UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE

ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
PENNSYLVANIA POWER & LIGHT COMPANY	)	
	)	Docket Nos. 50-387
and	)	50-388
	)	
ALLEGHENY ELECTRIC COOPERATIVE, INC.	)	
	)	
(Susquehanna Steam Electric Station,	)	
Units 1 and 2)	)	

AFFIDAVIT OF
GRAYSON E. McNAIR and PRESTON L. ROBERTS
IN SUPPORT OF APPLICANTS' ANSWER
TO NRC STAFF'S MOTION FOR
SUMMARY DISPOSITION OF CONTENTION 4

County of Lehigh)
: SS
Commonwealth of Pennsylvania)

Grayson E. McNair and Preston L. Roberts, being duly sworn according to law, depose and say as follows:

1. I, Grayson E. McNair, am Vice President-Consumer and Customer Services for Pennsylvania Power & Light Company ("PP&L") and give this Affidavit in support of Applicants' Answer to NRC Staff's Motion for Summary Disposition of Contention 4. A summary of my professional qualifications and experience is attached as Exhibit "A" to this Affidavit. I am sponsoring that portion of this Affidavit which describes the impacts that solar alternatives will have on energy and sales projections.

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2. I, Preston L. Roberts, am Manager-Research and Technical Services for PP&L and give this Affidavit in support of Applicants' Answer to NRC Staff's Motion for Summary Disposition of Contention 4. A summary of my professional qualifications and experience is attached as Exhibit "B" to this Affidavit. I am sponsoring that portion of this Affidavit which describes various solar alternatives.

3. PP&L programs involving solar energy alternatives and the effects which those alternatives will have on PP&L's electricity demand and sales, are described in Exhibit "C" to this Affidavit, a document entitled "Applicants' Testimony of Grayson E. McNair [and] Preston L. Roberts on Contention 4D (Solar Energy Alternatives)", dated September 15, 1981. As shown in that document, PP&L has had and continues to have extensive programs relating to solar energy alternatives. However, solar energy cannot be expected to replace the need for Susquehanna.

Grayson E. McNair

Grayson E. McNair

Preston L. Roberts

Preston L. Roberts

Sworn to and subscribed before me this 22nd day of September, 1981.

Jean A. Smolick

Notary Public

JEAN A. SMOLICK, Notary Public
Allentown, Lehigh County, Pa
My Commission Expires May 14, 198_

EXHIBIT "A"

RESUME

OF

GRAYSON E. McNAIR

Q. Please state your full name and business address.

A. Grayson E. McNair, Two North Ninth Street, Allentown, Pennsylvania 18101.

Q. By whom are you employed and in what capacity?

A. I am employed by Pennsylvania Power & Light Company (PP&L) as Vice President-Consumer and Community Services.

Q. What are your responsibilities as Vice President-Consumer and Community Services?

A. I am responsible for the development and administration of PP&L's conservation and load management programs, customer services, rates, market research, customer-relation activities and economic and community development programs. I am also responsible for research andd development of ways the customer can more wisely use electric energy supplemented by alternate energy sources.

Q. What is your educational background?

A. I received a BEE degree from the University of Virginia in 1962; completed the Power Systems Engineering course in Schenectady, New York in 1967; became a registered Professional Engineer in the Commonwealth of Pennsylvania in 1968; completed several post-graduate courses in electrical engineering at Lehigh University; and was Visiting Lecturer in Electrical Engineering for three years at Lehigh Univer-

EXHIBIT "A" TO AFFIDAVIT OF GRAYSON E. McNAIR AND PRESTON L. ROBERTS

/'sity.

Q. How long have you been employed by PP&L and in what capacities?

A. I joined PP&L in 1962 as Graduate Trainee followed by assignment to Distribution Engineering in 1963 with responsibilities for design of overhead and underground 12 kv facilities. In 1964 I was transferred to the Relay and Control Engineering group and became Project Engineer in 1966, representing PP&L on the Conemaugh Relay and Communications Task Force for designing protective relaying for the 500 kv transmission lines. I was also Chairman of the Transient Stability Committee. In 1968, I transferred to the Interconnection Planning Section of the System Planning Department as a Project Engineer. After being a Senior Project Engineer, I was named Transmission and Distribution Planning Engineer in 1971 with responsibilities for long- and short-term planning of all electrical facilities operating at less than 230 kv. In 1975, I became Assistant Manager-Rates & Market Research. I assumed the position of Manager-Conservation Services in 1978. On January 1, 1980, I was appointed to my present position.

EXHIBIT "B"

BIOGRAPHICAL DATA

PRESTON L. ROBERTS

EDUCATION:

B. S. 1969 Pennsylvania State University

Major in Physics, Minor in Mathematics.
Studied in Aerospace Engineering curriculum for three years.

M. S. 1976 Villanova University

Electrical Engineering Program, specializing in Automatic Control.
Emphasis on Digital Control utilizing Microprogrammable Processors.

PROFESSIONAL DATA:

Registered Professional Engineer

Member. American Section of the International Solar Energy Society, Inc.; American Wind Energy Association (AWEA); American Society of Heating, Refrigerating and Air Conditioning Engineers; Association of Energy Engineers; Advance Conversion and Storage Task Force (EPRI); Utility Interface Standards Committee of AWEA; EPRI Passive Solar Utility Impact Assessment Project.

Board Member: Lehigh Valley Manpower Solar Utilization Economic Development and Employment Program; Lehigh County Community College Solar Curriculum Advisory Committee

EXPERIENCE:

1978 to Present - Manager-Research and Technical Services, Pennsylvania Power and Light Company

I am Manager, Research and Technical Services for Pennsylvania Power and Light Company, and am responsible for overall Company applications research into alternative and conventional energy technologies on both a residential and commercial/industrial level.

The thirty research projects my group is involved with range from a study to characterize the operating costs and efficiencies of commercially available electric residential space heating systems to a demonstration of solar repowering of an industrial steam process using high temperature tracking solar concentrating collectors.

EXHIBIT "B" TO AFFIDAVIT
OF GRAYSON E. McNAIR
AND PRESTON L. ROBERTS

EXPERIENCE: (con't)

1976 to 1978 - Applications Consultant, Consumer & Community Services, PP&L

I specialized in experimental HVAC design both residentially and commercially, electronic equipment design and applications, solar and photovoltaic applications. Accomplishments included design of supplemental energy storage systems and the first base load ice builder design concept for cooling of commercial buildings.

1974 to 1976 - Building Systems Engineer, General Office Building Operations, PP&L

Responsible for proper operation and design modifications to the electrical, mechanical and control systems in the General Office complex. I had direct supervisory responsibility for nine employees and coordination of work by outside contractors performing work in the General Office. I specified, and coordinated the installation of the computer based monitoring and control system for the General Office complex. I was also responsible for all technical training of Building Department employees.

1972 to 1973 - Sales Engineer, Powers Regulator Company, Phila., PA.

In this position I was responsible for control system applications and sales. My responsibilities included specification writing and application assistance to consulting engineering firms, coordination of system installations and customer training.

1969 to 1973 - Regional Automation Engineer, Powers Regulator Company, Phila., PA.

In this position I was responsible for the design and application engineering of all centralized digital control systems. The territory included all of the East Coast. I also developed training programs for in-house use and customer training. I was responsible for field installation coordination, purchasing of materials and start-up of systems.

EXHIBIT "C"

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
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PENNSYLVANIA POWER & LIGHT COMPANY	)	
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ALLEGHENY ELECTRIC COOPERATIVE, INC.	)	
	)	
(Susquehanna Steam Electric Station, Units 1 and 2)	)	

APPLICANTS' TESTIMONY OF
GRAYSON E. McNAIR
PRESTON L. ROBERTS
ON CONTENTION 4D (SOLAR ENERGY ALTERNATIVES)

September 15, 1981

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EXHIBIT "C" TO
AFFIDAVIT OF
GRAYSON E. McNAIR AND PRESTON L. ROBERTS

I. Introduction

PP&L is committed to the development and use of solar energy in its various forms.

This commitment includes the use of solar energy by PP&L's customers where it is in the best interest of the customer utilizing solar energy to reduce his energy costs, the cost to the utility, and to its other ratepayers.

The use of solar energy by PP&L customers can reduce future electricity costs for all utility customers if the need for additional utility generating capacity can be reduced or eliminated, or consumption of higher cost fuels such as oil can be reduced.

Meeting this goal is a much more complex problem than merely reducing an individual customer's conventional energy use through application of alternative energy forms.

In an effort to find ways in which solar can be of benefit to the customer, PP&L has a diversified, on-going research program investigating the various ways of best utilizing solar energy. The results of this research activity is shared with PP&L's customers and others through published reports, technical papers, customer consultation and advice, and the Company's various customer communications and programs.

Since 1973, the Company has spent over $1 million on solar research and $500,000 on wind research. This amount does not include PP&L's contributions for solar research to the Electric Power Research Institute. The 1980 Electric Power Research

Institute survey of electric utilities' involvement in solar energy research and demonstration shows PP&L to be third among all utilities nationally in the number of activities in solar energy (Ref. 1). PP&L is surpassed only by two utilities in California.

PP&L's research effort encompasses customer or dispersed applications and also utility central station generating applications of solar energy. Among these efforts are:

A. Active Solar Systems

1. The Schnecksville Energy Efficient Residence

This 1,600 sq. ft. research home was one of the first active solar heated homes constructed in the U.S.

Conceived in 1972-1973 and opened to the public in 1974, the Schnecksville unit utilized 200 sq. feet of flat plate collector and extensive heat recovery from waste heat along with innovative thermal insulation improvements to create a residence with extremely low operating costs.

With respect to the solar features of the home, it was found that:

a) South facing glazing was more cost effective for collection of solar energy than active solar space heating systems.

b) Solar assisted domestic water heating and solar assisted heat pumps were the most cost effective use of active solar.

2. The Bicentennial Homes

In this demonstration of residential solar technology in 1976, PP&L incorporated the best active solar features of the Schnecksville Energy Efficient Residence, principally solar assisted heat pumps and active flat plate domestic water heating, into five homes.

The most significant conclusion reached as to solar energy utilization was that solar water heating was far more cost effective than solar space heating.

3. Concentrating Solar Collectors

PP&L is investigating the potential for high temperature, concentrating type collectors for industrial and commercial process heating use. The study will focus on the performance of the systems in our service area which has large amounts of diffuse solar radiation. The Company plans to make its first test installation of about 100 kilowatts peak thermal output in 1982.

4. Solar Heat Pump Demonstration

The purpose of this demonstration project is to design, develop, install and monitor a heat pump system that uses refrigerant cooled solar absorbers as the heating evaporator and cooling condenser. The potential advantages of such a system are improved efficiency and direct utilization of solar energy by the heat pump for space heating. The project will test the potential demand and energy savings of such a system, which is designed to be operated without supplemental electric resistance heating. A prototype installation is now in place in Berks County. Final results of the testing are expected in 1982.

5. Low Temperature Grain Dryer

The installation of the grain dryer will help determine if solar energy can be used cost-effectively in agricultural applications. The project is designed to show that some solar applications can be placed into operation at a low installation cost and without the sophisticated hardware that is normally associated with active solar systems. The test installation is located on the farm of Arthur Wert, Mayor of Mifflinburg. Wert and the Vocational-Agricultural class of Mifflinburg High School built the solar collector with funding and instrumentation supplied by PP&L. It is scheduled to operate for two drying seasons with a final performance report expected in December, 1981. (Ref. 2)

This grain dryer represents a refinement of a PP&L concept tested in 1978-1979 on a farm in Montour County, Pennsylvania.

6. Photovoltaic Cells

PP&L has installed a photovoltaic cell array, capable of generating 1 kilowatt of electricity, at its Harwood Wind Electric Station near Hazleton. This installation consists of polycrystalline silicon photovoltaic cells. An additional array, consisting of cadmium sulfide thin film cells will be installed at the site during 1981, depending on cell availability. Through this project, PP&L is collecting data on peak and average array capacity, degradation of cell output related to environmental changes and other factors associated with this technology.

Since 1976, PP&L has funded research with major universities in the development of advanced photovoltaic devices and manufacturing techniques designed to reduce their cost.

7. Solar Availability

PP&L, in cooperation with Lehigh University, Bloomsburg State College, and Lehigh County Community College, is collecting data on solar availability at various locations within its service area. This data will be made available to customers planning solar installations, and it will be used to assess solar energy impact on electric service and as a basis for future solar research by PP&L. The three sites are in operation and collecting solar availability data with two more planned.

8. Solar Assisted Water Heating

PP&L is testing the long-term performance of solar assisted domestic water heating systems in homes, to determine the impact on electric load and the customer's energy cost. Since 1973 PP&L has designed and measured the performance of approximately 20 active solar assisted water heating systems.

9. Hybrid Solar Wall Panel

PP&L is testing the use of the panel as a low-cost technique for incorporating solar thermal collection, storage, and distribution into existing buildings. The panel, which uses phase-change material to collect, store, and distribute solar energy, is expected to reduce electrical space heating demand and save energy. The principal benefit of a phase-change material is that it can store 70 times more energy per pound than water at temperatures between about $20^{\circ}F$ and $130^{\circ}F$, reducing the physical size of thermal energy storage systems. Phase-change materials absorb large amounts of energy in changing from a solid to a liquid (change of phase) and release this energy as required for space heating by resolidifying.

B. Passive Solar Systems

Much current PP&L research emphasis is being placed on passive solar space heating technology including:

1. Passive Solar Home Research Project

PP&L coordinated construction of six passive solar homes in its service area which were open to the public in early 1981 and are now being occupied. This is the second largest utility sponsored passive solar program in the United States, surpassed only by the program initiated by the Tennessee Valley Authority, and has received wide acclaim within the solar industry. The Company is evaluating the potential of this solar technology as a load management tool. The Company hopes to demonstrate that passive solar space heating can be integrated effectively into electrically heated homes and PP&L's system. PP&L plans to monitor energy use in the homes for a 30 month period, after which it will make a final report available to the public.

2. Passive Solar Collection Using Phase-Change Salts

Two of the Company's passive solar homes will use heat pumps designed by PP&L that use phase-change salts as a method of storing solar energy. The system can store low-grade thermal energy collected from sunspaces and solar greenhouses during the day for use by the heat pump as required, eliminating the need for back-up electric resistance heat on-peak and allowing the heat pump to operate at maximum efficiency at all times.

3. Tannersville Service Center

PP&L is constructing a new area service center near Stroudsburg which has incorporated into its design a complete integration of passive solar concepts.

Included in the solar features of the building are natural lighting (commonly called daylighting) which reduces artificial lighting energy consumption, a convecting Trombe wall, and phase-change solar energy storage.

Many of the concepts embodied in the project are at the leading edge for the state-of-the-art in low energy use commercial buildings. Following suitable verification of the design elements, the features demonstrated at the Tannersville Service Center will be shared with architects and engineers in our service area for their consideration and inclusion in new commercial buildings.

C. Wind Energy

1. Harwood Wind Electric Experimental Station

The Company is continuing to monitor the electric energy produced by a commercially available 45 KW peak output downwind horizontal axis wind turbine at the Harwood substation site outside of Hazleton, PA. The asynchronous turbine, installed in 1978, is interconnected with PP&L's 12 KV distribution system through a D.C. to A.C. invertor incorporating battery storage. This is the prevalent means of interconnection among the nine customer owned wind electric systems in PP&L's service area.

This experimental installation has been constructed by PP&L to gain operating experience with equipment of the type utilizied by our customers. Out of this research facility we have learned much about the safety, performance, and electrical characteristics of small wind machines.

The knowledge gained has been shared with over 200 PP&L customers who have inquired about wind generation applications, over 35 utilities from across the U.S., and five foreign countries.

Unfortunately, the Harwood installation has not performed to our expectations, nor the manufacturers' claims. The power generated by the wind turbine has amounted to a disappointing 1-2% of its output capability. The potential in the wind at the Harwood site is 2,200 kilowatt-hours per square meter of rotor area per year. The wind turbine should be able to extract 15-18% of this available energy or about 48,000 KWH/yr.

An engineering study conducted in 1980 recommended several changes be made to the installation to improve performance. These changes are being made.

2. Assessment of Wind Potential

PP&L is undertaking a detailed study of the wind potential in the PP&L service territory. Through an innovative "computer mapping" technique developed by our engineering staff, PP&L can establish more precisely the wind potential of the service area and the best locations for wind generating systems. With this information, PP&L can better advise customers who are considering installation of these devices.

3. Wind Availability

PP&L, in cooperation with Lehigh University, Bloomsburg State College, and Lehigh County Community College, is collecting data on wind availability at various locations within its service area. This data will be made available to customers planning wind installations, and it will be used to assess wind energy impact on electric service and as a basis for future wind research by PP&L. The three sites are in operation and collecting wind availability data with two more planned.

II. Alternate Energy Resource Potential

Before the impact of solar energy on the need for conventional electrical energy and capacity can be determined, some assessment of the solar energy resource must be made.

As described above, PP&L has undertaken several research activities to determine the solar resource potential in our service area. The following discussion relates our findings to date.

A. Solar Radiation

The availability of solar energy determines in great part the economic viability of solar thermal applications.

Actual measurements of the daily amount of solar energy which is available to provide space and water heating, generate electricity through use of photovoltaic devices and generate steam for use in industrial processes are not available from any weather reporting station in our service area. All published data for major cities in central eastern Pennsylvania has been estimated using mathematical techniques.

Beginning in 1975, PP&L contracted with Lehigh University to conduct long term solar data gathering in the Allentown area. (Ref. 3)

The results of five years of data collection show the average annual total radiation on a horizontal surface to be 382,892 BTU/sq. ft. This is about 8% less than the 415,282 BTU/sq. ft. estimated for Allentown by the National Oceanographic and Atmospheric Administration (Ref. 4).

As a result, solar installations can be expected to save the customer less conventional energy than estimated. This has been observed in installations monitored by PP&L and others.

When the Lehigh University data is correlated to our recorded annual system peak load for the same years, we find that our peak day can be characterized as a one of high solar availability (clear, sunny skies) preceded by several days of low availability (cloudy or overcast).

The implications of this correlation is that the only solar technologies which could impact on our peak capacity requirements are those which can provide energy directly and immediately under the typical solar conditions observed. Since PP&L's annual peak typically occurs between the last two weeks in January and first two weeks in February near 10AM - 11AM only photovoltaics and direct gain passive solar technologies can impact at that time.

B. Wind Resource

Similar data collection has been and is being performed for wind energy potential, as previously described.

While wind energy potential is more site specific and fewer generalized conclusions can be reached, our work to date indicates that several small areas of our service area may have excellent wind energy potential. However, they are located in uninhabited, isolated locations.

Pennsylvania's prevailing winds are from the northwest. The mountains in our service area run generally from southwest to northeast. The best wind sites, therefore lie on the mountain ridges. Unfortunately, most of our customers live in the valleys which have very little wind energy potential.

C. Institutional Barriers

Although not related to the availability of solar energy, institutional barriers can impede the full development potential of the solar resources.

These barriers include:

1. The lack of reliable, trained installation and service organizations.
2. The overall complexity of active solar installations.
3. Restrictive zoning ordinances and state tax laws.
4. Reluctance of lending institutions to finance solar in new construction.

PP&L has made a concerted effort to create a utility environment where alternative energy development is not impeded. In fact, by removing rate restrictions, introducing special buy-back rates for electrical energy generated from alternative sources, working actively with our customers interested in solar applications, soliciting support of community planners and officials in alternative energy development projects, minimizing interconnection requirements for wind and other small producers, and investigating the best means of utilizing solar energy, PP&L is hoping to foster economical solar development.

III. Alternate Energy Development Potential

Active solar systems are currently the most widespread method of capturing and utilizing solar energy. Passive solar systems are gaining increased attention and are expected to play an increasingly important role in the future. For all types of solar systems, however, there exist practical limitations that preclude extensive market penetration before 1995.

A. Active Solar Applications

Of all dispersed solar technologies, flat plate active solar thermal is by far the most commonly used. As of December, 1979, it was estimated that over 275,000 square feet of flat plate collector was in place in Pennsylvania (Ref. 5). Almost 70% of this was installed in space heating and domestic hot water heating applications. The technology base for flat plate collector systems is nearly fully developed commercially. The costs of flat plate collectors and associated hardware are nearing a point where no further reductions due to economies of scale can be expected. The range of unit costs quoted by installers in our service area for flat plate collectors is currently approximately $27-$36 per square foot for commercially available systems (installed) including the 40% federal tax credits.

In work done by PP&L, in over 20 test installations since 1973, it has been demonstrated that the average energy collected on an annual basis by flat plate systems with water storage ranges from 25 KWH/sq. ft./yr. for space heating to 31 KWH//sq. ft./year for domestic hot water heating (Ref. 6, 7, 8). In a major study by Penn State University actual collection of solar energy for flat plate domestic hot water systems averaged 25.1 KWH/sq. ft./yr over Pennsylvania (Ref. 9). Based on these estimates of energy production and the previously stated installed costs, current life cycle costs for domestic hot water flat plate systems is estimated at approximately 21¢/kilowatt-hour with the 40% federal tax credit included (see calculation 1). When compared to PP&L's current average residential rate of approximately 4-1/2¢/kilowatt hour, flat plate active solar domestic hot water systems are not yet cost-effective. Similarly, the economics for active solar space heating are not favorable at this time. The customer cost for solar space heating is approximately 17.7¢ per kilowatt hour (see calculation 2).

Because of the current poor economics of solar hot water heating relative to conventional water heating we do not expect high saturations of active solar water heating in the time frame of 1980-1995. The impact of new water heating technologies such as the heat pump water heater developed by the Department of Energy which achieves energy savings comparable to solar water heating at a substantially lower cost ($900 installed vs. $1,800 for solar including tax credits) will tend to slow the growth of solar installation.

Likewise, the complexity and cost of active solar space heating will prevent substantial market penetration for this technology. The simplicity and favorable economics of passive solar space heating will make this the preferred technology for new homes which utilize solar energy for space heating. The majority of active space heating installations will be made in retrofit applications.

By 1995, we expect 6,000 homes with electric water heating will install active solar water heating and 1,500 homes will install active solar space heating, mostly as retrofits to existing homes.

B. Solar Concentrator Systems

Concentrating technology is seeing more frequent application especially where higher quality thermal energy, including steam is required. Concentrators are in a dynamic state of development with much work being done on reflector design, materials, etc.

A concentrating collector system requires large amounts of flat land. Several square miles would be required, for example, for a 100 megawatt plant. In the PP&L service territory, this would mean farmland, which is not likely to be eliminated for this purpose.

Relatively more land area is required in the northeastern U.S. than the southwest and other areas where this technology is being demonstrated. The reason for this is that Pennsylvania has larger amounts of diffuse solar radiation due to sunlight scattering from dust, pollutants, and absorption by water vapor, and smaller amounts of direct beam radiation required for concentrator systems.

No empirical data for concentrating type systems are available for PP&L's service area although PP&L is hoping to gain some operating experience from the solar concentrator demonstration project previously discussed under PP&L alternate energy initiatives. The U.S. Department of Energy has estimated the capital costs of a concentrator solar plant to range between \$2,760 to \$5,020 per kilowatt (Ref. 1[illegible]). This equates to approximately 12.8 to 15.1¢ per kilowatt hour levelized over the life of the plant. Again, this is significantly higher than current PP&L costs to generate electricity.

As a result, PP&L does not expect to see much development of solar concentrators until after 1995.

C. <u>Photovoltaic Technology</u>

Photovoltaic arrays have been used to supply power in remote locations and in space program applications. The primary drawbacks of photovoltaics are high costs and low efficiency, both of which were being addressed by several federal programs administered by the U.S. Department of Energy.

The General Electric Co., in a study of photovoltaic impacts on electric utilities for the Electric Power Research Institute indicates that photovoltaic power plant applications would require about 30 percent of all silicon produced annually in the U.S. to support a national goal of 1%-2% of total installed capacity in the form of photovoltaics by the year 2000. This is clearly not achievable without substantial increased production capability by manufacturers. This means that photovotaics must compete with the demands of the electronics industry for the existing silicon production capacity. (Ref. 11)

This same study indicates that current levelized busbar costs for photovoltaic technologies are approximately 14¢ to 25¢/KWH for a 100 megawatt plant. These costs are based on a 30 year life, but actual life expectancy is actually closer to 20 years. In dispersed residential applications costs are even higher due to the lack of economies of scale available in large installations.

D. Passive Solar Space Heating

PP&L expects that the largest solar potential will be realized in passive solar space heating applications.

We feel that the most cost effective applications of passive solar space heating will be the increased use of south facing glazing with some form of moveable night insulation to reduce heat loss through the glazing at night or on overcast days (a "Sun-Tempered Home"). Other homes will be built with more extensive passive solar treatment, similar to PP&L's passive solar research homes, which will generate greater savings than sun-tempering and have inherent ability through mass storage to qualify for time-of-day rate structures.

As an example of the savings which can be expected from the sun-tempering type of solar construction, for a 2000 sq. ft. home in Allentown with 120 sq. ft. of south glazing (80% of the total glass area) using night insulation, a homeowner can expect to save about $128/yr. at current rates (see calculation 3).

This analysis assumes that the night (moveable) window insulation is in place from about 5 PM to 8 AM during the winter months. This also assumes (from Balcomb) an R-9 moveable insulation (Ref. 11). In fact, the overall thermal resistance of the best night insulation is only R-4. This alone would reduce solar savings by 15% or $19/yr.

The above savings analysis also assumes adequate thermal storage mass exists in the home without need to add mass to store solar energy and minimize space temperature fluctuation. For the example given, mass storage of 30 lbs./ft.^{2} of south glazing would be required to keep daily space temperature swings to less than 10°F/day. The actual mass of a frame partition wall home would be only about 18 lbs./ft.^{2} The result of this low mass case would be very large daily temperature swings, on the order of 18°F.

To limit these space temperature swings to less than 10°F/day requires either an increase in thermal mass (at some cost) or a reduction in south glazing area to about 120 sq. ft. with a corresponding reduction in annual savings.

Based on the preliminary performance estimates for PP&L's six passive solar research homes, we expect that a passive solar home optimized on an economic basis can result in a demand savings of 3 KW/home on the winter peak and an energy savings of 6,000 KWH/yr. (Ref. 12)

There are costs associated with implementing passive solar space heating or suntempering. PP&L's Passive Solar Home Research Project resulted in the following average incremental construction costs:

Direct Gain (South Windows): $5.00/sq. ft. of glass
Night insulation (R4): $5.50/sq. ft. of glass
Trombe Wall Construction: $19.00/sq. ft. of trombe wall
Greenhouse: $42.00/sq. ft. of greenhouse floor area
Site Built Sunspace: $24.00/sq. ft. of floor area
Additional Insulation: $1,500/home

From this data construction costs for suntempering range from $3,000 to $6,000 and from $6,000 to $14,000 for a passive solar home.

We are forecasting that 5,000 passive solar homes using electrical space heating as a supplement will be in-place in our service area by 1995 and that an additional 10,000 electrically heated homes will be sun-tempered.

This corresponds to 8% to 12% of the new electrically heated homes expected to be constructed between 1980 and 1995 and assumes greater consumer acceptance of passive solar construction.

For a significantly greater number of homes to be constructed using passive solar technologies, several current barriers will have to be overcome.

One major barrier is zoning restrictions. Zoning restrictions would have to be changed to permit or require southern orientation in new construction and to protect solar access.

In a study of solar zoning for the City of Los Angeles, city planners concluded that zoning to protect solar access for single family construction would significantly reduce housing densities, increasing costs to the homeowner. The impact was much less severe for multifamily dwellings where more architectural and planning control by local zoning boards exists (Ref. 13). PP&L has attempted to address these issues in a document on energy efficient community planning sent to planners and zoning officials throughout our service area (Ref. 14). While PP&L can and has suggested ways to address these issues, their resolution rests with institutional and governmental bodies.

IV. Expected Impact of Alternate Energy Technologies on PP&L's Capacity and Energy Requirements

The combined demand for electrical energy from all customers determines, in large part, the installed generating capacity required to meet that demand. The greatest demands on PP&L's system occur between 7:00 AM and 9:00 PM which is defined as the "on-peak" period. The highest annual hourly demand for energy is defined as the annual system peak. The growth in this annual demand each year must be constrained to allow new capacity additions to be deferred.

The goal of PP&L's conservation programs, of which solar utilization is a component, is to reduce on-peak <u>demand</u> and electrical energy <u>use</u>. For example, the characteristics of solar utilization technologies, could, if planned only to reduce energy consumption, result in a higher demand.

Even though PP&L's peak day can be typically characterized as one of high solar availability, as previously stated, it is possible that in a given year the solar availability will be low on our peak day. For this reason solar energy cannot always be counted on to make a positive contribution to annual peak load reduction and therefore capacity requirements. Thus PP&L must either have available the capacity to supply the load on that day or be able to obtain the needed capacity from other generating sources.

Costs are currently the principal deterrent to widespread development of solar technologies. This conclusion has been confirmed in PP&L's own research and demonstration projects and by other solar investigators. This is evidenced by the need to offer tax credits and other financial incentives to make a technology, which cannot now compete with conventional energy sources, attractive to consumers. In addition, only passive solar, flat plate collectors, and wind energy systems have been developed commercially to the point where widespread application is possible.

Most other solar applications require energy storage to make the technology economical. However, once the customer has invested in storage, it may be cheaper for him to buy off-peak electrical energy under PP&L's time-of-use rate structures. The availability of these rate structures may actually discourage solar applications because the same economic advantage can be achieved through the time-of-use rates as for the solar system without the need to invest in solar equipment. For instance, when off-peak water heating is compared to solar water heating using PP&L's off-peak water heating rate provision, the average residential customer can realize economic savings better than those from a solar water heater for about one-sixth the initial cost of the solar system.

In addition, with time-of-use rates, the entire load is moved off PP&L's peak to a period when existing capacity is available. Even though the fuel consumed at the power plant is not saved, the individual rate payer achieves the same economic benefit as he would from investing in solar and the utility sees a real reduction in on-peak demand.

A. Active Solar Water Heating

The company expects active solar water heating to result in a demand reduction of 1 KW per installation and an energy savings of 2,500 KWH/yr. The total impact by 1995 is expected to be:

$$6{,}000 \text{ installations} \times \frac{1 \text{ KW}}{\text{installation}} = 6 \text{ MW saved}$$

$$6{,}000 \text{ installations} \times \frac{2{,}500 \text{ KWH/yr.}}{\text{installation}} = 15{,}000 \text{ MWH/yr. saved}$$

The demand savings quoted by the intervenors for owner built active solar water heating systems at 2 KW per unit (Ref. 15) is high. Based on our experience, the demand contribution to PP&L's peak from conventional electric domestic hot water heating is only about 1 KW.

B. Active Solar Space Heating

The average reduction in electrical heating energy demand through application of active solar space heating is approximately 2 KW/home and an energy savings of 5,000 KWH/home, based on our prior experience with the Schnecksville residence, the Bicenntenial Homes demonstration, and metered data from other active solar space heating systems in our service area. Based on our estimates of active system penetration by 1995 we expect to see a savings of:

Demand: $2 \frac{\text{KW}}{\text{home}} \times 1{,}500 \text{ homes} = 3 \text{ MW saved}$

Energy: $\frac{5{,}000 \text{ KWH}}{\text{home/year}} \times 1{,}500 \text{ homes} = 7{,}500 \text{ MWH/yr.}$

C. Passive Solar Space Heating

Based on our projections of development potential PP&L expects to realize savings from passive solar heated and sun-tempered homes of:

Demand

Passive Homes: 5,000 Homes x $\frac{3\ KW}{Home}$ = 15 MW saved

Suntempered Homes: 10,000 Homes x $\frac{1.7\ KW}{Home}$ = 17 MW saved

Total Demand Savings 32 MW

Energy

Passive Solar Homes: 5,000 Homes x $\frac{6,000\ KWH}{Home}$ = 30,000 MWH saved per year

Sun-tempered Homes: 10,000 Homes x $\frac{2,500\ KWH}{Home}$ = 25,000 MWH saved per year

Total Energy Savings 55,000 MWH saved per year

D. Wind Technologies

PP&L expects the savings from an estimated 250 installations of wind electric systems by 1995 to amount to a reduction in winter peak load (demand savings) of 1 MW and an annual energy savings of 750 MWH/yr.

E. Total Impact

The total expected savings from all solar technologies by 1995 is, therefore:

Technology	Demand Savings	Energy Savings
Active Solar Water Heating	6 MW	15,000 MWH/yr.
Active Solar Space Heating	3 MW	7,500 MWH/yr.
Concentrating Collectors	Negligible	Negligible
Photovoltaics	Negligible	Negligible
Passive Solar Space Heating	32 MW	55,000 MWH/yr.
Wind	1 MW	750 MWH/yr.
Total	42 MW	78,250 MWH/yr.

These projected savings are already included in our current load forecast.

It must be recognized that, even under the most optimistic projection, not all of these customers could be expected to follow PP&L's recommendations relative to solar energy alternatives. We also expect, however, that some customers will implement alternative energy technologies regardless of economic viability. Our long range forecast attempts to account for these factors.

Conclusions

In light of the activities described previously, and our consideration of solar energy's impact on energy and capacity planning, solar energy in its various forms has been adequately considered as an alternative to new capacity additions and conventionally generated electrical energy.

Solar energy cannot be expected to replace the need for the Susquehanna Steam Electric Station.

PP&L will continue to research solar technologies and develop sound programs to encourage practical solar utilization for the benefit of all it's customers.

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7) "Performance Analysis - Solar Systems in PP&L's Bicentennial Homes Demonstration Project:' R. Romancheck, PP&L. September, 1978.

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9) "Solar Systems Monitoring in Pennsylvania"; W. Aungst. Pennsylvania State University for the Northeast Solar Energy Center. May, 1980.

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11) Photovoltaic Power Plants Assessment: General Electric Corp. for the Electric Power Research Institute. June, 1978.

12) "A Passive Solar Research Project for an Electric Utility" P. Roberts, PP&L. Paper presented at ISES/Solar Rising Conference, May, 1981.

13) "Solar Envelope Zoning: Application of the City Planning Process"; City of Los Angeles for SERI, June, 1980.

14) "Energy Conservation Ideas for Community Planning"; PP&L, June, 1979.

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15) ECNP's Responses to Board's Memorandum and Order on Discovery Motions (II) dated January 18, 1980.

16) Procedings of the Second National Passive Solar Conference; paper presented by J. D. Balcomb, "A Simple Empirical Method for Estimating the Performance of Passive Solar Buildings", Volume II p. 377, March, 1978.

CALCULATION 1

Annual Water Heating Load for Family of four (4):
19.364 MMBTU (from p. 31)

$$\text{or } \frac{19{,}364{,}000}{3413 \frac{BTU}{KWH}} \frac{BTU}{yr.} = 5674 \frac{KWH}{yr.}$$

Annual Solar Savings from Solar:
27.46% (from p. 31)

$$\text{or } 5674 \frac{KWH}{yr.} \times 0.2746 = 1558 \frac{KWH}{yr.}$$

$$\text{or } \frac{1558 \frac{KWH}{yr.}}{60 \text{ sq. ft. collector}} = 26 \frac{KWH}{yr.\text{-}ft.^2}$$

Total cost of solar over 20 years = \$6,547 (from p. 31)
Total savings in energy over 20 years = $1558 \frac{KWH}{yr.} \times 20$ yrs.
= 31,160 KWH

Equivalent cost of energy saved from solar:

$$\frac{\text{Cost}}{\text{Energy Saved}} = \frac{\$6{,}547}{31{,}160 \text{ KWH}} = \frac{\$0.21}{KWH}$$

5 ALLENTOWN PA LATITUDE: 40.65

*** ACTIVE SYSTEM ANALYSIS ***

IME	PERCENT SOLAR	INCIDENT SOLAR (MMBTU)	HEATING LOAD (MMBTU)	WATER LOAD (MMBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
AN	22.48	1.49	0.0	1.645	1153.8	28.40
EB	28.18	1.54	0.0	1.485	997.2	30.20
AR	29.83	1.80	0.0	1.645	833.4	37.40
PR	26.30	1.65	0.0	1.592	453.6	50.00
AY	23.45	1.59	0.0	1.645	190.8	60.80
UN	24.96	1.52	0.0	1.592	21.6	69.80
UL	26.78	1.61	0.0	1.645	0.0	73.40
UG	30.22	1.69	0.0	1.645	5.4	71.60
EP	36.08	1.76	0.0	1.592	84.6	64.40
CT	40.30	1.95	0.0	1.645	343.8	53.60
OV	25.89	1.44	0.0	1.592	680.4	42.80
EC	15.27	1.24	0.0	1.645	1063.8	30.20
EAR	27.46	19.26	0.0	19.364	5828.4	

***

ECONOMIC ANALYSIS*

PECIFIED COLLECTOR AREA = 60. FT2

NITIAL COST OF SOLAR SYSTEM = $ 3000.

HE ANNUAL MORTGAGE PAYMENT FOR 10 YEARS = $ 345.

R	INTRST PAID	END OF YR PRINC	DEPRC DEDUC.	PROP TAX PAID	INC TAX SAVED	BACKUP FUEL COST	INSUR. MAINT COST	COST WITH SOLAR	SAVNGS WITH SOLAR	PW OF SOLAR SAVNGS
0	0	1800	0	0	0	0	0	1200	-1200	-1200
1	251	1706	0	59	109	172	29	498	-260	-234
2	238	1600	0	63	105	190	31	524	-262	-213
3	224	1479	0	67	102	209	33	553	-264	-193
4	207	1341	0	71	97	230	35	584	-267	-176
5	187	1184	0	75	92	253	37	619	-270	-160
6	165	1005	0	80	86	278	40	657	-273	-146
7	140	801	0	85	79	306	42	700	-277	-133
8	112	568	0	90	70	336	45	746	-282	-122
9	79	302	0	95	61	370	47	797	-286	-112
0	42	0	0	101	50	407	50	854	-292	-103
1	0	0	0	107	37	448	53	572	46	14
2	0	0	0	113	39	493	56	624	55	15
3	0	0	0	120	42	542	60	681	66	17
4	0	0	0	127	44	596	63	744	78	18
***										
5	0	0	0	135	47	656	67	812	92	19
6	0	0	0	143	50	722	71	887	108	20
7	0	0	0	152	53	794	76	969	125	21
8	0	0	0	161	56	873	80	1059	145	22
9	0	0	0	171	59	961	85	1158	167	22
0	0	0	0	181	63	1057	90	1266	191	23

HE DISCOUNTED RATE OF RETURN IS LESS THAN 0.0%

RS UNTIL UNDISC. FUEL SAVINGS = INVESTMENT 19.

UMULATIVE SAVINGS NEVER EXCEEDED THE 'MORTGAGE PRINCIPAL

NDISCOUNTED CUMULATIVE SOLAR SAVINGS = $ -2862.

RESENT WORTH OF YEARLY TOTAL COSTS WITH SOLAR = $ 6547.

RESENT WORTH OF YEARLY TOTAL COSTS W/O SOLAR = $ 3946.

RESENT WORTH OF CUMULATIVE SOLAR SAVINGS = $ -2600.

****READY*****

CALCULATION 2

Assumptions: See p. 33

Analysis includes savings for space heating using active solar.

Annual space heating load from p. 33

$$\text{Space heat: } 45{,}961{,}000\ \frac{\text{BTU}}{\text{yr.}} \div \frac{3{,}413\ \text{BTU}}{\text{KWH}} = 13{,}466\ \frac{\text{KWH}}{\text{yr.}}$$

Solar contribution to load (from p. 33) = 34.21%

The annual solar savings is:

$$13{,}466\ \frac{\text{KWH}}{\text{yr.}} \times 0.3421 = 4607\ \frac{\text{KWH}}{\text{yr.}}$$

The cost of the solar system over 35 years is:
$23,585 (from p. 34)

The equivalent cost per kilowatt-hour of energy saved by the solar system is:

$$\$28{,}585 \div \left(4607\ \frac{\text{KWH}}{\text{yr.}} \times 35\ \text{yrs.}\right) = \frac{\$0.177}{\text{KWH}}$$

2	IF .WHAT IS (FLOW RATE/COL.AREA)(SPEC.HEAT)?	2.15	BTU/H-F-F2
3	IF 2.WHAT IS (EPSILON)(CMIN)/(UA)?...........	2.00	
4	COLLECTOR AREA..................................	200.00	FT2
5	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.70	
6	FRPRIME-UL PRODUCT..............................	0.83	BTU/H-F-F2
7	INCIDENCE ANGLE MODIFIER (ZERO IF NOT AVAIL.)	0.0	
8	NUMBER OF TRANSPARENT COVERS.................	2.00	
9	COLLECTOR SLOPE.................................	60.00	DEGREES
10	AZIMUTH ANGLE (E.G. SOUTH=0. WEST=90)........	0.0	DEGREES
11	STORAGE CAPACITY................................	20.82	BTU/F-FT2
12	EFFECTIVE BUILDING UA..........................	420.00	BTU/F-HOUR
13	AVERAGE HOURLY INTERNAL HEAT GENERATION......	2000.00	BTU/H
14	HOT WATER USAGE.................................	0.0	GAL/DAY
15	WATER SET TEMP.(TO VARY BY MONTH. USE CT)....	140.00	F
16	WATER MAIN TEMP(TO VARY BY MONTH. USE CT)....	51.80	F
17	CITY CALL NUMBER................................	5.00	
18	ACTIVE PRINT OUT BY MONTH=1. BY YEAR=2.......	1.00	
19	ECONOMIC ANALYSIS ? YES=1. NO=2..............	1.00	
20	(UNUSED)..	2.00	
21	SOLAR SYSTEM THERMAL PERFORMANCE DEGRADATION.	0.50	%/YR
22	PERIOD OF THE ECONOMIC ANALYSIS..............	35.00	YEARS
***			
23	COLLECTOR AREA DEPENDENT SYSTEM COSTS........	55.00	$/FT2 COLL
24	CONSTANT SOLAR COSTS...........................	2500.00	$
25	DOWN PAYMENT(% OF ORIGINAL INVESTMENT).......	32.59	%
26	ANNUAL INTEREST RATE ON MORTGAGE..............	14.00	%
27	TERM OF MORTGAGE...............................	30.00	YEARS
28	ANNUAL NOMINAL(MARKET) DISCOUNT RATE.........	12.00	%
29	EXTRA INSUR.,MAINT. IN YEAR 1(% OF ORIG.INV.)	2.50	%
30	ANNUAL % INCREASE IN ABOVE EXPENSES..........	8.00	%
31	PRESENT COST OF SOLAR BACKUP FUEL (BF).......	12.31	$/MMBTU
32	BF RISE: %/YR=1.SEQUENCE OF VALUES=2(USE CF).	1.00	
33	IF 1. WHAT IS THE ANNUAL RATE OF BF RISE.....	10.00	%
34	PRESENT COST OF CONVENTIONAL FUEL	12.31	$/MMBTU
35	CF RISE: %/YR=1.SEQUENCE OF VALUES=2(USE CF).	1.00	
36	IF 1. WHAT IS THE ANNUAL RATE OF CF RISE.....	10.00	%
37	ECONOMIC PRINT OUT BY YEAR=1. CUMULATIVE=2...	1.00	
38	EFFECTIVE FEDERAL-STATE INCOME TAX RATE......	39.00	%
39	TRUE PROP. TAX RATE PER $ OF ORIGINAL INVEST.	2.00	%
40	ANNUAL % INCREASE IN PROPERTY TAX RATE.......	6.00	%
41	CALC.RT. OF RETURN ON SOLAR INVTMT?YES=1.NO=2	1.00	
42	RESALE VALUE (% OF ORIGINAL INVESTMENT).....	0.0	%
43	INCOME PRODUCING BUILDING? YES=1.NO=2........	2.00	
44	DPRC.: STR.LN=1.DC.BAL.=2.SM-YR-DGT=3.NONE=4.	1.00	
45	IF 2 WHAT % OF STR.LN DPRC.RT.IS DESIRED?...	150.00	%
***			
46	USEFUL LIFE FOR DEPREC. PURPOSES.............	20.00	YEARS

5 ALLENTOWN PA LATITUDE: 40.65

*** ACTIVE SYSTEM ANALYSIS ***

TIME ***	PERCENT SOLAR	INCIDENT SOLAR (MMBTU)	HEATING LOAD (MMBTU)	WATER LOAD (MMBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	20.50	5.43	10.142	0.0	1153.8	28.40
FEB	27.96	5.96	8.708	0.0	997.2	30.20
MAR	43.54	7.56	6.913	0.0	833.4	37.40
APR	76.96	7.72	3.132	0.0	453.6	50.00
MAY	100.00	7.98	0.435	0.0	190.8	60.80
JUN	0.0	7.64	0.0	0.0	21.6	69.80
JUL	0.0	8.26	0.0	0.0	0.0	73.40
AUG	0.0	8.20	0.0	0.0	5.4	71.60
SEP	0.0	7.75	0.0	0.0	84.6	64.40
OCT	94.01	7.70	1.978	0.0	343.8	53.60
NOV	36.39	5.34	5.418	0.0	680.4	42.80
DEC	16.51	4.48	9.235	0.0	1063.8	30.20
YEAR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

****ECONOMIC ANALYSIS****
SPECIFIED COLLECTOR AREA = 200. FT2
INITIAL COST OF SOLAR SYSTEM = $ 13500.
THE ANNUAL MORTGAGE PAYMENT FOR 30 YEARS = $ 1300.

YR	INTRST PAID	END OF YR PRINC	DEPRC DEDUCT	PROP TAX PAID	INC TAX SAVED	BACKUP FUEL COST	INSUR. MAINT COST	COST WITH SOLAR	SAVNGS WITH SOLAR	PW OF SOLAR SAVNGS
***										
0	0	9100	0	0	0	0	0	4399	-4399	-4399
1	1274	9074	0	269	602	372	337	1677	-1111	-992
2	1270	9045	0	286	607	410	364	1753	-1131	-901
3	1266	9012	0	303	612	452	393	1837	-1152	-820
4	1261	8974	0	321	617	499	425	1928	-1174	-746
5	1256	8931	0	340	622	[illegible]	459	2027	-1198	-680
6	1250	8882	0	361	628	[illegible]	495	2135	-1224	-620
7	1243	8826	0	382	634	669	535	2253	-1251	-565
8	1235	8762	0	405	640	738	578	2382	-1279	-516
9	1226	8690	0	430	646	814	624	2522	-1309	-472
10	1216	8607	0	456	652	897	674	2675	-1341	-431
11	1204	8512	0	483	658	989	728	2843	-1375	-395
12	1191	8404	0	512	664	1091	786	3025	-1411	-362
13	1176	[illegible]	0	543	670	1203	849	3225	-1449	-332
14	1159	8141	0	575	676	1327	917	3443	-1490	-304
15	1139	7981	0	610	682	1463	991	3681	-1533	-280
16	1117	7799	0	647	688	1613	1070	3942	-1579	-257
17	1091	7592	0	685	693	1778	1156	4227	-1627	-237
18	1062	7355	0	727	698	1961	1248	4538	-1678	-218
19	1029	7085	0	770	702	2162	1348	4878	-1733	-201
20	992	6778	0	816	705	2383	1456	5251	-1791	-185
21	948	6427	0	865	707	2628	1573	5658	-1852	-171
***										
22	899	6028	0	917	708	2897	1698	6104	-1918	-158
23	843	5572	0	972	708	3194	1834	6593	-1987	-146
24	780	5053	0	1031	706	3521	1981	7127	-2061	-135
25	707	4461	0	1093	702	3882	2140	7712	-2140	-125
26	624	3786	0	1158	695	4279	2311	8353	-2223	-116
27	530	3016	0	1228	685	4717	2496	9056	-2313	-108
28	422	2139	0	1301	672	5200	2695	9825	-2408	-100
29	299	1139	0	1380	655	5733	2911	10669	-2510	-93
30	159	0	0	1462	632	6319	3144	11593	-2619	-87
31	0	0	0	1550	604	6966	3396	11308	-1435	-42
32	0	0	0	1643	641	7678	3667	12349	-1489	-39
33	0	0	0	1742	679	8464	3961	13488	-1542	-36
34	0	0	0	1846	720	9329	4278	14734	-1594	-33
35	0	0	0	1957	763	10283	4620	16098	-1644	-31

THE DISCOUNTED RATE OF RETURN IS LESS THAN 0.0%
YRS UNTIL UNDISC. FUEL SAVINGS = INVESTMENT 23.
CUMULATIVE SAVINGS NEVER EXCEEDED THE 'MORTGAGE PRINCIPAL
UNDISCOUNTED CUMULATIVE SOLAR SAVINGS = $ -61988.
PRESENT WORTH OF YEARLY TOTAL COSTS WITH SOLAR = $ 28585.
PRESENT WORTH OF YEARLY TOTAL COSTS W/O SOLAR = $ 13232.
PRESENT WORTH OF CUMULATIVE SOLAR SAVINGS = $ -15353.

CALCULATION 3

CALCULATION:

Assumptions:

2,000 sq. ft. sun-tempered home in Allentown
Heatloss (design): 4 watts/sq. ft. @ $10^{\circ}F$
5800 degree days/yr. @ $65^{\circ}F$ Base
3800 degree days/yr. @ $55^{\circ}F$ base (accounting for improved thermal insulation and internal gains)
South Glazing equal to 6% of floor area or 120 sq. ft.
Insulated to R-30 ceiling
R-16 walls
R-19 floor over basement
double glazed windows
Design temp. diff.: $70^{\circ} - 10^{\circ} = 60^{\circ}F$

$$\text{Heat Loss} = \frac{\text{watts}}{\text{sq. ft.}} \times \text{No. sq. ft.}$$
$$= \frac{4\ \text{W}}{\text{sq. ft.}} \times 2{,}000\ \text{sq. ft.}$$
$$= 8{,}000\ \text{W}$$
$$= 8\ \text{KW}$$

$$\text{Annual Energy Consumption} = \frac{\text{Loss} \times \text{Degree Days/yr.} \times 24}{\text{Design Temp. Difference}}$$

$$= \frac{8\ \text{KW} \times 3800 \times 24}{60}$$

$$= 12{,}160\ \text{KWH/yr.}$$

The Solar Load Ratio passive performance estimating method developed by D. Balcomb defines the building load coefficient (BLC) as (Ref. 16):

$$\text{BLC} = \frac{\text{BTU Load}}{\text{degree days @ }65^{\circ}\text{F Base}}$$

$$\text{Load} = 12{,}160\ \frac{\text{KWH}}{\text{yr.}} \times 3413\ \frac{\text{BTU}}{\text{KWH}}$$

$$= 41{,}502{,}080\ \frac{\text{BTU}}{\text{yr.}}$$

CALCULATION 3 (Con't)

The building load coefficient then is:

$$BLC = \frac{41{,}502{,}080 \ \frac{BTU}{yr.}}{5800 \ \frac{D.D.}{yr.}}$$

$$= 7155.5 \ \frac{BTU}{D.D.}$$

The load collector ratio (LCR) is defined as:

$$LCR = \frac{BLC}{\text{Area of South Glazing}}$$

$$= \frac{7156}{120 \text{ sq. ft.}}$$

$$= 59$$

From tables of solar savings fraction (SSF) vs. LCR for Allentown using direct gain south facing glass we find that an LCR of 59 corresponds to an annual solar savings fraction of 25%. Therefore the annual savings in energy is:

12,160 KWH/yr. x 0.25 = 3040 KWH/yr.

or

Based on PP&L's average cost per kilowatt-hour for the trailing block of our Residential Rate (RS) the annual dollar savings is $128/yr.