A Technical and Policy Analysis of Building Integrated Photovoltaic Systems

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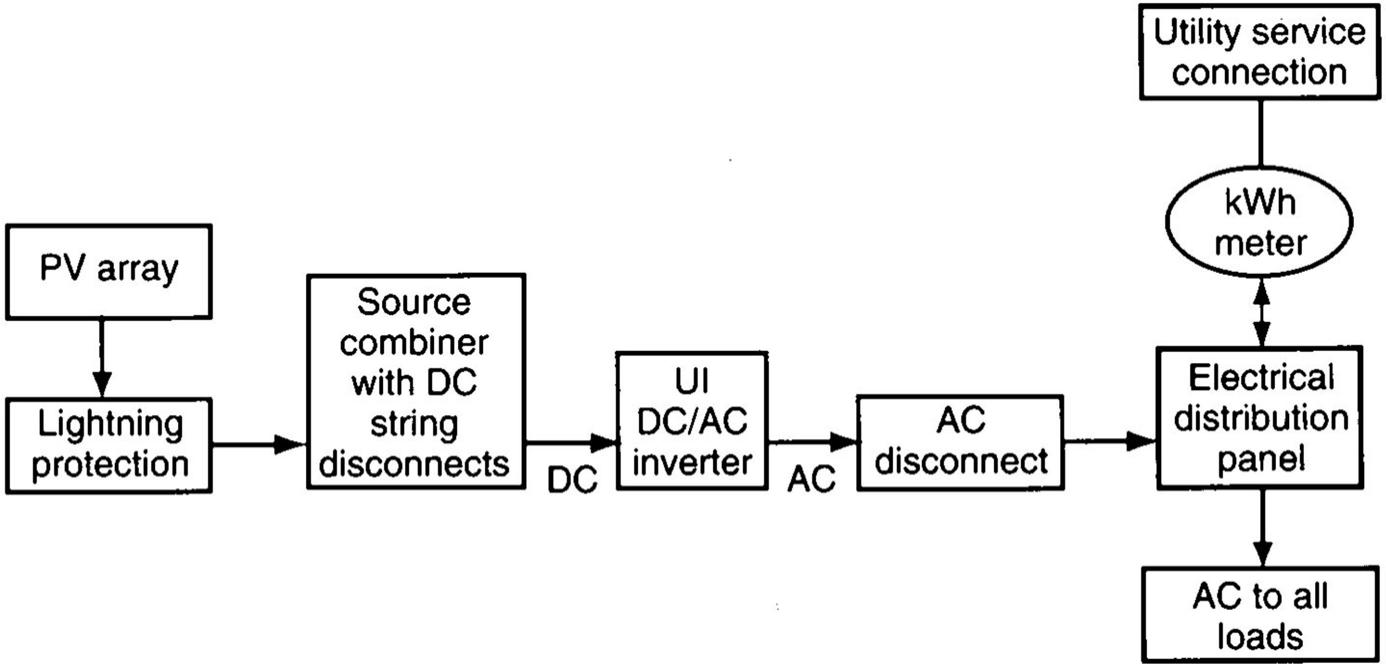
Objectives

- Define current and future BIPV systems.
- Analyze applicability of BIPV systems for commercial building applications.
- Model Commercial building energy use and BIPV energy production.
- Integrate the building and BIPV energy models. Most work on BIPV system has been done on the residential sector where the models are not integrated.
- Evaluate the effect of environmental externalities on system economics.
- Analyze the effect of BIPV systems on commercial building demand reduction.
- Investigate the economic impact of combining other system functions to BIPV systems.
- Estimate system economics in the near term and mid term.
- Provide a policy analysis of BIPV systems, i.e., that would promote the more rapid adoption of this technology to achieve energy and/or environmental benefits.

Overview of BIPV

- Building-integrated photovoltaics (BIPV) is a technology that allows buildings to generate all or a portion of their energy needs using photovoltaic (PV) panels that are an integral part of the structure.
- In BIPV systems the PV array is part of the building's roof, windows and walls. When PV panels are used as a portion of the buildings facade, they replace conventional building materials, and the PV system becomes less costly because of a reduction in the use of conventional building materials.
- Advantages of BIPV systems include:
  - Minimal environmental externalities during its operation.
  - Displacement of conventional building materials.
  - No additional land requirements.
  - Distributed modular power generation.
  - The elimination, or reduction of losses associated with transmission and distribution (T&D) systems.
  - Systems are reliable.
  - BIPV systems generate electricity on the customer's side of the meter, displacing energy at the retail rate.

Diagram of a BIPV Utility Interactive System



PV Panel Technology

- **There are two basic types of PV modules that make-up the majority of the commercial market:**
  - Single and multi crystalline silicon that has a typical output of 120 W/m^2 at standard test conditions (STC) of 1,000 W/m^2 and a 25^oC cell temperature.
  - Amorphous silicon is a thin-film material, with a typical output of 50 to 60 W/m^2 at STC, and is less expensive than single and multicrystalline cells.
- **Examples of PV materials under development include:**
  - Cadmium Telluride which is a thin-film polycrystalline material. Current efficiency is approximately 70 W/m^2 at STC with laboratory efficiencies approaching 16%.
  - Gallium Arsenide is a high-efficiency photovoltaic cell. In the laboratory efficiencies have reached over 25%.
  - Copper Indium Diselenide is a thin-film polycrystalline material with a laboratory efficiency that has reached 17.7%.

BIPV System Components

- PV panels that convert sunlight into direct current (DC) can be manufactured as an integral component of:
  - Curtain walls
  - Skylights
  - Atrium roofs
  - Awnings
  - Roofing
  - Semi-transparent PV windows
- Balance of system (BOS) components include:
  - Power conditioning unit to convert DC into AC power at the correct voltage and frequency
  - Backup equipment such as batteries or a generator
  - Control equipment that operates the system in accordance with safety standards and user inputs
  - Appropriate support and mounting hardware
  - Electrical switchgear and wiring

Policy Issues

- Electricity is used by more than 95% of U.S. commercial buildings and it serves lighting systems, office equipment, heating, ventilating and air conditioning (HVAC) equipment, domestic water heating and life safety equipment. Electricity is the dominant power source for building cooling and is the second most dominant energy source for building heating.
- Electricity production accounts for 33% of U.S. primary energy consumption.
- Most electrical energy production processes are a source of harmful air and water pollutants. These include, but are not limited to, electricity production from coal, natural gas and oil.
- Emissions of particulates, sulfur dioxide and nitrogen oxides are linked with human health effects and with the regional problem of acid rain. Increased atmospheric concentrations of greenhouse gases, especially carbon dioxide, are likely to alter the earth's climate system.
- A key goal of this research is to determine if BIPV system can play a role in U.S. energy supply over the next several decades.

Model Office Buildings

- Building Type – One, two and three story office building were modeled. The two story building represents the mean office building size in the US. These buildings include 95% of U.S. office buildings.
- A typical 60’ x 125’ footprint was used. Long dimension of building faces north and south.
- Occupancy - 7 people per 1000 sq. ft.
- Load Profile - ASHRAE profile
- Building construction and energy use will be modeled using standard engineering and architectural practice.
- Model Building Locations - Phoenix, Arizona; New York, New York; Los Angeles, California; Miami, Florida; and Reno, Nevada.
- Grid connected system.
- PV cells will be an integral portion of the roof.

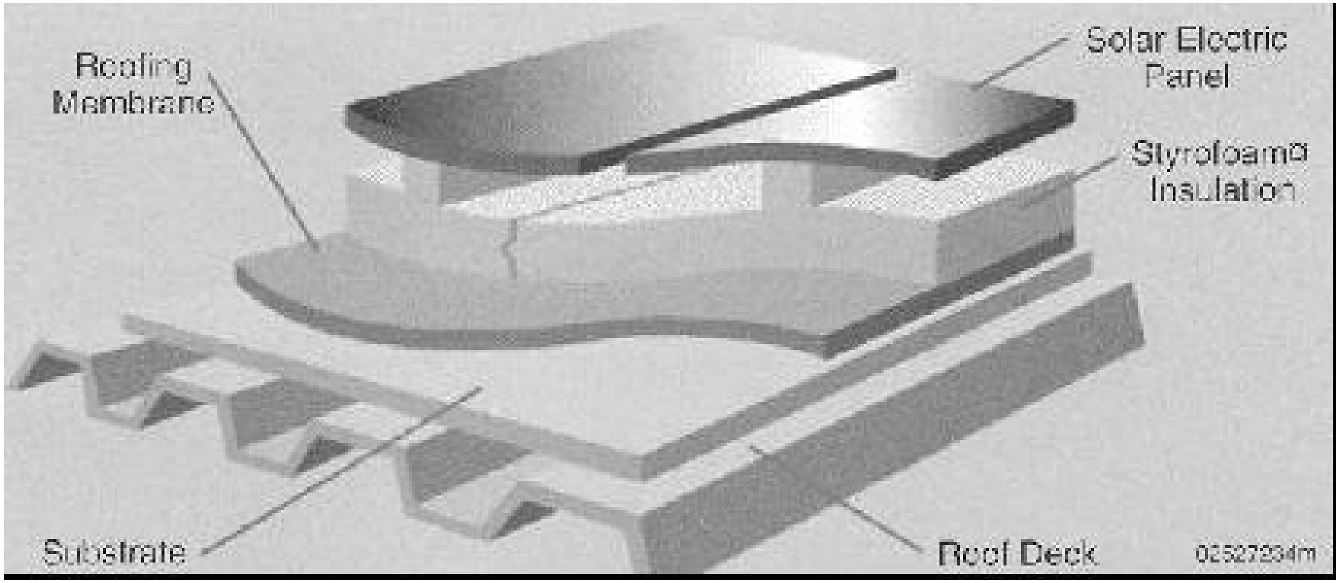
Overview of Energy Modeling

- Develop accurate building energy use models.
- Develop accurate BIPV output models.
- Integrate the above models to:
  - Analyze building peak power requirements and time of occurrence.
  - Quantify and analyze key office building base loads such as lighting, HVAC, domestic hot water production, plug loads and equipment loads.
  - Compare building loads to BIPV system power output.
  - Analyze the effect of building dynamics on building electricity use.
- Building energy modeling requires that a complete description of building construction and use be completely defined such as construction, location, occupancy, equipment and lighting.
- BIPV energy modeling requires that all characteristics of the system be defined such as PV panel characteristics, location and BOS components.
- This thesis uses detailed building and PV hourly energy models to analyze building energy use and PV outputs.

PV System Characteristics

- PV panels are standard thin-film a-silicon with a nominal 6% efficiency, and are PV panels are mounted on standard R-10 Styrofoam rigid expanded foam insulation.
- 780 panels (130 parallel strings) were modeled. The maximum power output of this array is 34.1 kW at 426 volts.

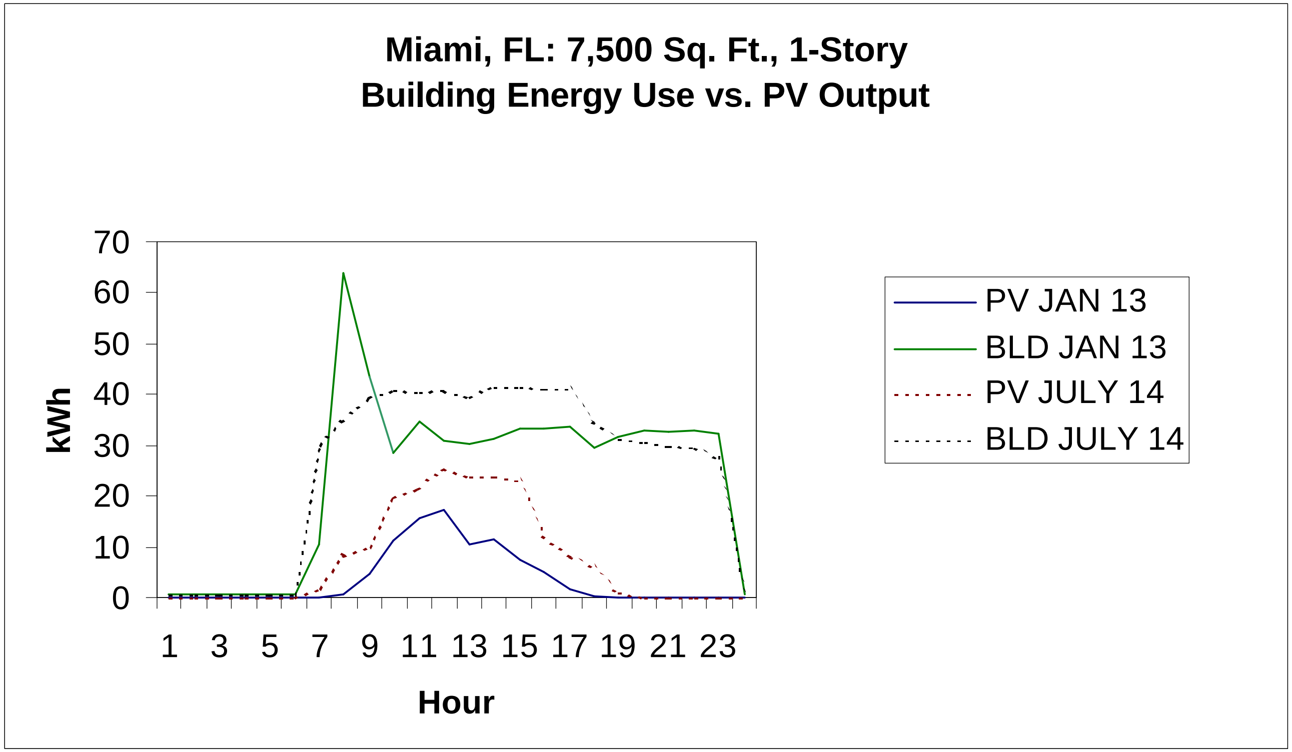
PowerLight PowerGuard BIPV system.



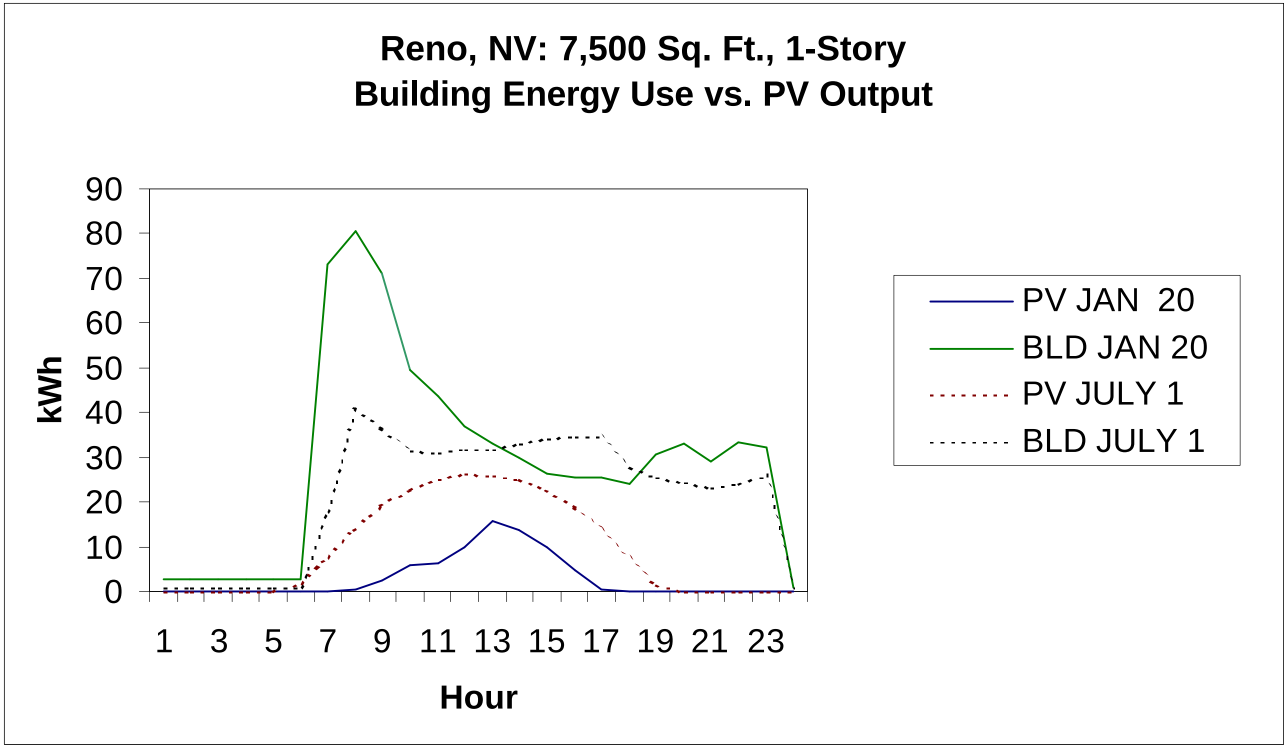
Building Energy Modeling Approach

- There are no tools available for general public use that integrate PV systems. Therefore the following was done:
  - Detailed hourly building energy use models for all five locations and three building sizes were performed.
  - Detailed hourly BIPV energy output models for all five locations and three building sizes were performed.
  - Results were analyzed and integrated to investigate the interaction of PV systems on commercial building energy use.
- All energy simulations included hourly power demand (kW) and total usage (kWh).
- Peak monthly electrical energy use profiles were were used to develop the term heating dominated climate and cooling dominated climates, which will be elaborated on later in this presentation.

Miami Load Profiles



Reno Load Profiles

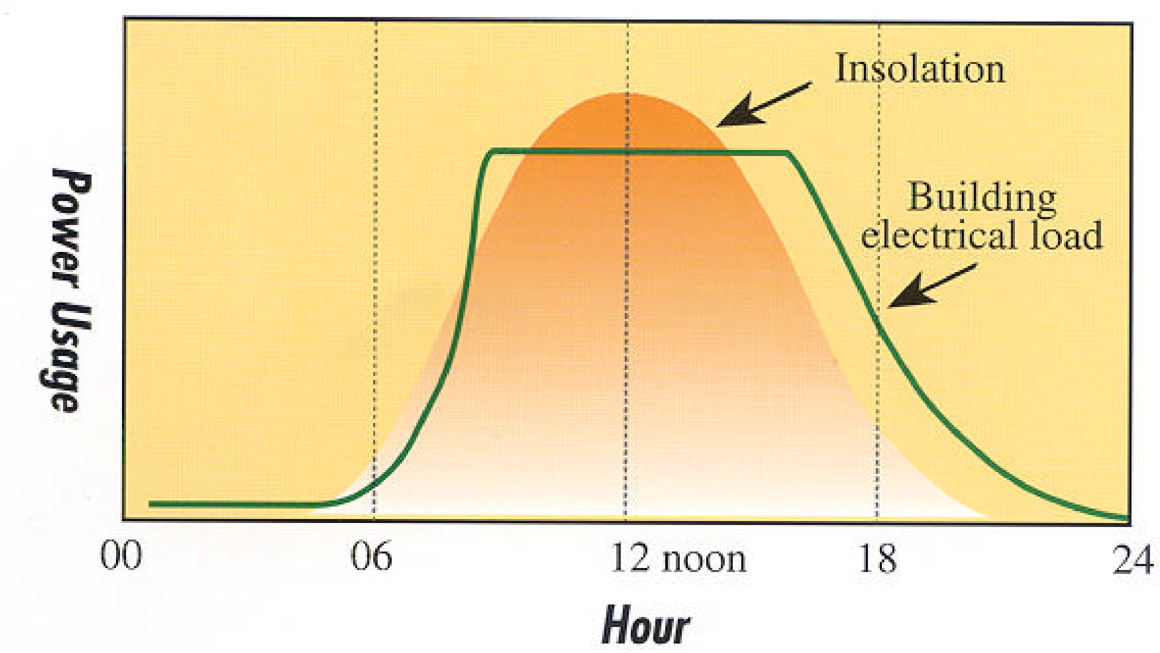


Key Results - Building Energy Simulation

- Buildings with high morning heating peaks year round are classified as heating dominated. These buildings have their peak demands in the morning year round. Locations included Los Angeles, New York and Reno.
- Buildings with winter only peak morning demands are classified as cooling dominated. These buildings have electrical demand profiles that do not have morning peaks during the summer. Locations included Miami and Phoenix.
- The morning peaks occurred because the HVAC systems were indexed from unoccupied to occupied.
- Height of building changed the energy usage in proportion to the added floors. The roof had very little influence on the building energy use.
- The building HVAC system accounted for the largest variability in the building hourly electrical usage.
- The PV system power output more closely tracks peak building energy requirements during warm weather than cold weather.
- BIPV systems had almost no effect on building peak demand reduction.

Hypothetical Demand Reduction

Building Electricity Use vs. PV Power Output



Demand Reduction

- As shown current studies assume that PV output closely follows building energy requirements. This research indicates that this hypothesis is not correct.
- To account for some of the BIPV demand offsets, the average effective load-carrying capacity (ELCC) was developed.
- The average effective load carrying capacity (the average % of the building load met by the PV array over a specified daily time interval) was analyzed by comparing hourly PV power output during the hours of 8 A.M. to 6 P.M. for the months of January, April, July and October to the hourly building peak power requirements occurring during these four months.
- The BIPV system was sized so that its power output does not exceed any of the predicted monthly building peak hourly demand profiles for all twelve months.

Economics - Methodology

- Actual regional electric rates were used in developing the economic models.
- Net present value was used to model the life cycle cost of the office building with and without the BIPV system. Several different discount rates were evaluated.
- Life cycle costs were evaluated with and without demand savings, and with and without environmental externalities.
- The BIPV system was evaluated over a system life that coincides with standard manufacture’s warranties.
- Effects of BIPV subsystems were reviewed and modeled.
- Effects of technological change and future price reductions were evaluated and modeled.

Utility Rates

- Electric rate structures were analyzed for each of the building locations.
- The lowest regional electric rate was used.
- In all of the electric rate structures reviewed, power companies calculated peak building demand as the maximum average kilowatt input over a 15-minute period.
- All of the electric rates were different by region.
- Power Companies

Power Company	Rate Schedules	Region Served
Arizona Public Service Company	GS and Individ. Solar	Phoenix, AZ
Southern Edison Power Company	GS-2 and TOU	Los Angeles, CA
Florida Power and Light Company	GSD and TOU	Miami, FL
Consolidated Edison Power Co.	GSL and TOU	New York, NY
Sierra Pacific Power Company	GS-2, PV and TOU	Reno, NV

Year 2000 BIPV Capital Costs

Component	Description	Cost $
Roof Insulation (savings)	Eliminate 7,500 Sq. Ft. 2” of Rigid Insulation	(7,500)
Power Conditioning Unit	Output Rating - 208/120 VAC, 50 kW	
	Trace Engineering	25,000
Photovoltaic Panels	PowerGuard BIPV System Rated 34.1 kW with	
	780 Solarex MST-43MV a-Si panels	105,000
	Roofing Rigid Insulation System	7,500
	Wiring/Installation	62,500
	Sub Total	175,000
Electrical Distribution	Disconnect and Wiring to Main Building Panel	5,000
Total System Cost		**$205,000**
Total Cost with Roof Insulation Credit		**$197,500**

Year 2000 Results

Range of BIPV Financial Results at a 6% rate of Return

Location	No Demand Reduction NPV $	No Demand Reduction $/kWh	With Demand Reduction NPV $	With Demand Reduction $/kWh	Breakeven Cost $
Phoenix, AZ	-150,100	0.40	-139,900	0.37	49,200
Los Angeles, CA	-161,600	0.46	-142,900	0.41	41,300
Miami, FL	-162,900	0.45	-147,800	0.41	40,800
Reno, NV	-164,900	0.45	-155,500	0.42	42,400
New York, NY	-152,200	0.64	-114,000	0.48	76,700

Other BIPV Benefits

- Adding some form of energy storage can enhance the benefits of a BIPV system. Adding battery storage to a BIPV system is considerably less expensive than purchasing a separate UPS system or emergency power system.
- Currently deep discharge lead-acid batteries are the most common source of power storage.
- With battery storage BIPV systems can also act as power supplies for:
  - UPS systems providing power to computers and other equipment.
  - Emergency lighting systems.
- BIPV systems can be combined with other uses that increase overall system efficiency. These systems generally use the PV panel as a heat and electricity source. Examples include the heating of water and air.
- An economic analysis was completed to compare the BIPV system payback for Miami, FL, New York, NY and Reno, NV. These three locations were chosen because they represent vastly different climates.

Results of Adding a UPS Systems to BIPV

Summary of BIPV System NPVs
Analysis Including Battery Storage (6%, 20 year life)

	Year 2000 BIPV Cost		*Year 2000 Base Case $*
Location	***50 kVA UPS***	***100 kVA UPS***	
Miami, FL	*-127,400*	*-118,400*	*-147,800*
Reno, NV	*-125,800*	*-116,900*	*-155,500*
New York, NY	*-93,400*	*-84,600*	*-114,000*

Overview of Environmental Externalities

- Externalities refer to costs or benefits that are borne by third parties who are not directly involved in a transaction.
- The focus is on externalities induced by environmental emissions.
- The burning of fossil fuels produces harmful gasses such as CO_2 and the six major air pollutants regulated by the U.S. EPA - particulate matter (PM_{10}), sulfur dioxide (SO_2), ozone (O_3), oxides of nitrogen (NO_x), lead (Pb) and carbon monoxide (CO).
- BIPV systems studied in this thesis have minimal externalities during the production of power.
- Aside from the environmental externalities from manufacturing, disposal and recycling of equipment, which are necessary for every technology, PV technologies produce no atmospheric emissions or toxic wastes during operation.
- Even when the emissions are included for the energy used to manufacture solar cells, PV generation produces 1/100 of the CO_2 of a conventional coal fired power.

Externality Costs for Conventional Electricity Production

- The US EPA environmental emission estimates for electricity generation by region are used in estimating the externality costs associated with each of the BIPV systems along with the U.S. EPA AIRS particulate emission rates of PM_{10}.
- The EPA's regional emissions rates for CO_2, SO_2, NO_x, and PM_{10} were used in conjunction with the Unit Social Damage Estimates (Lave, et. al.) to estimate the value of reducing externalities.
- Low, medium and high externality estimates were developed to parametrically estimate full cost accounting savings.
- The inclusion of externalities has the effect of increasing the cost of conventional power production compared to BIPV.

Model Building BIPV Emission Reductions

Location	Power kWh/Yr	CO_2 Tons/Yr	SO_2 Lbs./Yr	NO_x Lbs./Yr	PM_{10} Lbs./Yr
Phoenix, AZ	*40,980*	*24.6*	*99.4*	*135.5*	*9.0*
Los Angeles, CA	*37,006*	*22.2*	*89.7*	*122.4*	*8.1*
Miami, FL	*36,229*	*39.9*	*551.1*	*199.7*	*10.1*
Reno, NV	*35,500*	*21.3*	*86.1*	*117.4*	*7.8*
New York, NY	*31,310*	*26.6*	*234.7*	*89.7*	*12.1*

Year 2000 Results Including Externalities

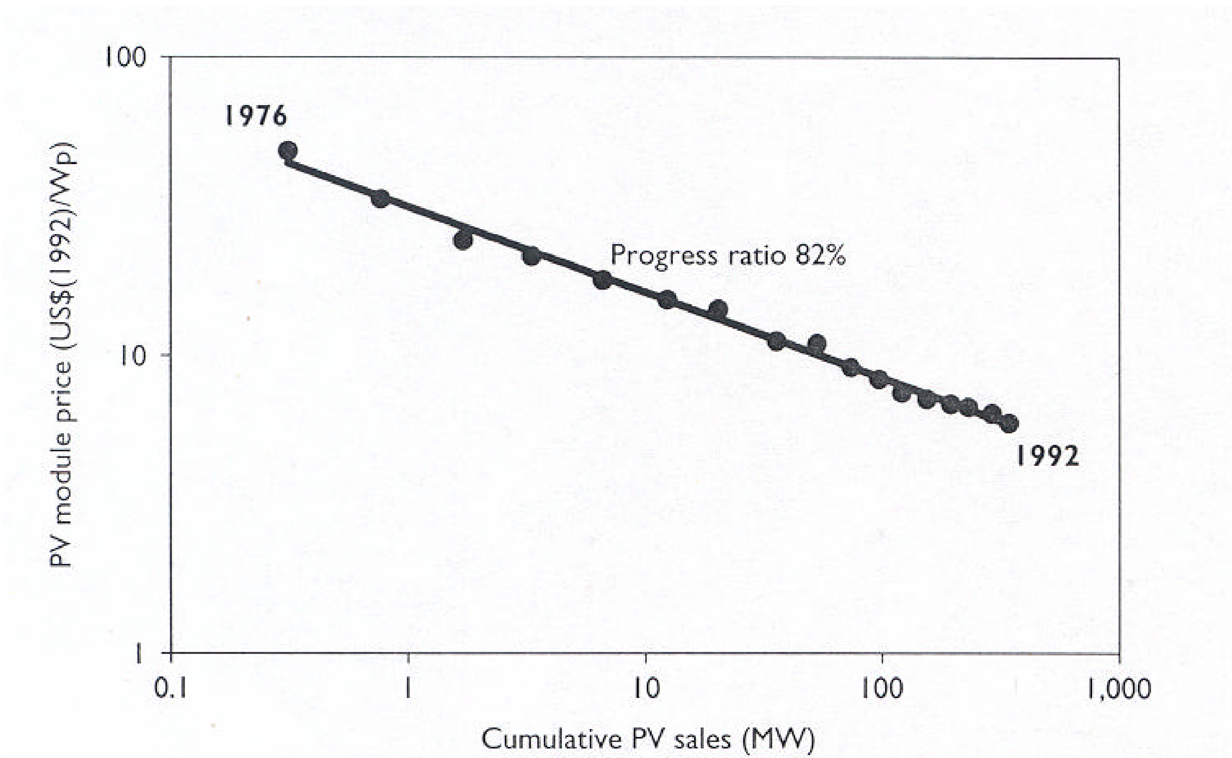
NPV of BIPV Systems for the year 2000
Including Externalities and Peak Demand Credits
(1 Story Building, 6% Real Return, 20 Year Life)

	NPV with Externality Adder $			Breakeven System Cost $	Breakeven No Externalities Cost $
Location	***Low***	***Medium***	***High***		
Phoenix, AZ	***-138,700***	***-135,600***	***-132,800***	***53,800***	***49,200***
Los Angeles, CA	***-146,300***	***-143,500***	***-140,900***	***45,400***	***41,300***
Miami, FL	***-144,200***	***-139,100***	***-134,600***	***50,000***	***40,800***
Reno, NV	***-145,300***	***-142,600***	***-140,200***	***46,300***	***42,400***
New York, NY	***-112,200***	***-108,800***	***-105,800***	***82,100***	***76,700***

BIPV Cost Trends

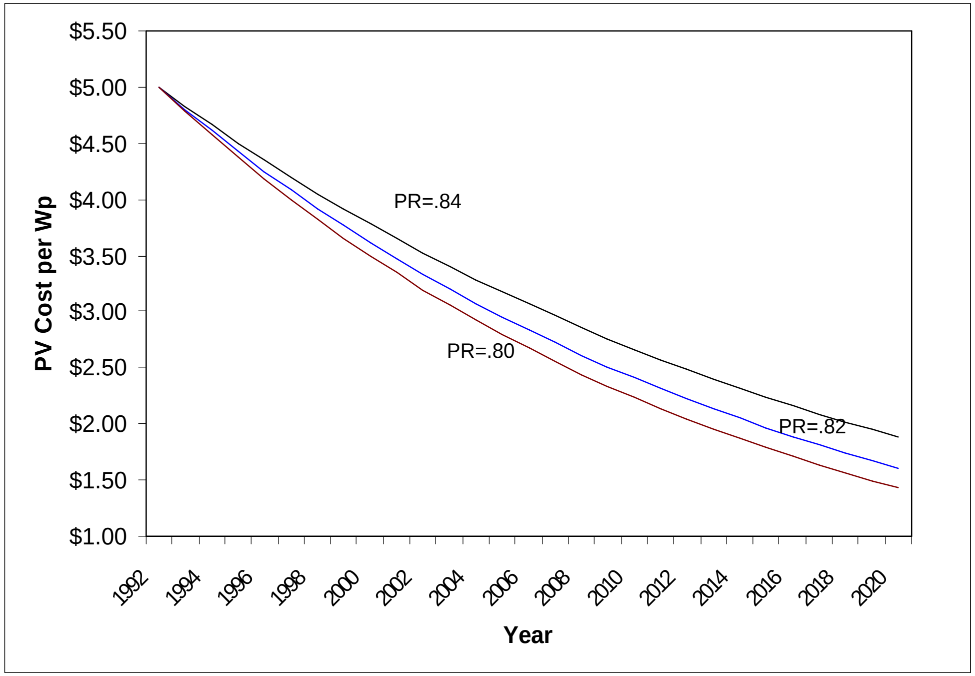
- There has been a sharp decline in the real cost of PV systems since their commercial introduction in the early 1970s.
- One of the methods that can be used to describe the overall decline in the price of PV technologies is an experience curve.
- Using historical data the experience curve for world-wide PV sales results in a progress ratio of 82%, meaning that price of PV modules is reduced to 82% of its previous level after a doubling of its cumulative sales.
- It is expected that PV modules will continue to decrease in price as cell efficiencies increase, and mass production techniques improve.
- Cost improvements are expected through increased cell efficiencies, reduced material use, new technologies, recycling and economies of scale.
- A review of the literature indicates that the total BIPV system prices should be approximately $4.00 per peak watt in 2010 for the system analyzed in this research.

Experience Curve



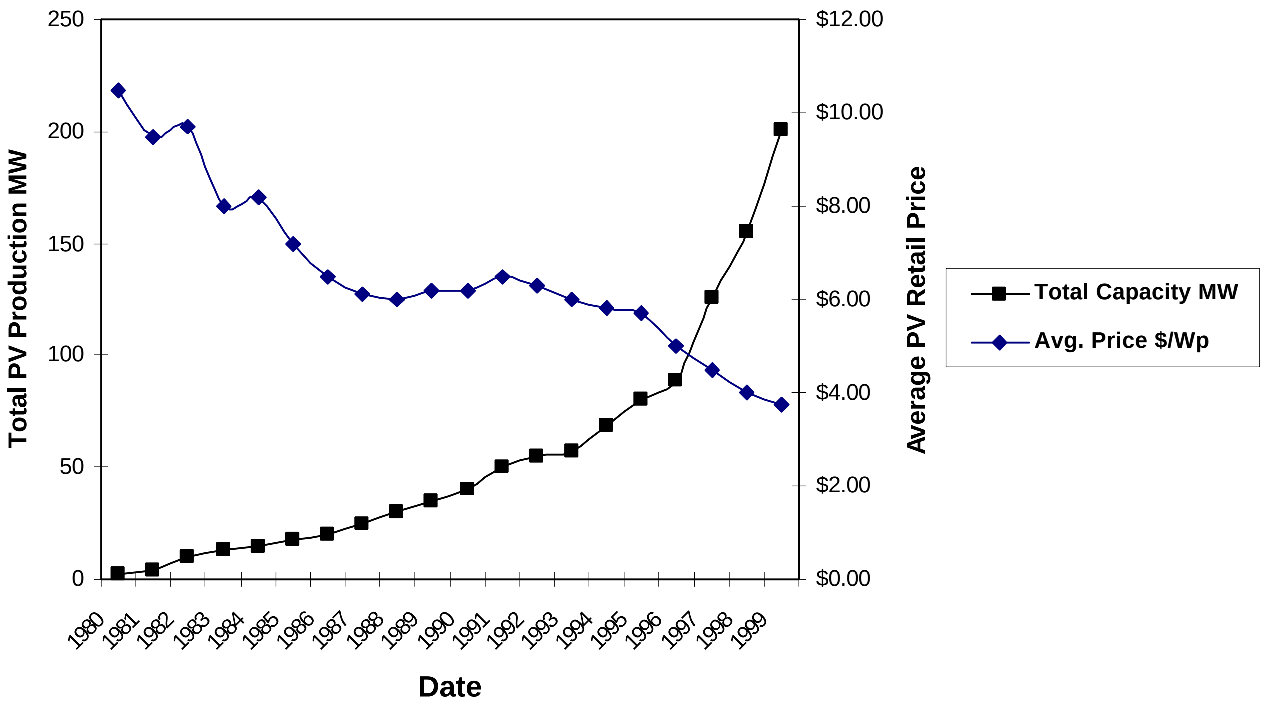
Progress Ratios

- The Figure below presents 3 different progress ratios (0.80, 0.82 and 0.84), at a 15% per year PV growth rate (base PV sales = 1992 worldwide PV sales of 340 MW_p). The data shown indicates that a small change in the progress ratio creates a moderate variation in future mid-term (i.e., 2015 to 2020) PV prices.



Historical Data

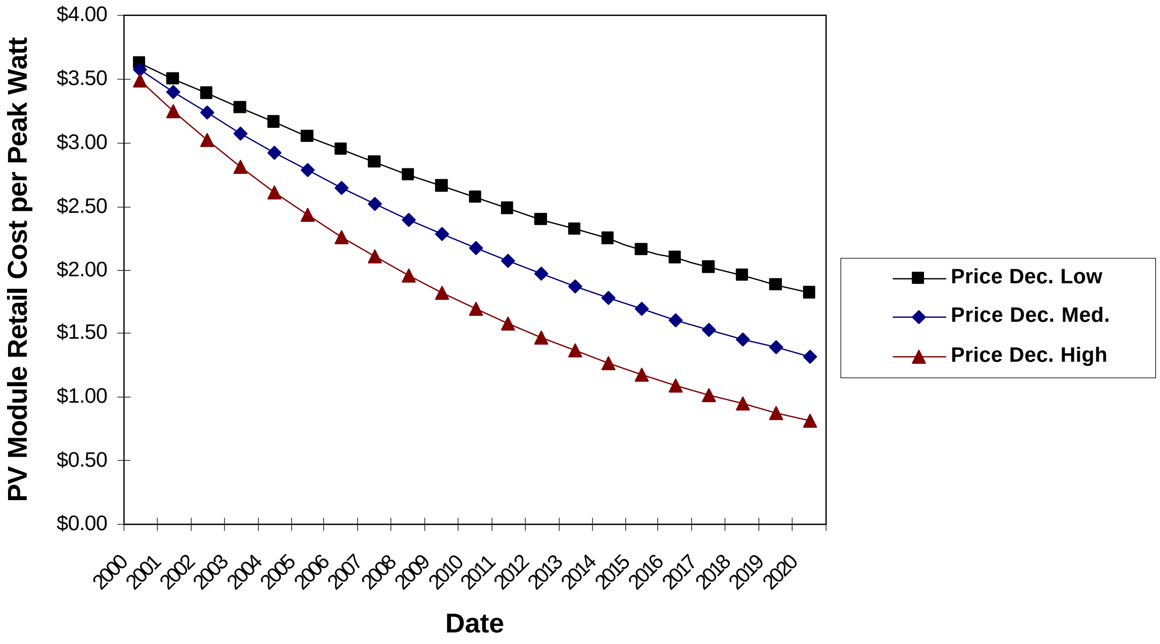
- Another method that can be used to estimate future PV prices is to extrapolate worldwide PV sales versus their price. The Figure below illustrates worldwide PV sales and their average retail prices.



Parametric Analysis of Future PV Price Trends

- To account for the uncertainty in future PV cell prices, the present value of future PV retail prices was calculated at low, medium and high price reduction factors.

Total PV Sales vs. PV Module Retail Prices (2000 Dollars)



Year 2010 BIPV Capital Costs

Component	Description	Cost $
Roof Insulation (savings)	Eliminate 7,500 Sq. Ft. 2” of Rigid Insulation	(7,500)
Power Conditioning Unit	Output Rating - 208/120 VAC, 50 kW Trace Engineering	22,500
Photovoltaic Panels	BIPV System Rated 34.1 kW with with a-Si panels	50,000
	Roofing Rigid Insulation System	7,500
	Wiring/Installation	50,000
	Sub Total Including Installation	107,500
Electrical Distribution	Disconnect and Wiring to Main Building Panel	5,000
Total System Cost		**$135,000**
Total Cost with Roof Insulation Credit		**$127,500**

Year 2010 Results

Summary of BIPV Financial Results for 2010

Location	No Demand Reduction NPV $	With Demand Reduction NPV $	With Demand Reduction $/kWh	Breakeven Cost $
Phoenix, AZ	*-80,900*	*-69,700*	*0.25*	*53,600*
Los Angeles, CA	*-95,300*	*-77,900*	*0.27*	*44,900*
Miami, FL	*-96,800*	*-81,800*	*0.28*	*40,800*
Reno, NV	*-97,100*	*-76,800*	*0.28*	*46,100*
New York, NY	*-86,100*	*-48,000*	*0.32*	*76,700*

Summary of BIPV System IRR
Analysis Including Battery Storage and 25-Year Life

Location	Year 2010 50 kVA UPS	Year 2010 100 kVA UPS
New York, NY	*3.67%*	*4.62%*

Year 2010 Results Including Externalities

NPV of BIPV Systems for the year 2010
Including Externalities and Peak Demand Credit
(1 Story Building, 6% Real Return, 20 Year Life)

	NPV with Externality Adder $			***Breakeven System***	***Breakeven System Cost $***
Location	***Low***	***Medium***	***High***	***Cost $***	***No Externalities***
Phoenix, AZ	***-68,500***	***-65,400***	***-62,500***	***58,200***	***53,600***
Los Angeles, CA	***-76,800***	***-74,000***	***-71,500***	***49,100***	***44,900***
Miami, FL	***-78,100***	***-73,100***	***-68,500***	***50,000***	***40,800***
Reno, NV	***-75,700***	***-73,000***	***-70,600***	***50,100***	***46,100***
New York, NY	***-46,100***	***-42,800***	***-39,700***	***82,100***	***76,700***

Year 2020 BIPV Capital Costs

Component	Description	Cost $
Roof Insulation (savings)	Eliminate 7,500 Sq. Ft. 2" of Rigid Insulation	(7,500)
Power Conditioning Unit	Output Rating - 208/120 VAC, 50 kW	
	Trace Engineering	$15,000
Photovoltaic Panels	BIPV System Rated 34.1 kW with	
	with a-Si panels	$37,500[a]
	Roofing Rigid Insulation System	7,500
	Wiring/Installation	35,000
	Sub Total Including Installation	$80,000
Electrical Distribution	Disconnect and Wiring to Main Building Panel	$5,000
Total System Cost		**$100,000**
Total Cost with Roof Insulation Credit		**$92,500**

[a] Assuming \$1.10 per W_p

Year 2020 Results

BIPV Financial Information at a 6% Rate of Return

Location	*NPV no Demand $*	*NPV w/ Demand $*	*$/kW*	*System Cost $*
Phoenix, AZ	***-41,200***	***-27,800***	***0.15***	***63,000***
Los Angeles, CA	***-58,500***	***-37,700***	***0.16***	***52,600***
Miami, FL	***-60,400***	***-42,300***	***0.17***	***47,600***
Reno, NV	***-60,700***	***-36,300***	***0.17***	***54,000***
New York, NY	***-47,500***	***-1,700***	***0.19***	***90,700***

Estimated Price Trends for BIPV Power

Location	***2000 $/kW***	***2010 $/kW***	***2020 $/kW***
Phoenix, AZ	***0.37***	***0.25***	***0.15***
Los Angeles, CA	***0.41***	***0.27***	***0.16***
Miami, FL	***0.41***	***0.28***	***0.17***
Reno, NV	***0.42***	***0.28***	***0.17***
New York, NY	***0.48***	***0.32***	***0.19***

Year 2020 Results Including Externalities

- Below is a summary of the results in year 2000 dollars for the year 2020. The NPVs outlined include the effect of peak demand reduction (system life is 30 years).

BIPV Financial Information for the Year 2020
(6% ROR, Including Externalities)

Location	*NPV with Demand $ (Externality) Low*	*Medium*	*High*	*System Cost $*	*System Cost $ No Externalities*
Phoenix, AZ	*-26,300*	*-22,600*	*-19,200*	*68,600*	*63,000*
Los Angeles, CA	*-36,300*	*-33,000*	*-29,900*	*57,600*	*52,600*
Miami, FL	*-37,900*	*-31,900*	*-26,400*	*58,700*	*47,600*
Reno, NV	*-35,000*	*-31,800*	*-28,900*	*58,800*	*54,000*
New York, NY	*470*	*4,500*	*8,100*	*97,200*	*90,700*

Parametric Analysis for 2020

- The PV systems were analyzed under favorable and unfavorable future conditions. In this research an unfavorable condition is considered to entail slower growth in the PV market resulting higher than expected pricing. Some mechanisms that could result in a slowing of PV growth include:
  - Reduced funding of basic PV research.
  - Other renewable technologies with a lower life-cycle cost are procured in lieu of PV.
  - Unfavorable regulatory conditions.
  - Changes in tax laws.
  - Loss or a reduction of current federal and state subsidies.
- Some favorable conditions that could result in increased PV sales and reductions of PV costs include:
  - Increased funding of basic PV research.
  - Favorable regulatory conditions.
  - Compliance with an International green house gas reduction standard.
  - Beneficial changes in tax laws.
  - Increases in current federal and state subsidies for renewable energy.

Analysis Results

BIPV Financial Information for the Year 2020
High Cost Scenario (6% ROR, $116,000 System Cost)

Location	*NPV no Demand $*	*NPV w/ Demand $*	*$/kW*
Phoenix, AZ	*-63,400*	*-50,000*	*0.19*
Los Angeles, CA	*-80,700*	*-59,800*	*0.21*
Miami, FL	*-82,500*	*-64,500*	*0.21*
Reno, NV	*-82,900*	*-58,500*	*0.22*
New York, NY	*-69,700*	*-23,900*	*0.28*

BIPV Financial Information for the Year 2020
Low Cost Scenario (4 & 6% ROR, $75,000 System Cost)

	NPV no Demand $		*NPV w/ Demand $*		
Location	*4%*	*6%*	*4%*	*6%*	*$/kW*[a]
Phoenix, AZ	*-13,800*	*-24,700*	*3,000*	*-11,300*	*0.12*
Los Angeles, CA	*-35,590*	*-42,000*	*-9,400*	*-21,100*	*0.13*
Miami, FL	*-37,900*	*-43,800*	*-15,211*	*-25,800*	*0.13*
Reno, NV	*-38,300*	*-44,200*	*-7,700*	*-19,800*	*0.14*
New York, NY	*-21,800*	*-31,000*	*35,800*	*14,800*	*0.15*

[a]At a 6% real rate of return.

Discussion of Bounding Analysis Results

- With stable utility costs, the analysis of BIPV economics for the year 2020 indicates that even with the inclusion of demand savings and externalities, BIPV power production will still be more costly in most U.S. regions than current conventional power generation technologies.
- The estimated cost per peak watt for the year 2020 roof-integrated BIPV system is $2.71. Total BIPV system costs of less than $2.20 per peak watt, which, corresponds to a cost of $75,000 for the system analyzed, are necessary to allow BIPV systems to become marginally cost competitive with conventional generation in some markets, and to make them self-sustaining in the market place (using 4% and 6% real rate of returns).
- These results indicate that net BIPV system costs will need to be less than $2.00 per peak watt for them to be self sustaining in most markets at low rates of return.
- Based on this trend, BIPV systems will not be cost competitive with conventional power production until some time after 2030 unless one or some of the following events were to occur:
  - Increases in fuel costs.
  - Pricing of electricity includes environmental externalities.
  - Rapid technological advancement.

Several Key Barriers to BIPV Use

- Initial cost barrier; PV systems require high initial investments despite their low operating costs. Also, the present supply and cost of fossil fuels, such as coal, oil and natural gas make electricity production from these sources less expensive than from PV sources.
- Market-related barriers; most renewable energy technologies are at an early stage of technological maturity and market penetration, and the amount of information available on resources and technology is limited, i.e., there is not widespread understanding of the modeling, use and design of PV systems.
- Lack of standard systems on the market.
- Lack of qualified system designers and installers – Increases design and installation costs.
- The failure to add the cost of fossil fuel environmental externalities such as global warming and pollution damage to electricity use charges.
- Lack of uniform standards on system integration with the electrical grid.

Policies Related to PV and Renewable Energy

- State based incentives for solar technologies - Include tax credits, sales tax exemptions, low interest or no interest loans, renewables portfolio standard (RPS) and grant programs.
- RPS - Is a requirement that a minimum percentage of each electricity generator's or suppliers resource portfolio come from renewable energy, and it includes two principal characteristics:
  - It specifies the minimum percentage of electricity that must come from approved renewable resources.
  - The standard permits renewable energy credits to be traded.
- The goal of the RPS is to provide a sustained orderly development of renewable energy technologies.
- A sustained orderly development is the key goal of the U.S. DOE PVMat program that provides subsidies to PV manufactures to develop new more efficient PV manufacturing processes, BOS components and PV cells. This is a cost-sharing program between the U.S. Federal government and PV and BOS component manufactures.
- An important state based program for adoption of BIPV systems has been net metering provisions, which credits the consumer the full retail rate of excess energy produced by their renewable energy system.

Policy Overview

- The following are several key policy strategies to reduce the cost of BIPV systems and increase their use:
  - Develop and disseminate advanced energy modeling software to accurately model the effect of a BIPV system on a structure’s predicted energy use.
  - Establish incentives such as RPS standards, low interest loans, tax rebates, etc., to increase the use of BIPV systems.
  - Provide a pricing mechanism to account for a BIPV systems ability to reduce building peak electrical demand.
  - Develop uses that could piggyback on BIPV systems, such as integrated UPS and emergency lighting systems.
  - Develop and exploit niche markets, i.e., such as the New York city region.
  - Price electricity at its full cost to society, i.e., include the cost of environmental externalities.
  - Increase public awareness of BIPV systems through public information, such as through energy labels.
  - Promote increased research and development of PV technologies to reduce the manufacturing cost of PV modules and increase their life.

Key Findings

- Peak PV hourly power production does not coincide with peak hourly commercial office building power consumption. The peak output of the PV system often is separated from building peak energy requirements by many hours.
- The results of this research indicate that BIPV power in the years 2000, 2010 and in most cases in 2020 are projected to be more expensive than current conventional fossil fuel or nuclear power production. It is likely that over the next 20 years, new niche markets or significant technological advances are required for PV systems to be cost competitive with conventional power production.
- Modeling tools are needed for performing detailed building energy simulations when buildings include PV systems. Tools need to be developed that allow the integration of PV system output in conjunction with building energy use.
- BIPV systems are not yet considered mainstream, and their design requires detailed analysis and research (i.e., resulting in high transaction costs).

Policy Recommendations

- Develop advanced energy modeling tools that integrate building energy simulation with PV system output.
- Develop a demand factor, that is a percent of the maximum BIPV systems rated output, and use this as a fixed monthly demand reduction factor.
- Include the cost of environmental externalities in energy prices.
- Fully exploit niche markets and develop sub-systems that can be economically combined with BIPV.
- Research projects need to be funded that develop dual function or triple function uses for PV panels, I.e., combining heat and power, or heat, power and lighting.
- Increase research and demonstration funding to accelerate increases in cell efficiency, system longevities and to reduce manufacturing costs.
- Reduce overall BIPV installed system prices by decreasing transaction costs, i.e., system installation costs can be reduced through training of electrical contractors. Also, provide consumer information, such as by including disclosure labels with electric bills. Most studies of consumer choice of power systems has shown that consumers will chose “cleaner energy”, i.e., renewables even if their cost is slightly more than that produced by conventional fossil fuel or nuclear plants.