: NREL

In order to effectively mitigate the consequences of rising fuel costs and declining supplies approaches need to vary region to region according to local resources and energy end uses. The leadership from the federal government will be crucial in the coming years, however they will not be able to craft a single master plan. In order to implement effective conservation methods and alternative energy programs they must be designed at the local level.

The Northeast, West and Southwest are suitable for effective solar implementations, which can effectively curb significant demand. The Midwest may benefit more from wind power and investments in ethanol agriculture. Others still may choose to develop geothermal, hydro, or wave power resources. No matter what the method is, the conversations of alternative energy solutions need to be trickling down to where the solutions will be engineered. The federal government will be vital in providing the policy and financing of sectors as complicated as transportation, but the energy demand chain is simply too large for it to come up will all the solutions.

Although alternative energy and efficiency technologies have been developing for the past decades largely without government incentive, national priority must be given to continually developing this industry. At the very least, the U.S. congress must renew legislation for the 30% tax credit available to renewable energy technologies. Federal policy should insist local governments reduce energy demands while developing alternative sources consistent with available resources.

Conclusion

Soltron technology offers OMNI Development Corporation a very attractive opportunity to invest in energy savings and build on its community-oriented mission. Gauging the return on any alternative energy investment is difficult because the time it takes to recoup the costs depends on the volatile energy market. At the price of natural gas in December of 2005, OMNI can expect to recover the full cost of the system in less than 13 years. However, the current prices in the natural gas market are expected to continue north and OMNI will most likely enjoy an even quicker return.

The timing of the Mashapaug redevelopment couldn't be better for a Soltron installation. The tax incentives, market signals, local engineering expertise, attractive payback and technology are all present. As a responsible developer, this is the opportune time for OMNI to begin developing properties with appropriate energy technologies. In the words of Bill Thomas, Mashapaug has the potential be a ‘standout project’ and model to all.

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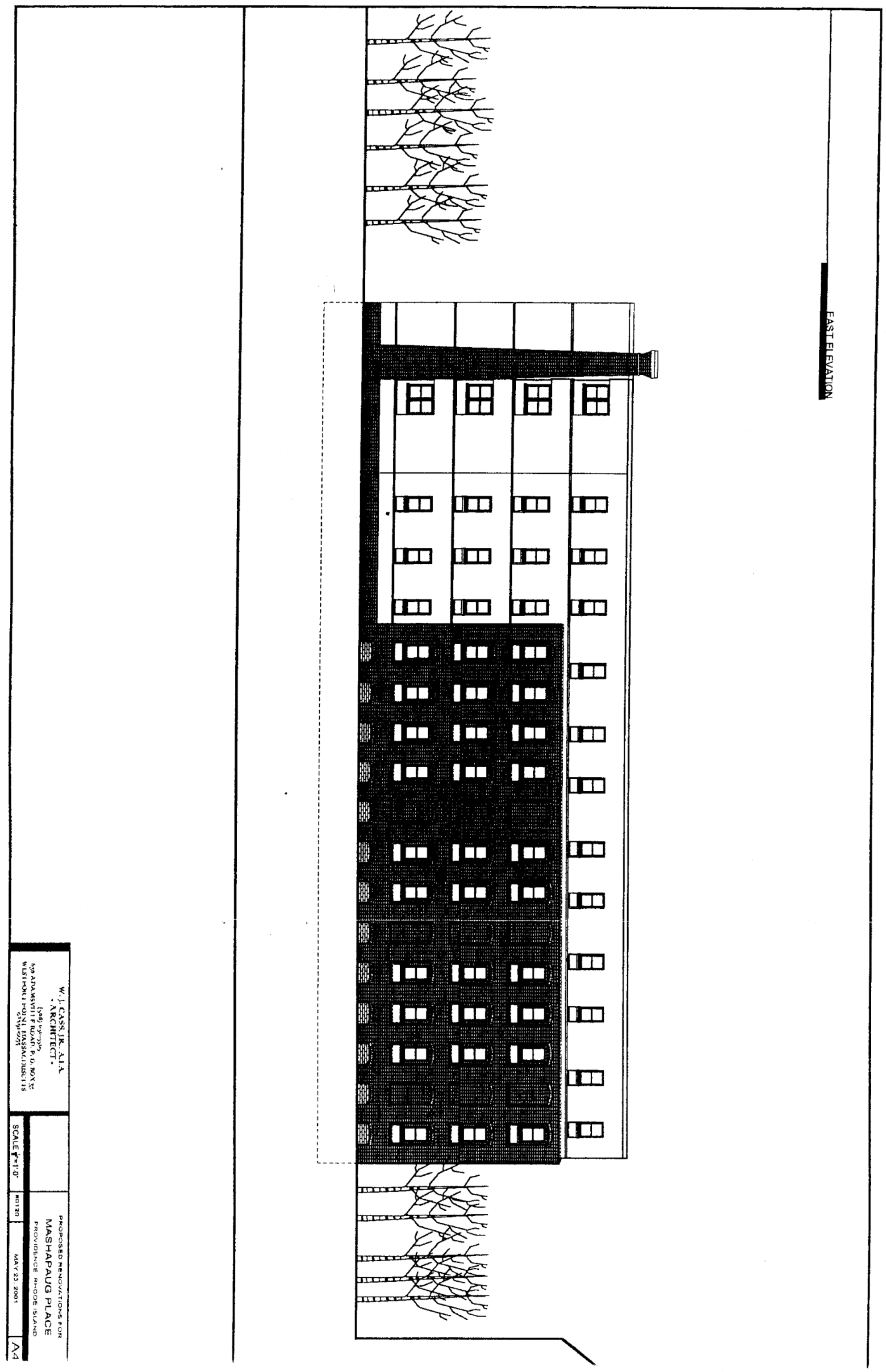
Appendix 1

Rendering of FHA's Proposal for Mashapaug Redevelopment with Addition. May 2001


EAST ELEVATION
PROPOSED RENOVATIONS FOR
MASHAPAUG PLACE
PROVIDENCE RHODE ISLAND
MAY 23 2001
A4

Appendix 2

Letter to HUD Addressing Environmental Assessment of Mashapaug Property. May 2001

EQUAL HOUSING OPPORTUNITY

FEDERAL HOUSING ASSOCIATES

CENTRAL OFFICE	REGIONAL OFFICE
1107 - 11th ST. N.W.	P.O. BOX 8171
WASHINGTON, DC 20006	CRANSTON, RI 02920
(202) 682-5821	(401) 942-1666

IN REPLY REFER TO:

May 24, 2001

Mr. Joseph Crisafulli
U.S. Department of Housing and
Urban Development
10 Weybosset Street
Providence, Rhode Island

Re: Overview of Environmental Assessment

Dear Mr. Crisafulli,

We have completed an Environmental Site Assessment Phase 1 and Phase 11 on the 1 Mashapaug Street, here in Providence. We have also developed a plan for containment of the hazards found on the site. The materials examined show the likely source of contamination as coal for heating purposes.

This building was constructed in 1882 and has a history of manufacturing and commercial uses. According to my engineer probably 99% of properties in this category have some type of coal use storage contamination or lead based paint contamination.

Our remediation plan to manage, isolate and control is also included in the Phase 11 and SIR or Site Investagation Report. These reports also evaluate alternatives and offers the best recommendation. These reports have gone through and initial review by the governing agency, DEM. It came back with two very minor questions or inquiries which were immediately answered and we are waiting daily for response.

We fully expect to have the DEM remediation approval letter in hand along with the estimate for clean up by the June 25th deadline date.

Thank you for your consideration and we look forward to developing this site for this much needed housing in this neighborhood.

Very truly yours,

Bernard Gemma
President

Appendix 3

Letter addressing remediation plans and costs for Mashapaug. May 2001

DiPrete Engineering Associates, Inc.

75 SOCKANOSSET CROSSROAD
CRANSTON, RI 02920
TEL (401) 943-1000
FAX (401) 464-6006

May 25, 2001

Federal Housing Associates
P.O. Box 8171
Cranston, RI 02920

Subject: AP 43 Lots 956-959, 989 - Mashapaug Street, Providence,

Dear Mr. Voccola:

The following construction estimate to implement the proposed remediation and management of contaminated soils on the property is provided based on the following scope of work:

1. Importing 1' minimum of clean granular fill over all exposed soil surfaces, whether they will end up paved or unpaved when the Site is redeveloped. This excludes any soils underlying the existing building because these provide an adequate barrier to prevent contact with future occupants and therefore require no additional fill.
2. Installing a geotextile fabric on top of the contaminated soils and below the 1' of clean fill. The barrier is intended to serve as a physical and visual barrier for any future work on the Site that may expose contaminated soils. A detailed work plan will dictate how future work onsite may be conducted so as to protect human health and welfare.

Estimated Costs:

- Providing 1' clean granular fill over an estimated 36,000 square foot area requires approximately 1,330 cubic yards of material. Assuming $9/cubic yard, the total is estimated at $11,970.
- Providing a nonwoven geotextile filter fabric (AEF Geotextile Model 1680 in lime green color) at a cost of $1.50/square yard. For an estimated coverage area of 4,000 square yards, the total is estimated at $6,000.
- The total estimated costs for goetextile and soil cap is $17,970

Please feel free to contact me directly with any questions regarding this estimate.

Sincerely,

DiPrete Engineering Associates, Inc.

Kevin C. Morin, PE

APPENDIX 4

Norwegian Oil Production

In 2003 Norway was exporting 3 mbd, roughly 90% of its total production. However, by August of 2005 the EIA advised, "Most of the country's flagship oil fields have peaked, with production remaining flat or declining slightly."[101] As of October 2005 Norway's production fell to an average of 2.5 mbd. Figure 14 depicts Norway's drop in production in the last fours years.

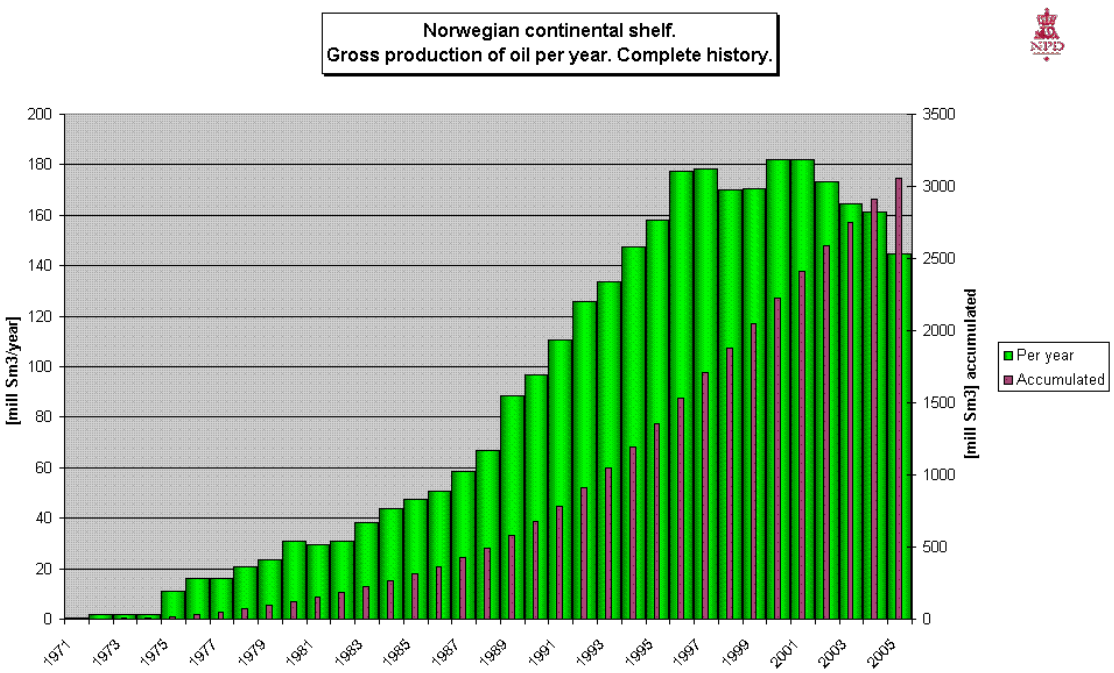


Figure 14 Norway's annual oil production peaked in 2002 and has been steadily declining since. Source: Norwegian Petroleum Directorate

Mexican Oil Production

[101] EIA, Country Analysis Briefs, Norway, Oil, August 2005

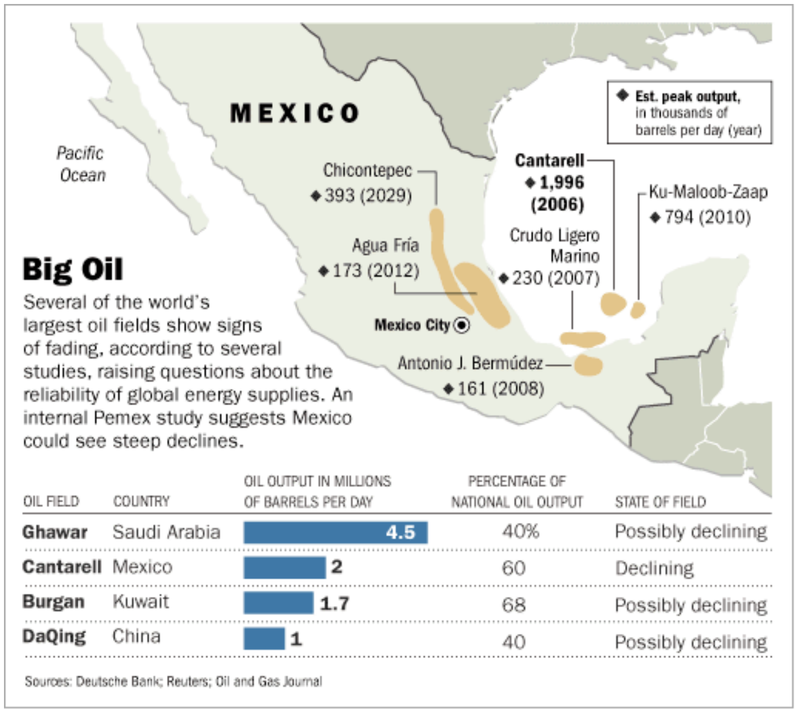


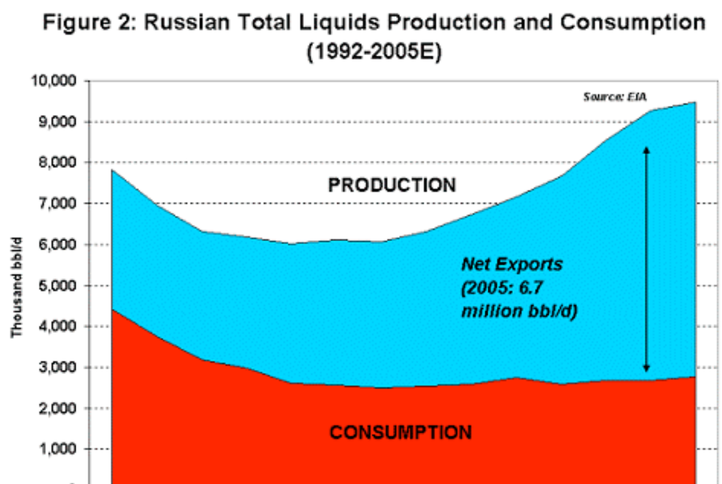
Figure 15 Documents Mexico's Cantarell field as the 2nd largest in the world and in decline. Source: Deutsche Bank, Reuters, Oil and Gas Journal

The largest producing field within Mexico is Cantarell, the second largest in the world after Saudi Arabia's monster Ghawar as listed in Figure 15. In 2004 Cantarell represented 63% of total oil produced in Mexico, yielding 2.1 mbd[102]. However, a study conducted and released by Mexico's national oil corporation, Pemex, said, "Cantarell production will begin to decline by 14 percent a year in 2006-2007, despite any incremental expansions to the field."[103] On February 9th, 2006 the *Wall Street Journal* reported "the [study] shows Pemex production in Cantarell may fall to as low as 520,000 barrels per day in 2008 from 2 million barrels a day in 2005". [104] As this decline evolves, Mexico's production will surely have peaked.

Russian Oil

[102] EIA, Country Analysis Briefs, Mexico, Oil, December 2005
[103] EIA, Country Analysis Briefs, Mexico, Oil, December 2005
[104] Lunhow, David, Wall Street Journal, "Mexico's Oil Output May Decline Sharply" February 9th, 2006

Russia's production capacity may still be growing, but is expected to decline soon. In July 2004 the *Moscow Times* quoted the Russian Federal Energy Agency as saying, "Russia's oil production is unlikely to grow in the years to come, and may even drop slightly in 2005."[105] In October of 2005, Russia's Energy Minister Victor Khristenko announced, "It [oil industry] will reach a certain plateau of production within the time frame of 2010… That plateau would be about 510 to 520 million tons a year, he said, or the equivalent of about 10.2 to 10.4 million barrels per day."[106] In order to reach this level Russia plans to continue production at full capacity, taking advantage of oil's record high prices. In 2005 Russia averaged production at 9.48 mbd[107]. Figure 16 shows Russia's rising oil production versus consumption, however the rate of increased produces appears to slowing.



	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004E	2005E
Production	7,819	6,951	6,307	6,172	6,017	6,101	6,070	6,312	6,724	7,160	7,660	8,527	9,265	9,480
Consumption	4,423	3,750	3,179	2,976	2,619	2,562	2,489	2,538	2,578	2,737	2,580	2,675	2,680	2,759

Figure 16 Shows Russia's increasing production, although it is expected to plateau around 10.3 mbd. Source: EIA

[105] Pustilnik, Marina, Moscow News, "In 2005 Russia's Oil Production May Fall," June 7th, 2004

[106] Moscow News, "Russia Aims to Produce 510M Tons of Oil Annually by 2010 — Energy Minister," October 10th, 2005

[107] EIA, Country Analysis Briefs, Russia, Oil, January 2006

There is conclusive data that many, if not most, of the world's largest conventional oil producing fields are in decline. Chevron Oil Corporation ran an ad campaign stating 33 of the largest 48 producing nations are in decline[108]. ExxonMobil advertises global oil discoveries peaked in 1964[109], a trend detailed in Figure 17. Declining rates of discovery are therefore a long-established trend, regardless of whether they are attempting to justify higher oil and gas prices. Of all remaining proven reserves 69% lie in OPEC nations[110] where detailed reserve data is withheld from public information. Therefore evaluating the status of these nations' reserves involves estimates and speculation.

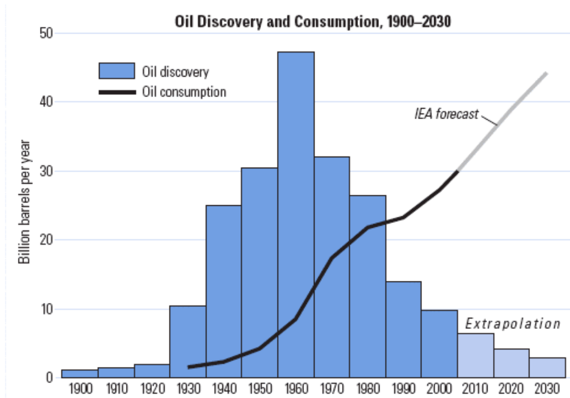


Figure 17 showing oil discoveries rates since 1900 compared to consumption. Source: EIA

The U.S. Geological Services (USGS) and EIA contend, "For the forecast period out to 2025, there is sufficient oil to meet worldwide demand. Peaking of world oil production is not anticipated until after 2030."[111] However, many speculate this forecast incorporates data of 'proven reserves' that may exist only on paper. In the mid 1980's OPEC implemented quotas, requiring all members to limit production to a certain percentage of their 'proven reserves'. After the agreement OPEC members suspiciously adjusted their reserves from a little over 400 billion barrels to over 700 billion without

[108]Chevron, "Will You Join US," http://www.willyoujoinus.com/advertising/print/
[109] ExxonMobil, "Energy Challenges," http://www2.exxonmobil.com/corporate/Campaign/Campaign_energychallenge_home.asp
[110] EIA, Country Analysis Briefs, "Non-OPEC Fact Sheet", June 2005
[111] EIA, "International Oil Outlook 2005"

registering any corresponding new discoveries[112]. Figure 18 graphs the jump in reported reserves among 7 OPEC members in the 1980s.

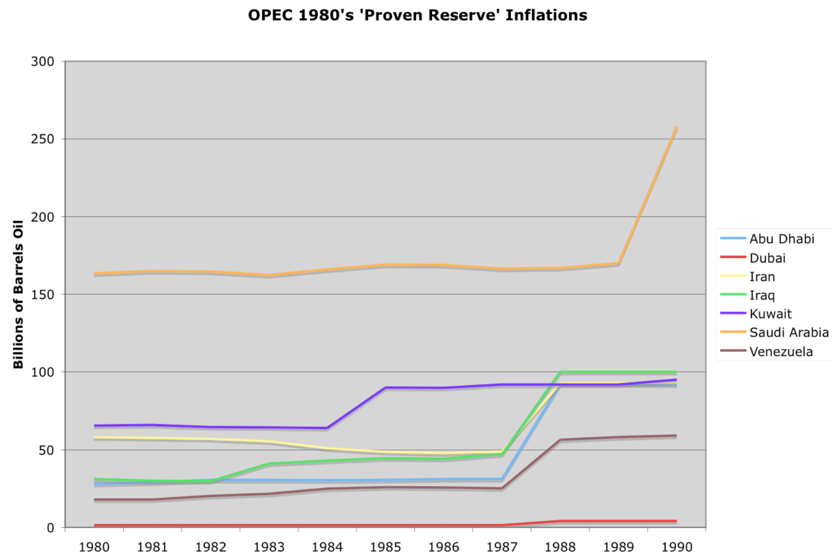


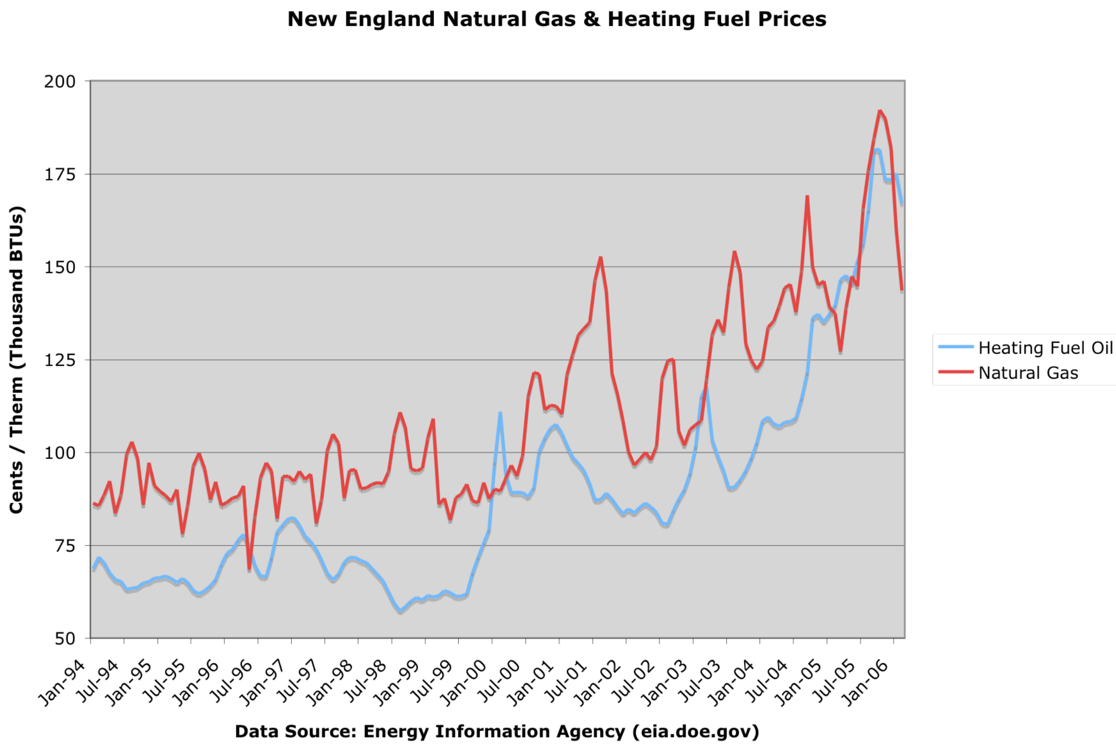
Figure 18 Graphs OPEC's spurious increases in 'proven reserves' during the 1980's. No new discoveries accompanied these inflations. Data Source: Dr. Colin Campbell, SunWorld, 1995

The higher proven reserves OPEC members list, the larger market share of OPEC exports they gain. Higher reserve listings also serve as more collateral for international loans. Hence, significant incentives exist for OPEC to inflate proven reserves with no regulatory commission restricting it. As non-OPEC producers begin and continue declining in the next few years, and OPEC is called to bring their 'proven reserves' online, the truth will be revealed.

[112] "David Schneider Interview," American Scientist, Sigma Xi, Scientific Research Society, http://www.americanscientist.org/template/InterviewTypeDetail/assetid/34501;jsessionid=aaa4KxL1uKYE6

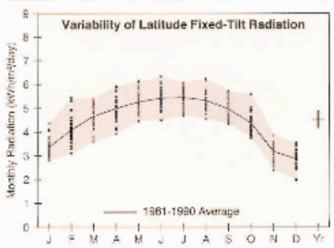
Appendix 5

Rising heating oil and natural gas costs in New England since 1994



Appendix 6

NREL's Solar Radiation Data Manual for Flat Plate and Concentrating Collectors for Providence, RI



Providence, RI

WBAN NO. 14765

LATITUDE: 41.73° N
LONGITUDE: 71.43° W
ELEVATION: 19 meters
MEAN PRESSURE: 1014 millibars

STATION TYPE: Secondary

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±11%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.9	2.7	3.7	4.7	5.6	6.0	5.9	5.2	4.2	3.1	1.9	1.6	3.9
	Min/Max	1.7/2.3	2.3/3.3	3.1/4.1	3.9/5.5	4.7/6.4	5.0/7.0	5.2/6.5	4.6/5.9	3.8/4.8	2.8/3.7	1.7/2.2	1.3/1.8	3.7/4.1
Latitude -15	Average	3.0	3.7	4.5	5.1	5.6	5.9	5.9	5.5	4.9	4.1	2.9	2.5	4.5
	Min/Max	2.5/3.8	2.9/4.9	3.5/5.2	4.1/6.0	4.7/6.5	4.9/6.9	5.1/6.5	4.8/6.4	4.3/5.6	3.5/5.2	2.2/3.4	1.8/3.0	4.2/4.8
Latitude	Average	3.4	4.1	4.7	5.0	5.2	5.4	5.5	5.3	5.0	4.4	3.2	2.9	4.5
	Min/Max	2.8/4.4	3.1/5.4	3.6/5.4	3.9/5.9	4.5/6.1	4.5/6.3	4.7/6.1	4.6/6.2	4.3/5.7	3.7/5.6	2.4/3.8	2.0/3.5	4.2/4.8
Latitude +15	Average	3.5	4.2	4.6	4.6	4.7	4.7	4.8	4.8	4.7	4.4	3.3	3.1	4.3
	Min/Max	3.0/4.7	3.2/5.7	3.4/5.4	3.6/5.5	4.0/5.4	3.9/5.5	4.1/5.3	4.1/5.7	4.1/5.5	3.7/5.7	2.4/4.1	2.0/3.8	4.0/4.6
90	Average	3.4	3.7	3.5	3.0	2.7	2.6	2.7	3.0	3.4	3.6	3.0	2.9	3.1
	Min/Max	2.8/4.5	3.7/5.3	2.6/4.3	2.4/3.6	2.4/3.1	2.3/2.9	2.4/2.9	2.5/3.5	3.0/3.9	3.0/4.7	2.1/3.7	1.9/3.7	2.9/3.4

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±11%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.7	3.8	5.0	6.1	7.0	7.5	7.4	6.7	5.6	4.3	2.7	2.2	5.1
	Min/Max	2.3/3.5	2.9/5.1	3.7/5.9	4.6/7.4	5.5/8.3	5.8/9.0	6.2/8.4	5.6/8.0	4.8/6.5	3.7/5.5	2.0/3.2	1.6/2.8	4.7/5.5
Latitude -15	Average	3.5	4.6	5.6	6.4	7.1	7.5	7.5	7.0	6.2	5.0	3.4	2.9	5.6
	Min/Max	2.9/4.7	3.4/6.3	4.1/6.7	4.8/7.9	5.6/8.5	5.7/9.1	6.2/8.5	5.8/8.4	5.2/7.3	4.3/6.6	2.5/4.2	2.0/3.7	5.1/6.0
Latitude	Average	3.9	4.9	5.8	6.4	6.9	7.2	7.2	6.9	6.2	5.3	3.6	3.2	5.6
	Min/Max	3.2/5.1	3.6/6.7	4.1/6.9	4.7/7.9	5.4/8.3	5.5/8.7	5.9/8.2	5.7/8.2	5.2/7.3	4.4/6.9	2.6/4.5	2.1/4.1	5.2/6.1
Latitude +15	Average	4.1	5.0	5.7	6.1	6.5	6.7	6.7	6.5	6.0	5.3	3.7	3.4	5.5
	Min/Max	3.3/5.4	3.6/6.9	4.0/6.8	4.4/7.6	5.0/7.8	5.1/8.1	5.5/7.7	5.4/7.8	5.0/7.1	4.4/7.0	2.6/4.7	2.2/4.4	5.0/6.0

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±11%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	4.1	5.0	5.8	6.5	7.2	7.7	7.6	7.0	6.2	5.3	3.8	3.5	5.8
	Min/Max	3.4/5.5	3.6/6.9	4.2/6.9	4.8/8.0	5.7/8.6	5.8/9.3	6.3/8.7	5.9/8.4	5.3/7.3	4.5/7.0	2.7/4.7	2.2/4.4	5.3/6.3

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±11%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W Horiz Axis	Average	2.4	2.6	2.7	2.8	3.1	3.4	3.3	3.1	2.9	2.8	2.1	2.0	2.8
	Min/Max	1.7/3.4	1.6/4.0	1.7/3.6	1.7/3.9	1.9/4.0	2.0/4.7	2.2/4.1	2.2/4.2	2.1/3.7	2.1/4.2	1.2/2.9	1.0/2.8	2.5/3.2
1-Axis, N-S Horiz Axis	Average	1.6	2.3	3.0	3.6	4.0	4.4	4.3	3.9	3.4	2.7	1.6	1.3	3.0
	Min/Max	1.2/2.3	1.4/3.5	1.8/4.0	2.1/5.0	2.4/5.3	2.6/6.0	2.9/5.3	2.5/5.4	2.4/4.4	2.1/4.0	0.9/2.2	0.7/1.8	2.6/3.5
1-Axis, N-S Tilt=Latitude	Average	2.6	3.1	3.6	3.8	4.0	4.2	4.1	4.0	3.9	3.5	2.4	2.1	3.4
	Min/Max	1.9/3.7	1.9/4.8	2.1/4.8	2.2/5.4	2.4/5.2	2.4/5.7	2.8/5.1	3.0/5.6	2.8/5.0	2.7/5.2	1.3/3.3	1.1/2.9	3.0/4.0
2-Axis	Average	2.7	3.2	3.6	3.9	4.2	4.5	4.4	4.2	3.9	3.6	2.5	2.3	3.6
	Min/Max	2.0/3.9	1.9/5.0	2.1/4.8	2.3/5.4	2.5/5.5	2.5/6.2	3.0/5.4	3.1/5.7	2.8/5.0	2.7/5.3	1.4/3.5	1.2/3.2	3.1/4.1

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-2.3	-1.3	3.0	8.6	14.1	19.4	22.6	21.8	17.8	12.0	6.9	0.4	10.2
Daily Minimum Temp	-7.2	-6.2	-1.8	3.2	8.5	13.8	17.3	16.6	12.1	6.1	1.6	-4.2	5.0
Daily Maximum Temp	2.6	3.5	7.8	13.9	19.6	24.9	27.8	27.1	23.5	17.8	11.7	5.1	15.4
Record Minimum Temp	-25.0	-21.7	-17.2	-10.0	-1.7	5.0	8.9	4.4	0.6	-6.7	-14.4	-23.3	-25.0
Record Maximum Temp	18.9	22.2	26.7	36.7	34.4	36.1	38.9	40.0	37.8	30.0	25.6	21.1	40.0
HDD, Base 18.3°C	639	549	476	293	137	17	0	4	50	199	350	554	3269
CDD, Base 18.3°C	0	0	0	0	4	49	133	113	35	3	0	0	337
Relative Humidity (%)	64	63	63	61	67	70	71	72	73	70	69	67	68
Wind Speed (m/s)	4.9	5.1	5.4	5.4	4.8	4.4	4.2	4.1	4.2	4.2	4.7	4.8	4.6

191

Appendix 7

Floor plan sketch of Mashapaug