Zero Net Energy Buildings: Are they Economically Feasible?

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SUMMARY

During the past decade, energy consumption growth has closely paralleled economic activity. In addition to this growing demand for energy, consumers are demanding increasingly flexible, convenient, and clean energy forms. The focus of a sustainable energy future has been towards the energy demand sector. The building sector particularly consumes one third of total U.S. energy. As a result, reduced consumption in this sector has the potential for high impact.

Zero net energy buildings provide a technically feasible approach to reducing energy consumption in buildings. These buildings are designed and constructed to generate all of the energy they require through a combination of energy efficiency and renewable energy generation technologies. Viable renewable energy sources consist of photovoltaic cells, solar water heaters, and geothermal heat pumps. On the energy demand side, passive solar design techniques such as passive solar heating, insulation and air tightness, solar control windows, shading, interior space planning, and landscaping reduce the energy demand of buildings. The use of high efficiency lighting and appliances also contributes to energy efficiency.

Although they are technically feasible, under standard conditions zero net energy buildings are not economically practical. Technology innovations are required to drastically drop the cost of the necessary components. Until these equipment cost reductions materialize, however, financial incentives provided by the government can reduce the economic barriers. An increase in energy prices can also increase economic attractiveness of zero net energy buildings.

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1.0 INTRODUCTION

1.1 MOTIVATION

During the past decade, a very strong trend characterizing global energy markets has emerged. There is a strong link between energy consumption growth and economic activity growth. During the late 1970's and early 1980's, it appeared as if this link was broken and energy demand was "decoupled" from economic activity. During the past decade, however, there has been a "recoupling" of with energy consumption growth closely paralleling economic activity. (Hammonds, p81)

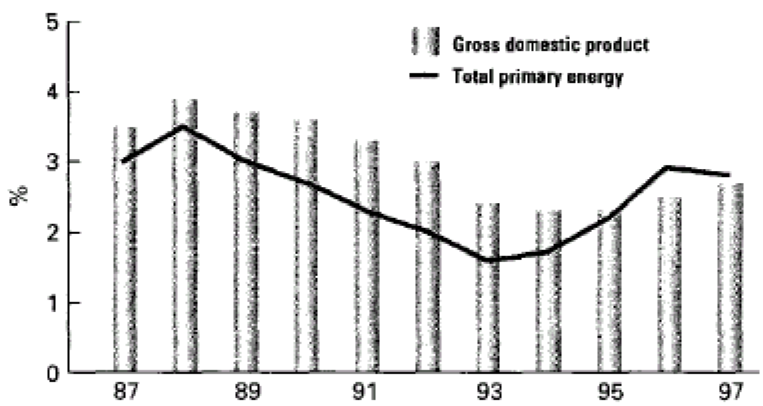

Figure 1: Global Energy GDP Growth

What this data doesn't capture is the demand from consumers for increasingly flexible, convenient, and clean energy forms.

In the quest for a sustainable energy future, focus has been shifting towards the energy demand sector. One of the key demand contributors is energy use in buildings. Buildings use two thirds of all electrical energy consumed in the United States. They also account for one third of peak electrical demand. This is equivalent to one third of total U.S. energy consumption. The buildings sector, which includes new construction and renovation as well as material and equipment suppliers, is valued at more than $800 billion per year—almost 13 percent of GDP. (President's Committee of Advisors, p3-3) Growth in this sector has averaged 4% in the past several years and is projected to grow at 2% for 2001. (Sandherr)

The extended lifetime of buildings, ranging from 50 – 100 years, has a large impact on energy use patterns. Due to this inertia, it is difficult to change building energy use patterns quickly. (EREN Solar Buildings Program) One method for minimizing building energy use is through the promotion of Zero Net Energy Buildings. These buildings are designed and constructed to generate all of the energy they require through a combination of energy efficiency and renewable energy generation technologies. Zero Net Energy Buildings use a two-pronged approach to becoming self-sustaining. First, efficiency boosting technology reduces the building loads. With the lower energy demand, solar and other renewable technologies have the potential to meet all of a buildings energy needs.

1.2 SCOPE OF PAPER

Construction of Zero Net Energy Buildings is an important lever for reducing U.S. energy consumption. This paper will review some of the available efficiency promoting technologies as well as renewable energy generation technologies that can be utilized to construct zero net energy buildings. In addition, the economic viability of zero net energy buildings will be examined. The economic enabling factors are discussed in consideration of the future for zero net energy buildings.

2.0 CURRENT ENABLING TECHNOLOGIES

A combination of technologies has enabled the existence of Zero Net Energy Buildings. Continuing improvements in the energy performance of building enclosures, lighting systems, heating and cooling systems, and controls have reduced new building energy requirements. In addition, advances and commercialization of generation technologies such as geothermal and solar have provided more abundant sources of renewable energy.

2.1 ENERGY GENERATION TECHNOLOGIES

There are several energy generation technologies which are being used to displace the use of fossil fuels on the supply side. These technologies are used to produce electricity, hot water, and heat in buildings.

2.1.1 Photovoltaic Systems

Photovoltaic (PV) systems convert sunlight directly into electricity. The semiconductor materials interact with the sunlight to free the electrons and produce electricity. The major raw material is silicon. Silicon is primarily used for its high light to electricity conversion properties and its abundance. A system is composed of individual PV cells that are wired together to form a module. PV modules provide from 10 to 300 Watts of power. (Consumer Guide to Buying a Solar PV System)

Power production from PV cells is intermittent due to their dependence on the sun. In addition, the quantity of electricity generated is proportional to the light intensity and the angle of light incidence on the PV cells. As a result, a well designed system needs unobstructed sunlight access for most of the day, year-round. The best location for PV cells are on a south facing roof since the sun is always in the southern half of the sky in the U.S. (Consumer Guide to Buying a Solar PV System)

The drawback with PV systems is their inability to effectively store energy. Batteries can be used for backup, however, they are expensive and do not have high efficiencies. A new measure called net metering alleviates this problem by tying PV systems to the utility grid. In these circumstances, the PV modules are connected to an inverter that changes the system's direct-current (DC) electricity to alternating current (AC), which is compatible with the utility grid. When the PV cells are producing more energy than needed by the building, the utility meter runs backwards and supplies electricity to the grid. This results in an even swap for grid power used by the building at other times. Net metering allows consumers to pay for their "net" electricity consumption from the utility. (Consumer Guide to Buying a Solar PV System)

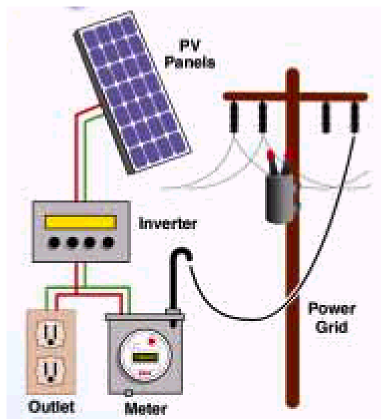

Figure 2: Layout of PV and Utility Grid Connection

2.1.2 Solar Water Heating

Solar water heaters use the sun to heat either water or a heat transfer fluid in the solar collectors. The water is then stored for use as needed. A typical solar water heater provides approximately two thirds of residential hot water needs. As a result, a conventional fuel is needed for backup.

There are two main categories of systems: active and passive. Active systems use electric pumps, valves, and other controllers to circulate the fluid through the collectors. The three types of active systems are direct, indirect, and drainback systems. Direct systems circulate the water directly through the solar collectors. These types of systems are most appropriate in areas that do not freeze for long periods of time. In addition, these systems perform the best when the water is not hard or acidic. Indirect systems circulate heat transfer fluids through the collectors. The heat from these fluids is then transferred to the water stored in the tanks through a heat exchanger. The final active system is a drainback system. (Solar Buildings Program)

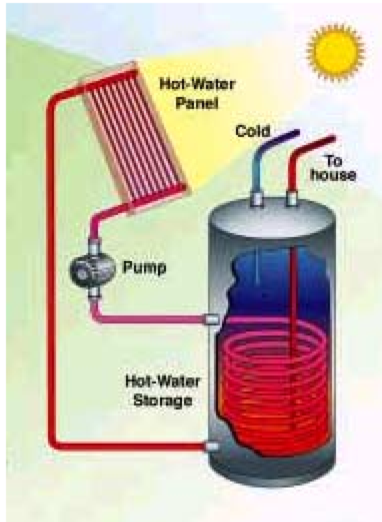

Figure 3: Indirect Solar Hot Water System

Drainback systems pump the water through the collectors. When the pump stops, the water in the collector piping drains into a reservoir tank. Consequently, this system is suitable for colder climates where freezing is an issue. (Solar Buildings Program)

Passive systems circulate water through the system without pumps or valves. The absence of electrical components makes these systems more reliable and easier to maintain. The two main types of passive systems are batch heaters and thermosiphon systems. Batch heaters, also called integral collector storage systems, are comprised of one or more storage tanks. The storage tanks are placed in an insulated box with a glazed side facing the sun. Batch heaters are only appropriate for warm climates since they must be protected from freezing. (Solar Buildings Program)

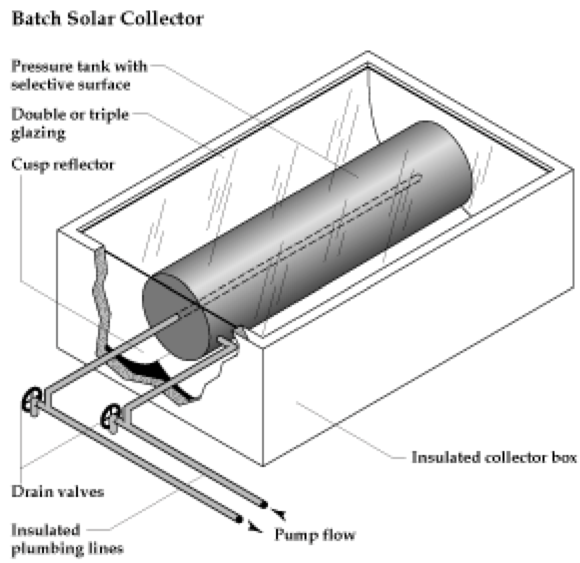

Figure 4: Batch Solar Water Heater

Thermosiphon systems take advantage of the natural convection of warm water. Water circulates through the collectors and heats up, becoming lighter as it gets warmer. The lighter water rises naturally into the tank, which is located above the collector. Simultaneously, the cooler water in the tank sinks down the pipes to the collector, resulting in flow circulation through the system. (Solar Buildings Program)

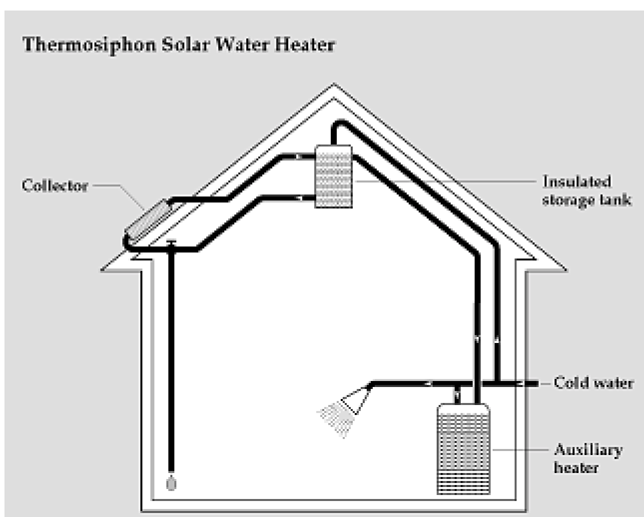

Figure 5: Thermosiphon Solar Water Heater

2.1.3 Geothermal Heat Pump

Geothermal heat pumps (GHP), also known as GeoExchange or ground source heat pumps, use the earth's natural energy to provide heating and cooling. The system consists of piping and a heat pump. While the system does not convert electricity to heat, it uses electricity to transfer the thermal energy between the building and the ground. In heat mode, the system draws heat from the ground and transfers it to the building. In cooling mode, the reverse occurs and heat from the building is extracted and transferred to the ground. A heat transfer fluid circulates through the pipes transferring heat between the earth and the ground. The earth provides a constant temperature of about 55^{o}F and acts as a heat sink. (Cook, p 46)

There are two types of GHP systems, open loop and closed loop systems. An open loop system draws in ground water and circulates it through the system. The water is discharged from the GHP circuit into a discharge well. From here, the groundwater can return to the aquifer it came from.

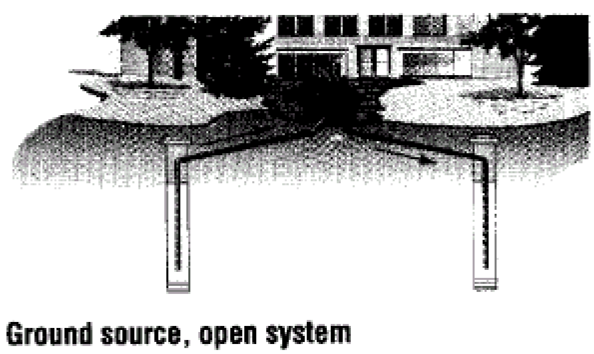

Figure 6: Open Loop GHP System

When there are concerns of groundwater contamination, a hybrid open loop is used. The groundwater is isolated from the building's water flow and is pumped through a heat exchanger where heat is transferred to the interior water flow. The two fluids never come in contact in this setup.

Closed loop systems are buried below grade or are submersed at least 10 feet down in a body of water in either a horizontal or vertical orientation. Horizontal loops are typically buried 4 to 5 feet below grade. Economically, it is cost prohibitive to place the piping deeper due to OSHA regulations. Due to their proximity to the earth's surface, horizontal loops are more vulnerable to the atmospheric temperature. More loop length is required to combat this effect. These effects limit the capacity of horizontal loops relative to vertical loops. A horizontal acre provides 25 – 30 tons of cooling compared to the 250-400 tons provided by a vertical acre. Vertical loops reach depths of 15- 450 ft depending on the soil's thermal conductivity. (Cook, p48)

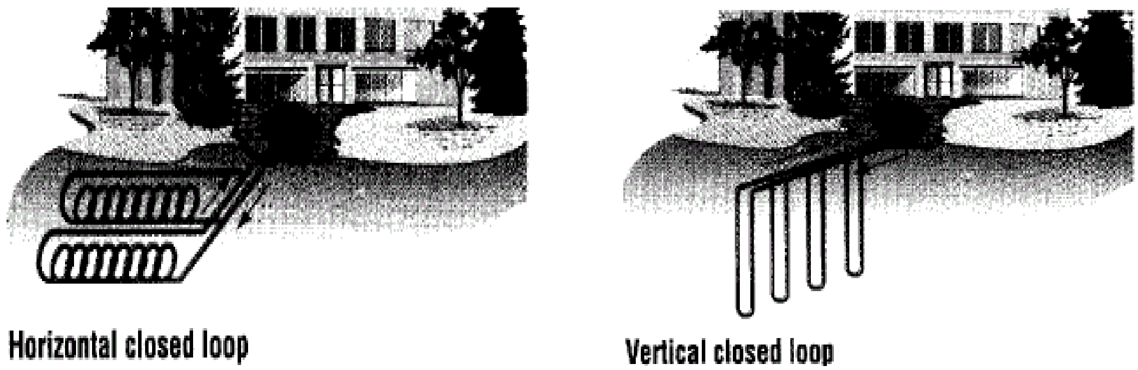

Figure 7: Closed Loop GHP Systems

2.2 ENERGY CONSERVATION TECHNOLOGIES

Demand side management of energy consumption in buildings can be controlled through energy efficient construction technologies. Not only do these technologies reduce the consumption of energy, they also make the use of renewable energy sources more viable.

2.2.1 Passive Solar Design

Passive solar design uses the sun's energy for the heating and cooling of living spaces. The building design takes advantage of the basic natural processes associated with radiation, conduction, and natural convection that are created in building materials by exposure to the sun. Building materials can reflect, transmit, or absorb solar radiation from sunlight. Air warmed by the sun also moves in predictable patterns within buildings.

2.2.1.1 Passive Solar Heating

Passive solar heating systems capture the sun's heat within the building's elements and release that heat when the sun is not shining. While the building's materials are absorbing the heat for later, solar heat is available for maintaining a comfortable temperature. The two main elements of passive solar heating are south facing glass, also known as glazing, to pass sunlight into the building, and thermal mass for absorbing, storing, and distributing heat. There are three approaches to passive systems – direct gain, indirect gain, and isolated gain.

In a direct gain system, the actual living space acts as the solar collector, heat absorber, and distribution system. Solar energy passes through the south facing glass and directly and indirectly strikes the thermal mass materials in the house. Thermal mass materials have a high capacity for absorbing and storing heat. A material's thermal conductivity, specific heat, and density determine its thermal storage capabilities. In direct gain systems, materials such as brick, concrete masonry, concrete slab, tile, adobe, and water are functional parts of the building. The thermal mass mitigates the daytime heat intensity by absorbing the heat. At night, the thermal mass radiates heat into the living space.

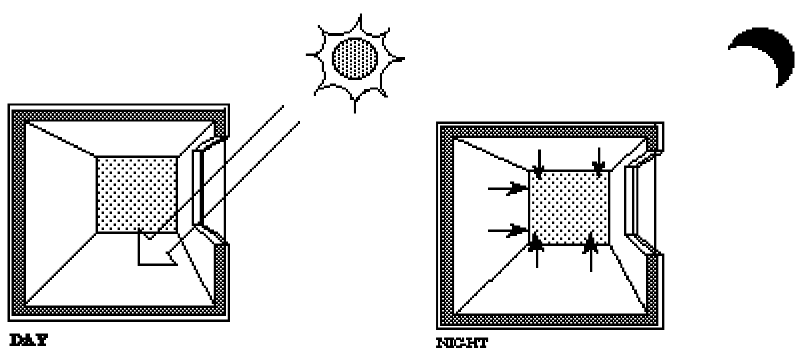

Figure 8: Direct Gain Passive Solar System Operation

In an indirect gain system, the thermal mass is positioned between the sun and the living space. The main application of an indirect gain system is with thermal mass walls also known as Trombe Walls. A portion of the south wall is constructed of thermal mass material. A glass pane is positioned about two inches from the thermal walls surface. Sunlight enters, the heat is trapped by the glass, and the thermal mass wall absorbs the heat. In the evening and at night, the heat is radiated into the interior of the room. The indirect gain system uses 30-45% of the sunlight streaming through.

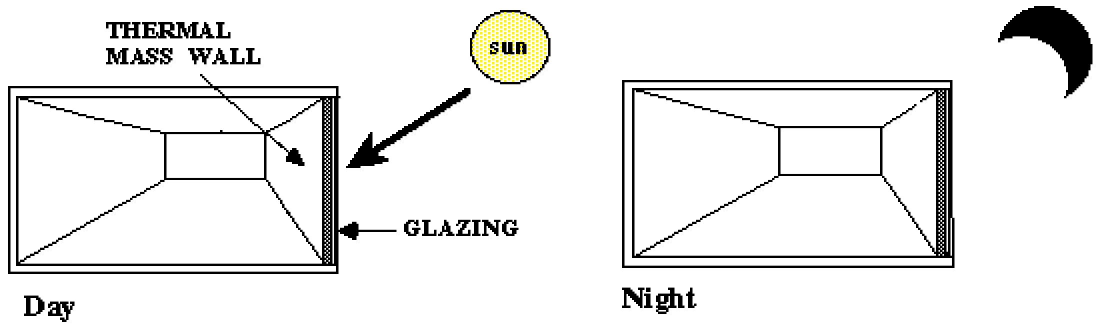

Figure 9: Indirect Gain Passive Solar System Operation

In an isolated gain system sunlight is collected in an area that can be closed off from the rest of the building. An example of an isolated system is a sunroom. Sunlight enters the sunroom and is retained in the thermal mass and air in the room. Heat is conducted through the shared thermal mass wall into the rest of the building. Vents can allow air to be exchanged between the sunroom and the rest of the building. The remainder of the solar energy is retained in the sunroom.

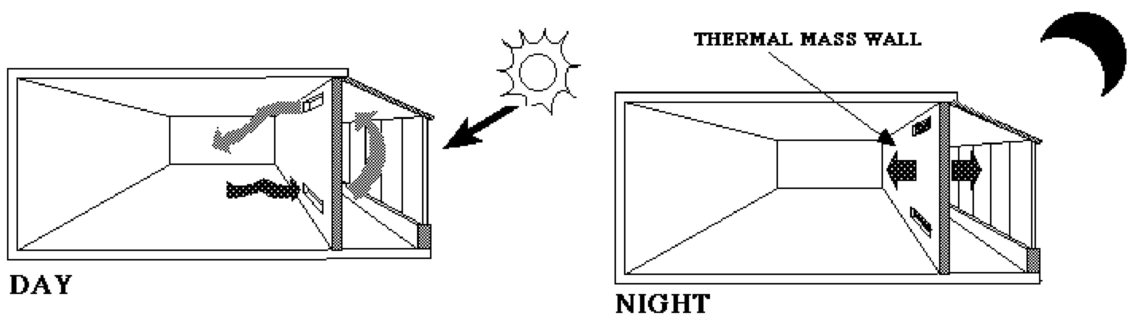

Figure 10: Isolated Gain Passive Solar System Operation

2.2.1.2 Insulation and Infiltration

Insulation thermally encloses buildings and improves their resistance to heat flowing out of the building. This allows buildings to stay cool in the summer and warm in the winter. The R-value measures a materials thermal resistance and a higher R-value indicates a better insulator.

Another essential key to a building's energy performance is minimal air infiltration or air leakage. Air will rapidly flow through cracks and crevices in the walls allowing heat and cold to bypass the insulation. This leads to large energy losses. Air infiltration is measured by the number of air exchanges per hour (ACH). A good energy efficient building will have between 0.35 and 0.50 ACH under normal winter conditions. When a building is more air tight than 0.35 ACH, mechanical ventilation is needed to avoid problems such as moisture build up, indoor air quality, and inadequate venting for fireplaces and furnaces. (Passive Solar Design)

2.2.1.3 Advanced Solar Control Windows

One important way to reduce energy demand in buildings is through advanced solar control windows. These types of windows need to be selected for the climate they will be used in. Coatings are added to windows to provide some of the desired properties. For cold climates, windows that maximize solar heat gain are ideal. The Solar Heat Gain Coefficient (SHGC) measures this property. A low SHGC keeps out the sun's heat, whereas a high SHGC allows the sun's heat to pass through. Another important property of windows is the conductance or U-value (Btu/hr-sqft-^{o}F). Windows with low U-values are better insulators and have reduced heat transmitted through them. Spectral selectivity is another important feature for energy efficient windows. With a spectral selective coating, only the visible portion of the solar spectrum is transmitted through the window. Infrared and ultraviolet light which cause overheating and fading of interior materials are filtered out. (Parker, p1)

In addition, special care should be taken with non-solar glazing. Non-solar glazing refers to windows that are not south facing. Windows on the north side of a building lose significant heat energy and gain little useful sunlight in the winter. East and west windows tend to increase heat gain and cooling needs in the summer. These energy needs can be balanced out with aesthetic needs for non-solar glazing. Triple glazing (three panes of glass) or low-e (low emissivity) coating reduces heat loss while allowing sunlight to enter. (Passive Solar Design)

2.2.1.4 Window overhangs

One method of reducing the amount of cooling required for buildings in the summer is by adding window overhangs. Window overhangs block the sunlight in the summer when the sun is higher in the sky. The shade created by the overhang helps prevent solar gain or heat buildup on the walls and windows. Conversely, in the winter, the sun is lower in the sky and more sunlight and heat can enter through the windows.

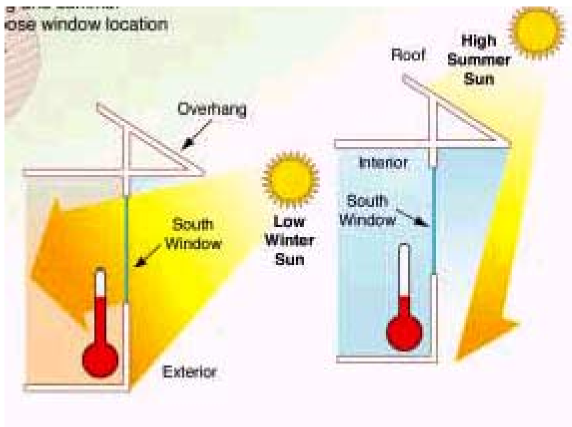

Figure 11: The Cooling Effect of Window Overhangs

2.2 Interior Space Planning

Energy can be conserved in homes by placing rooms in strategic locations. Considering how the rooms will be used in different seasons and at different times of the day can save energy and increase comfort. For example, locating the room that produces the most heat on the north side or coolest side of the house increases the heating/cooling efficiency. Similarly, low occupancy areas such as storage rooms and bathrooms can be placed in the north side of the building. These rooms don't need as much heat, and would not benefit as much from the warmth brought by a southern exposure. Accordingly, interior spaces that need the most light and heating/cooling should be along the south face of the building. Grouping baths, kitchens and laundry rooms near the water heater will also save the heat that would be lost from longer water lines. (Passive Solar Design)

2.2.1.6 Landscaping

Well designed landscaping can leverage different greenery to enhance the energy efficiency of homes. Trees that provide shade placed on the east and west side of the building help keep the interior cool in the summer. In the winter, shrubbery and trees can protect the house from cold winds. Low shrubs and plans placed on the south side of the house increase the exposure to the sun during the winter.

2.2.2 High Efficiency Lighting

The use of compact fluorescent lights can reduce a building's lighting electricity load by 75%. These lights provide almost equivalent light (lumens) and are indistinguishable from traditional incandescent bulbs. They also last 10,000 hours versus the 2,000 hour operating life of standard incandescent lamps. In warm weather, a secondary benefit is the reduced heat emitted by the lamp. This reduces building cooling loads. ("How to Build a Better Home")

2.2.3 High Efficiency Appliances

Although high efficiency appliances have higher upfront purchase costs, they can significantly reduce energy consumption resulting in long term operating savings. Many high efficiency appliances are commercially available. Among these are refrigerators, washer dryers, and HVAC systems.

3.0 TECHNICAL FEASIBILITY OF ZERO NET ENERGY BUILDINGS

There are many combinations of the enabling technologies that can be used to construct a zero net energy building. A project sponsored by the Florida Energy Office and Sandia National Laboratories demonstrates the technical feasibility of zero net energy buildings.

This prototype home built in Lakeland, Florida was built with the objective of testing the feasibility of constructing very efficient residential buildings combined with a net-metering PV system that exerts zero net demand on the utility during the summer peak demand period. Two homes were constructed by the same builder with identical compass orientations and floor plans of 2,424 square feet in 1998. One was a control home without any of the energy efficient features or PV system. The other building was constructed with many measures designed to make it more efficient. These features include:

- White-tile roof with 3-foot overhangs
- R-30 attic insulation
- R-10 exterior insulation over concrete block system
- Advanced solar control double-glazed windows
- Oversized, interior-mounted ducts
- High-efficiency refrigerator
- High-efficiency compact fluorescent lighting
- Programmable thermostat
- Solar water heater with backup propane
- Downsized SEER 15.0, variable-speed, 2-ton air conditioner with field-verified cooling-coil air flow
- 4-kW utility-interactive PV system.

One of the key things to note about these features is that the PV system was split into two subarrays. One subarray was placed on the south-facing roof and the other subarray was placed on the west-facing roof. This orientation provides more solar power during the afternoons when the utility grid faces peak demand. This configuration reduces the prototype home's demand and also supplies the excess PV power to the utility during this peak demand period. The other feature used to minimize the prototype home's demand during peak hours was the programmable thermostat. It was used to shift the building cooling load earlier during the day when the PV power production is greatest.

A breakdown of the energy savings attributed to each of the energy saving features is shown below in Figure 12.

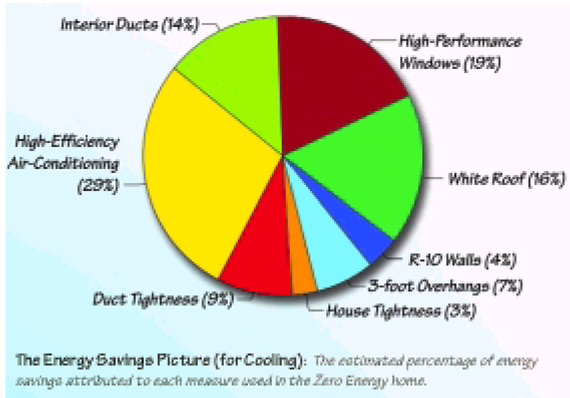

Figure 12: Percent of Energy from each Efficiency Component

The combination of the energy efficient design and the use of solar energy for electricity and heating proved to effectively bring the net electricity demand of the building close to zero. This is true even under extreme conditions. The chart below shows the energy performance of both the control home and the PV home on June 18, 1998. This was an exceptionally hot day (maximum ambient temperature of 100^{o}F) when Lakeland Electric and Water experienced their maximum annual utility summer peak for the summer.

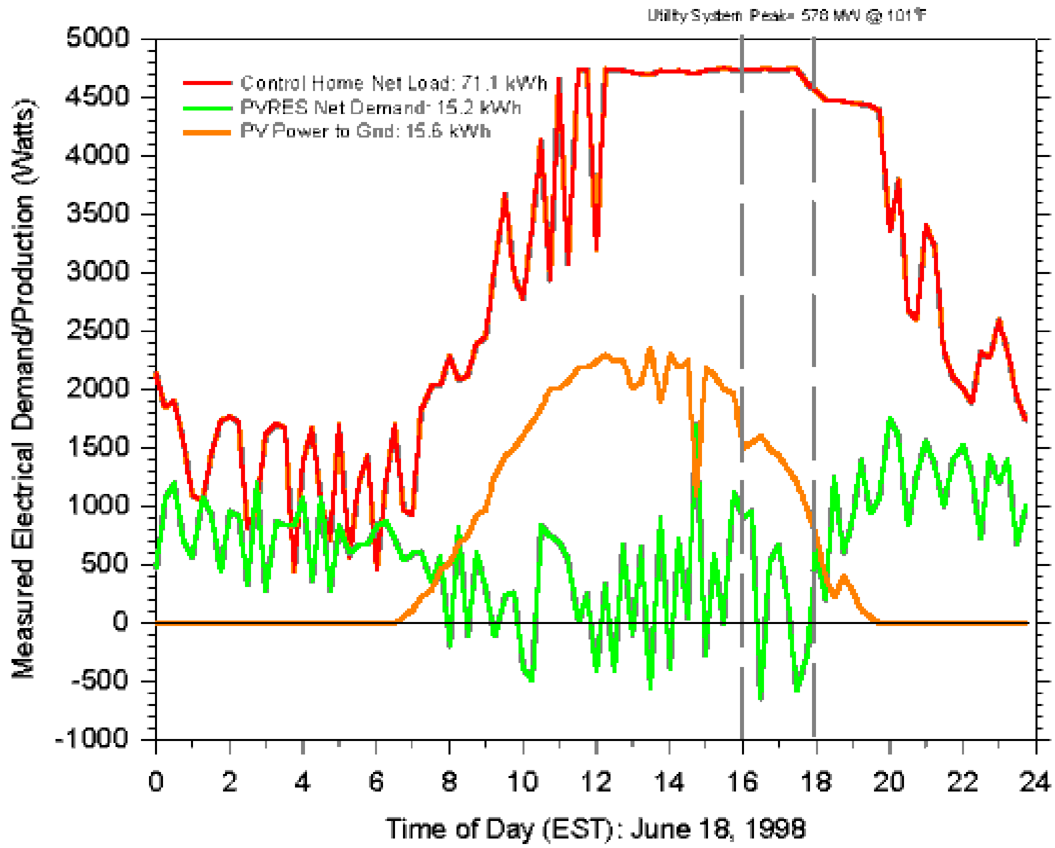

Figure 13: Prototype Home (PVRes) Generates Excess Electricity

PV electrical generation sent to the grid totaled 15.6 kWh. Net energy demand of the home (Total Load - PV power) shows that most utility electricity use (15.2 kWh) occurred during the evening hours. The net electricity used from the grid was –0.4 kWh.

4.0 ECONOMIC EVALUATION OF FLORIDA HOUSE

Clearly, net zero energy buildings are technically feasible. However, are they economically viable? An economic evaluation of the Lakeland, Florida prototype home will give some insight into this question.

Table 1 shows the different energy efficient components used in the Lakeland residence. The cost of each component in 1998 is listed as well as the energy saved by its efficiency performance. (Parker, 4) The cost of electricity in Florida was assumed to be 7 cents/KWh. (Klitgaard, 2). The payback period is calculated assuming there is no interest on the equipment payments.

Component	**Component Cost**	**Energy saved** kwh/yr	**$ saved** $/yr	**Payback** years
Advanced Windows (Materials & lab)	$ 4,266	1610	112.7	38
White Tile Roof (Materials & lab)	$ 10,829	1342	93.94	115
Wider Overhang	$ 1,882	537	37.59	50
High Performance AC	$ 1,263	2376	166.32	8
Interior Duct System	$ 950	1150	80.5	12
Exterior Wall Insulation	$ 11,500	307	21.49	535
Solar Water Heater	$ 2,989	2097	146.79	20
High Efficiency Lighting	$ 525	1479	103.53	5
Refrigerator	$ 298	388	27.16	11
Utility Integrated PV System	$ 40,000	5600	392	102
Total	**$ 74,502**	**16886**	**1182.02**	**63**

Table 1: Payback period for Efficiency Components in Base Case

Considering the long payback period of 63 years, the Florida prototype is clearly not economically viable. A much shorter payback period of 20-30 years is required to make the system more economically attractive. There are several components that do not provide much energy performance benefit compared to their cost. For example, the exterior wall insulation is extremely expensive in light of the energy savings it provides. The cost of several key components needs to drop drastically before the residence would be acceptable to environmentally minded consumers. The key levers for bringing the cost of the total home down are the windows, tile roof, exterior wall insulation, solar water heater, and PV system.

Component	**Component Cost**		**Assumed Cost Reduction (%)**	**Reduced Cost**		**Energy saved** KWh/yr	**$ saved** $/yr	**Payback** years
Advanced Windows (Mat & lab)	$	4,266	0.5	$	2,133	1610	112.7	19
White Tile Roof (Mat & lab)	$	10,829	0.5	$	5,415	1342	93.94	58
Wider Overhang	$	1,882	0	$	1,882	537	37.59	50
High Performance AC	$	1,263	0	$	1,263	2376	166.32	8
Interior Duct System	$	950	0	$	950	1150	80.5	12
Exterior Wall Insulation	$	11,500	0.5	$	5,750	307	21.49	268
Solar Water Heater	$	2,989	0.5	$	1,495	2097	146.79	10
High Efficiency Lighting	$	525	0	$	525	1479	103.53	5
Refrigerator	$	298	0	$	298	388	27.16	11
Utility Integrated PV System	$	40,000	0.5	$	20,000	5600	392	51
Total	**$**	**74,502**		$	39,710	**16886**	**1182.02**	**34**

Table 2: Payback period for Efficiency Components with Reduced Costs

Reducing the costs of each of these by 50% cuts the payback period to 34 years. Technological and manufacturing advances will drop the prices of these components, however, it will be many years before they drop 50%. Even in the rapidly growing solar sector, advances in PV systems have reduced the cost by 50% since 1995. (Fulford). Assuming this pace of cost reduction continues and applies to windows, roofing tile, and insulation, it will be at least 2004 until the Florida home becomes economically viable.

Another way for the Florida house to become economical is for a drastic jump in electricity prices. Figure 14 shows the required energy price to meet different payback periods.

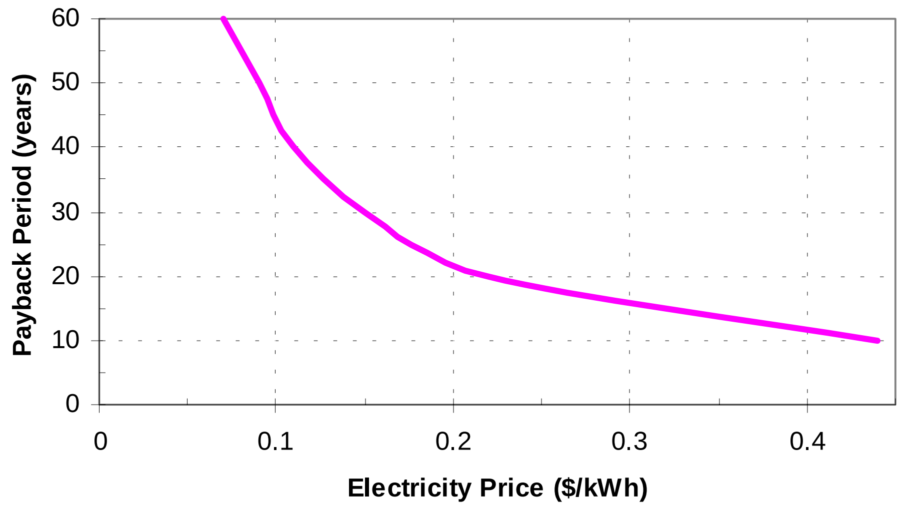

Figure 14: Increasing Electricity Prices result in Lower Payback periods

For a 30-year payback on all of the efficiency components and PV system in the prototype house, the cost of electricity must double to 15 cents/KWh. As the expected payback period drops, electricity price exponentially rises indicating the higher prices needed to increase the economic attractiveness of the project.

5.0 ECONOMICALLY ENABLING FACTORS

The brief economic analysis of the prototype home has introduced some of the ways to make zero net energy buildings economical. These consist of public policy, technology innovations, and energy market dynamics. A more in depth look will show how these methods can be applied.

5.1 PUBLIC POLICY

Public policy is one of the strongest ways to create economic incentives for using energy efficient construction and renewable energy sources. Since zero net energy buildings have such a large up front cost, financial incentives can make the investment much more attractive. There are many ways to implement these incentives on the federal, state, local, and utility level. Some of the financial incentives that can be used are:

- Personal Tax Incentives – provision of credits or deductions to help cover the renewable energy equipment expense
- Corporate Tax Incentives – provision of credits or deductions against a percentage of the equipment or installation cost
- Sales Tax Incentives - provide an exemption from state sales tax for the cost of renewable energy equipment
- Property Tax Incentives – excludes the added value of the renewable device from the property valuation for tax purposes
- Rebate Programs – promote installation of renewable energy equipment through rebates
- Grant Programs – encourage use and development of renewable energy technologies through grants
- Loan Programs – offer low-interest or no-interest loans for energy efficiency or the purchase of renewable energy equipment

The current availability of these types of financial incentives varies from state to state. These policies have the power to make a large difference in the economic attractiveness of zero net energy buildings. In Japan, this strategy has worked very well in increasing the solar power generation capacity. Government subsidies have motivated Japanese firms to produce 80 megawatts of new solar power generating capacity in 2000. This surpasses the 60 megawatts produced by the U.S., making Japan the world's leading producer of photovoltaic cells. (Fulford)

Another incentive that would promote the construction of net zero energy buildings is the availability of net metering. Net metering is currently unavailable in 20 states. (Binsaaca) Policies must also be put in place to incentivize utility companies to support net metering. There is a strong resistance from many utility companies to support independent energy production since this competes with a utility company's business. As a result, utility companies have erected many barriers to net metering. Some of these are a lack of common interconnection requirements, overly burdensome contract terms and agreements for interconnection, and excessive fees and charges. These barriers only act to increase the expense associated with installing a PV system. (Starrs)

There are two key ways to overcome the barriers put in place by utility companies. One is through government regulation. The government can require utility companies to provide net metering, standardize their connection requirements, and simplify contracts. However, the adoption of net metering would be much more successful if the utility industry backed it voluntarily. This can be achieved through a change in the incentives of utility companies. Currently they receive compensation for each unit of energy sold. If the government provided financial compensation for each net metering customer, utilities would have incentive to pursue these customers. Accordingly, utilities would make it easy for customers to use net metering.

5.2 Technology Innovations

Cost reductions in the equipment required for net zero energy buildings are another way to increase the financial attractiveness. The contributor to equipment cost reductions is technology innovation. Specifically for PV cells, cost reduction work focuses on increasing energy conversion efficiency and reducing manufacturing costs. These cost cutting breakthroughs are not an unrealistic expectation in the PV arena. Sanyo has developed a new panel that converts 20% of solar energy into electricity, nearly double the commercial record that BP Solar announced in May.2000. (Fulford) Similar technology and manufacturing breakthroughs are required in all of the components that make up zero net energy buildings.

5.3 ENERGY MARKET DYNAMICS

The other large area that has a strong influence on the economic viability of zero net energy buildings is the energy market. For the past decade, energy has been cheap, making it difficult for renewable technologies to compete. The rise in energy prices starting in 2000 is turning the tide. Larger energy bills are making it more cost effective to use renewable energy.

Another large shock that is promoting the attractiveness of zero net energy homes is the California energy crisis. With impending fear of energy shortages and climbing prices, renewable energy provides a stable and economic source of energy for many business and homes.

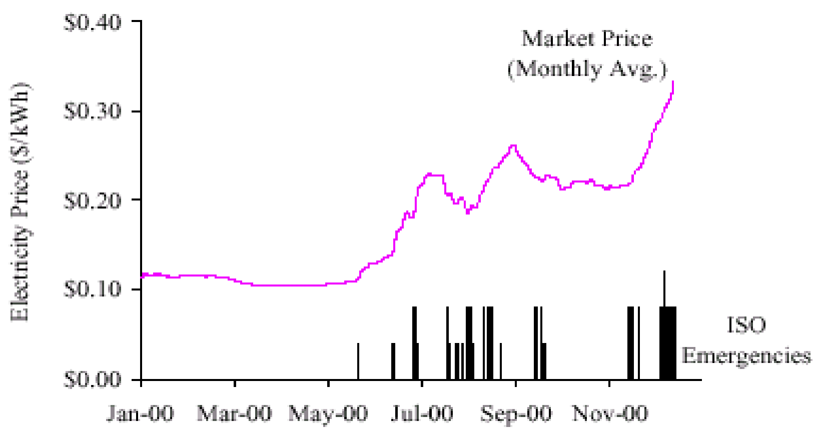

Figure 15: California has high market prices and dangerously low supplies.

As can be seen in Figure 1, electricity prices in California have been climbing since May 2000. (Hoff, p2) This upward trend has continued into 2001 with average energy prices in January 2001 at $0.29/kWh and increasing 25% to an average of $0.36/kWh in February 2001. (Sheffrin) With these rates of electricity, the Florida prototype becomes very economically attractive with a payback period of 15 years. The high rate of ISO supply emergencies, as shown in Figure 15, also contributes to the attractiveness of zero net energy buildings. (The ISO is the Independent System Operator of the ISO transmission grid who provides access to the grid, manages congestion, and maintains the reliability and security of the grid.) Zero net energy buildings reduce the dependence on the public utility and accordingly reduce the effect of the demand shortages.

6.0 CONCLUSION

Zero Net Energy buildings are a technically feasible method of reducing U.S. energy demand. The combination of demand side management with renewable energy sources provides a technically attractive way of constructing buildings with no demand on the utility grid. Viable renewable energy sources consist of photovoltaic cells, solar water heaters, and geothermal heat pumps. On the demand side, passive solar design techniques reduce the energy demand of buildings. The use of high efficiency lighting and appliances also contributes to energy efficiency.

The Florida prototype home demonstrates one way these different technologies can be combined to build a zero net energy home. There are other possibilities that include the use of geothermal heat pumps as an energy source and more passive design techniques. However, the study serves to demonstrate that zero net energy is more than just a long term vision. It is a current reality.

The Florida prototype home also provides a reference point for economic analysis of the feasibility of zero net energy buildings. Under standard conditions, the prototype home is clearly not financially viable with a payback period of 63 years. The model does point out key levers for increasing the economic viability of the home. Among these levers are technology innovations and financial subsidies and incentives. Technology innovations result in cost reductions in the necessary renewable energy equipment. These innovations take time, however. In the interim, government subsidies in the form of tax breaks, rebates, and loans can effectively reduce the intensive capital cost and make renewable systems more affordable.

One of the exogenous contributors to financial attractiveness is the energy market. Energy prices can change the economic prospects for zero net energy buildings drastically. For the past decade, U.S. energy prices have been too low to promote the use of renewable energy. In most of the U.S., financial incentives are necessary to overcome this barrier. However, prices appear to be on the rise. The California energy crisis, has created the spike in energy rates needed to make zero net energy buildings attractive. In California's current energy market, the prototype home is a very viable option and provides more than just economic benefits. This may be the disruptive force needed to shift the paradigm of the U.S. energy sector towards conservation and renewable energy.

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Appendix: Financial Calculations for Florida Prototype Home

Calculations:

$ saved (year) = Component Cost/ Energy saved

Payback period = t

Equipment cost payment are assumed to be an annuity with constant payments (C) for period of t years where PV is the capital expense

$$PV_{annuity} = C\left[\frac{1}{r} - \frac{1}{r(1+r)^t}\right]$$

Reduced Cost = Component cost * (1 – assumed cost reduction)

Base Case Assumptions:

- Zero interest rate financing: r = 0
- Florida electricity price = $0.07/kWh

Variable Payback Case Assumptions

- Zero interest rate financing: r = 0
- Payback period is fixed
- Florida electricity prices are variable