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Renewable Energy Applications for Existing Buildings

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Renewable Energy Applications for Existing Buildings

Applicazioni dell'energia rinnovabile su edifici esistenti

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SUMMARY

This paper introduces technical opportunities, means, and methods for incorporating renewable energy technologies into building designs and operations. This paper provides an overview of renewable energy resources and available technologies used successfully to offset building electrical and thermal energy loads. Methods for applying these technologies in buildings and the role of building energy efficiency in successful renewable energy projects are addressed. Tips on implementing effective renewable energy projects are also provided.

RIASSUNTO

Questa memoria considera le opportunità tecniche, i mezzi e i metodi per incorporare le tecnologie ad energia rinnovabile (RE) nei progetti e nel uso degli edifici. La memoria fornisce una panoramica delle risorse RE e delle tecnologie disponibile utilizzate con successo per ridurre i carichi elettrici e termici degli edifici. Vengono considerati anche metodi per applicare queste tecnologie negli edifici ed il ruolo dell'efficienza energetica nell'edificio per progetti RE riusciti. La memoria offre anche suggerimenti per implementare progetti RE ben riusciti.

1. INTRODUCTION

Buildings account for approximately 40% of the worldwide annual energy consumption (WBCSD 2009). Total global energy consumption in 2007 was 495 quadrillion British thermal units (Btu), meaning the buildings sector consumed about 198 quadrillion Btu. According to the Energy Information Agency, worldwide energy consumption is expected to increase 1.4% per year through 2035, implying that buildings will consume 296 quadrillion Btu by the year 2035 (EIA 2010).

Fossil fuels meet a majority of world energy needs and because buildings are a large energy consumer, they are also a major contributor to global carbon emissions and greenhouse gas (GHG) production. It is now largely recognized that addressing energy use in buildings can reduce total fossil fuel consumption and associated GHG emissions. Benefits such as decreased building operational energy costs have prompted growing interest among policy makers, the technical community, and the general public in addressing building energy issues and investigating solutions for decreasing building energy consumption.

While energy efficiency is being incorporated into new construction, existing buildings account for a majority of the building stock that will be in place in the foreseeable future. In his 2009 presidential address, American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) presidential member Gordon Holness stated that 75% to 80% of the buildings that will exist in 2030 already exist today (ASHRAE 2010). This statistic suggests that there is an opportunity for reducing the building sector's contribution toward global energy consumption through reduction of energy use in existing buildings.

Reducing existing building energy consumption consists of two synergistic approaches: (1) to reduce the need for energy through implementation of energy efficiency measures and (2) to offset the remaining building energy needs through use of renewable energy systems (Figure 1). It is important to note that building energy efficiency measures should be considered first, as the cost to invest in efficiency measures is approximately half the cost of installing renewable energy generating capacity equal to what

the efficiency measures offset (IEA 2006). It is advised that all energy efficiency opportunities are explored and as many are implemented as is feasible before or in conjunction with renewable energy projects for existing buildings. It should be noted that this paper focuses only on the opportunities and issues surrounding implementing renewable energy projects for existing buildings.

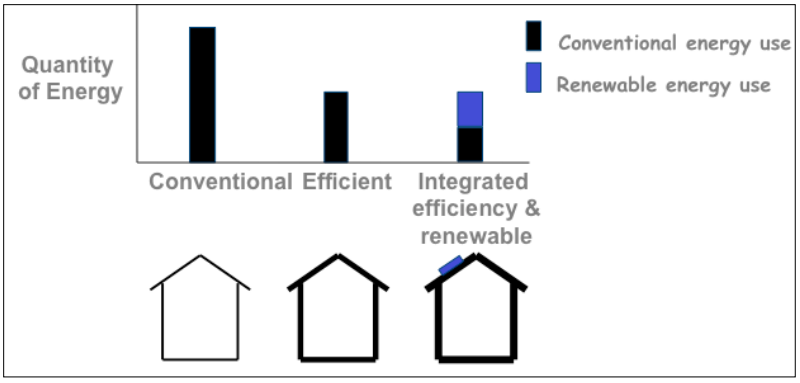


Figure 1. Demonstration of how combining energy efficiency and renewable energy strategies significantly reduce total building conventional energy use.
Source: National Renewable Energy Laboratory

National and local policy is being implemented in both developed and developing countries that require greater amounts of energy to come from renewable energy resources. For example, the 2009/28/EC Renewable Energy Sources (RES) Directive requires that 20% of energy produced within the European Union is from renewable energy systems by 2020 compared to 2010 (European Union 2009). Also, the 2002/91/ED Energy Conservation in Buildings Directive requires building energy labeling and sets standards for energy performance, including application of renewable energy resources (European Union 2002). As policies such as these are enacted, incentives for installing renewable energy systems are also being developed and regulatory barriers are being removed. The use of renewable energy systems for meeting building energy needs is also becoming a means for demonstrating leadership in environmental sustainability and resource conservation, increasing the reliability of on-site electrical and thermal energy supplies, addressing energy security issues, and other benefits. These actions are encouraging those who are making decisions regarding existing building retrofit projects to seek out ways to use renewable energy systems to meet sustainable building goals. In addition, these actions encourage those who are paying for the energy use associated with these buildings to explore using renewable energy systems as a means to reduce utility costs, and in many cases, the building's carbon footprint.

2. RENEWABLE ENERGY RESOURCES AND TECHNOLOGIES

Renewable energy resources commonly used for building applications include solar, wind, geothermal, and biomass. Before selecting an appropriate renewable energy technology to apply to an existing building retrofit project, it is important to first consider a number of factors. Examples of these factors include:

- Available renewable energy resource at or near the building site
- Available area for siting of the renewable energy technology
- Cost of energy purchased from the electrical or thermal energy provider for the building
- Available incentives for offsetting the installation cost of the renewable energy system
- Local regulations affecting renewable energy systems
- Desire to preserve or not alter existing architectural features
- Characteristics of the energy profiles to be offset by the renewable energy installation.

European renewable energy resource data are available through organizations such as the Global Energy Network Institute (GENI 2007). Renewable energy resource maps are a starting point to determine if a building site is located in an area with acceptable amounts of renewable energy resource. However, other factors such as the cost of alternative energy sources and available local incentives for renewable energy installations often make installing renewable energy systems cost effective even if the resource is not ideal. For example, Germany leads Europe in solar electric system installations with 5,351,000 megawatts peak (MWp) of cumulated installed capacity in 2008, yet, most of the country has a modest average annual solar resource of less than 1,000 kilowatt hours per square meter (kWh/m^2). Italy, on the other hand, has a solar resource ranging from modest to very good (between 900 and 1,800 kWh/m^2) and has 317,500 MWp installed solar electric capacity as of 2008 (**EurOberv'ER 2009)**. See Figure 2 for a comparison between solar resources in Germany and Italy. This example illustrates how factors other than renewable energy resource influence decisions to install solar electric systems.

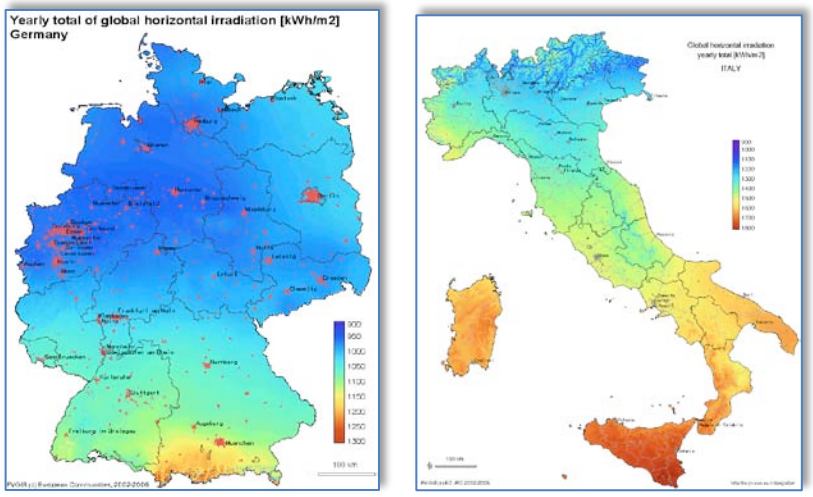


Figure 2. Solar resource maps for Germany and Italy.
Source: GENI 2007 (GIS PV/© European Communities)

Examples of renewable energy technologies that can be incorporated with building energy systems include:

- Solar electric, or photovoltaic (PV), systems
- Solar thermal, including solar hot water (domestic water heating and space heating), and solar ventilation air preheating
- Geothermal heat pump
- Wind turbines
- Biomass systems.

More information on each technology is provided in the following sections.

2.1. Solar Electric PV

PV arrays convert sunlight to electricity. Systems are made up of modules assembled into arrays that can be mounted on or near a building or other structure (Figure 3). A power inverter converts the direct current (DC) generated by the system into grid-quality alternating current (AC) electricity.



Figure 3. The Williams Building in downtown Boston, Massachusetts. 372 modules were installed for a total system capacity of 31 kW.
Source: Photo from SunPower, NREL/PIX 08466

Traditional single crystal solar cells are made from silicon, are usually flat-plate, and are generally the most efficient (the solar cell efficiency is an indicator of how well it converts sunlight to direct current electricity). Multi-crystal solar cells are a similar technology but slightly less efficient. Thin-film solar cells are made from amorphous silicon or non-silicon materials such as cadmium telluride. Thin-film solar cells use layers of semiconductor materials only a few micrometers thick. See Table 1 for an overview of module efficiencies for each type of solar cell.

Table 1. Typical Efficiency of Different Types of PV.

Module Efficiencies	Single crystal	14–19%
	Multi-crystal	13–17%
	Thin film	6–11%

Building-integrated photovoltaic (BIPV) products may be appropriately suited for applications on existing buildings during major renovations. These technologies can double as rooftop shingles (single-ply membrane, standing seam metal roofs, and others.) and tiles, building facades, or the glazing for skylights (NREL 2009). Figure 4 shows an example of this technology integrated into shingles. In some cases, BIPV can add cost and complexity to a project and may not be universally available, but may help enhance acceptance of a project on a visible surface.



Figure 4. Thin-film solar PV shingles.
Source: Photo from United Solar Ovonic, NREL/PIX 13572

Most PV systems installed today are in flat-plate configurations, which are typically made from solar cells combined into modules that hold about 40 cells. A typical American home will use about 10 to 20 solar panels to power the home. Many solar panels combined together to create one system is called a solar array. For large electric utility or industrial applications, hundreds of solar arrays are interconnected to form a large utility-scale PV system (NREL 2009). These systems are generally fixed in a single position but can be mounted on structures that tilt toward the sun on a seasonal basis or on structures that roll East to West over the course of a day (NREL 2011) Figure 5 shows the components of a typical PV system.

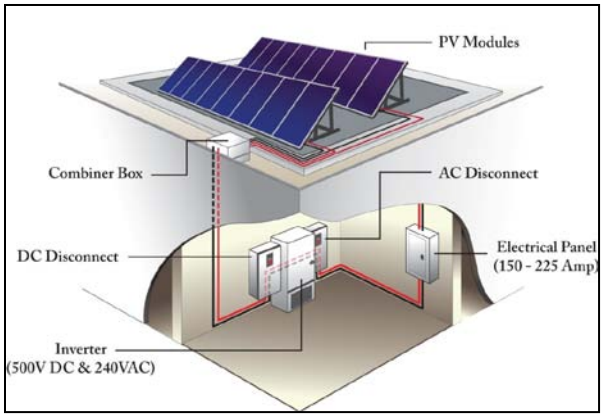


Figure 5. PV system components.
Source: Illustration by Jim Leyshon, NREL

There are typically three scales of solar installations: utility-scale, commercial, and residential.

- Utility-scale installations are very large arrays located on open lands, and provide power for hundreds or even thousands of homes and businesses.
- Commercial systems are smaller and may provide power for multiple or single commercial or municipal buildings on campuses, in complexes, neighborhoods, or other special districts.
  - Commercial-scale systems offer potential advantages for locating solar PV. Rather than attempting to find appropriate locations for solar panels on individual structures, a commercial-scale system might be located in a less visible or impactful location, such as above a parking structure or on an open lot. Power can be lost in transmission from these arrays to the end-use location, however, so distances need to be minimized.
- Residential-scale PV systems produce power for use on a single property.

The major challenge with siting solar PV technologies is ensuring appropriate siting for maximum electricity production. An ideal solar installation would be situated in an unshaded, south-facing location with an optimum tilt angle, and would supply electricity to a site where there is a demand for the electricity being produced. Not all sites are suitable for solar technologies, however. The following guidelines may be helpful in determining when solar technologies are appropriate for a site:

- Identify an unshaded area for solar PV installation, particularly between peak sun hours occurring during the middle part of the day, for example between 9:00 and 15:00. Shade will reduce the output of a solar panel and is commonly caused by trees, nearby buildings, and roof equipment or features (such as chimneys).
- Orient fixed-mount panels due South in the northern hemisphere and due North in the southern hemisphere. Siting panels so that they face East or West of due South/North will decrease efficiency. However, that effect varies by location, and could be minimal.
- Maximize the annual energy production from a fixed-mount PV system by tilting the array to approximately match the lattitude of where the system is located. For example, a system located at 40° north latitude shoud be tilted at approximately 40° for maximum annual efficiency.
- Install fixed-mount solar panels on roofs (flush- or tilt-mounted), or on the ground, (pole-mounted), or integrate into building materials, such as roofs, windows, and awnings. However, a desired tilt angle is not always feasible because of factors such as roof pitch, wind, or snow

loading considerations. It is possible to install panels at a different angle. The impact of a non-ideal tilt angle varies by location, and could be minimal.

- Obtain a thorough understanding of the size and nature of an electric load to properly select and size a PV system. PV systems can be designed to provide power simultaneously with the utility (grid-connected); independent of the utility (stand-alone, with batteries); or to do either (dual mode). The systems can be designed to power any percent of an electric load, from a very small percentage to over 100% of the load, depending on available area for the panels, sun availability, and allowances provided by utility policy to sell the energy back to the utility. When considering a system that will be tied to the utility grid, or grid-connected, it is essential to understand the applicable standards and rules for the serving electric utility company.
- Keep in mind the difference in efficiency of various PV modules. Efficiency is more important to consider than the available or required area of the PV system. Fewer modules made of a higher efficiency cell (such as single crystalline) would be needed for approximately the same power output as more modules made of a lower efficiency cell (such as thin film). Therefore, if a project location has limited space, then a higher efficiency, and potentially higher cost, module may make the most sense. However, if a project has an abundance of space, then a lower efficiency, less costly module may be more practical.

2.2. Solar Thermal

Solar water heating can be a cost-competitive way to generate hot water or air and eliminate both the cost of electricity or fossil fuel as well as the associated environmental impacts.

Solar Hot Water Systems. Solar hot water systems use a collector to absorb and transfer heat from the sun to water, which is stored in a tank until needed. These systems are categorized by the temperature at which heat is most efficiently delivered and the collector type that is best suited for that delivered temperature, including low-temperature (unglazed collectors), mid-temperature (flat-plate collectors), and high-temperature (evacuated tube collectors). See Figure 6.



Figure 6. From left to right, examples of unglazed, glazed, and evacuated tube solar hot water systems
Sources: Photos by (from left) Albert Nunez,, NREL/PIX 10651; Todd Spink, NREL/PIX 10050; Alan Ford, NREL/PIX 09501

In general, solar water systems are reliable and low maintenance because they have few moving parts. The primary components of a solar water heating system are the collectors and heat transfer systems, which include a heat exchanger, pumps, hot water storage, and controls.

The guidelines previously provided for siting solar electric systems are also applicable to siting solar thermal systems. Carefully considering siting issues will help increase the efficiency and cost effectiveness of solar thermal system installations.

Solar Ventilation Preheating Systems. Solar ventilation preheating systems heat ventilation air for applications needing high volumes of ventilation air. In principle, the sun warms the collector surface, where heat is then conducted from the surface to a thermal boundary layer of air. Fans then draw the boundary layer though holes in the collector before the heat can escape by convection (Figure 7).

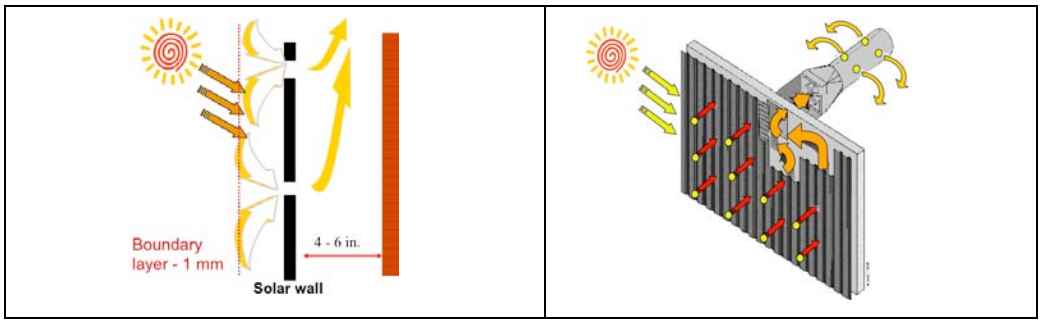


Figure 7. Solar ventilation preheating collector operation.
Source: National Renewable Energy Laboratory

Solar ventilation preheating collectors can be added to an existing building in a retrofit project. Factors to consider when determining whether solar ventilation preheating is a good option for a facility include: relatively high utility rates for heating, a relatively long heating season, and the building's south-facing wall has enough surface area to mount the collector (Figure 8). Methods for liking the solar ventilation preheating system to the buildings heating, ventilating, and air-conditioning system should also be considered. These systems are low cost, reliable (no moving parts other than the fan), low maintenance, high efficiency (up to 80% efficient), and have no storage requirements.



Figure 8. Solar ventilation preheating system installed on the U.S. Department of Energy's National Renewable Energy Laboratory Research Support Facility.
Source: Photo by Patrick Corkery, NREL/PIX 17412

2.3. Geothermal

Geothermal technologies use the heat from the center of the earth. Geothermal resources include the heat retained in shallow ground, hot water and rock found a few miles beneath the earth's surface, and extremely high-temperature molten rock called *magma* located deep in the earth. Almost everywhere, shallow ground, or the upper 3 meters of the earth's surface, maintains a nearly constant temperature of 10°–16°C. Using geothermal heat pumps, this heat can be tapped to provide heating and cooling for homes and buildings. Deeper and warmer geothermal reservoirs can be tapped directly for heat or through advanced technologies for heat and electricity generation (DOE 2011a). Building applications for geothermal technologies include geothermal heat pumps and direct use of the geothermal resource. However, because geothermal heat pumps are the most common geothermal energy technology used in buildings, this is the only geothermal technology discussed further in this paper.

Geothermal heat pumps use the constant temperature of the earth as an exchange medium for heat. Although many parts of the world experience seasonal temperature extremes—from scorching heat in the summer to sub-zero cold in the winter—the ground a meter or so below the surface remains at a relatively constant temperature.

Geothermal heat pumps are able to heat, cool, and, if so equipped, supply homes and buildings with hot water. A geothermal heat pump system consists of a heat pump, an air delivery system (ductwork), and a heat exchanger—a system of pipes buried in shallow ground. In the winter, the heat pump removes heat from the heat exchanger and pumps it into the indoor air delivery system. In the summer, the process is reversed, and the heat pump moves heat from the indoor air into the heat exchanger. The heat removed from the indoor air during the summer can also be used to provide a free source of hot water.

There are four types of geothermal heat pump systems. Three of these—horizontal, vertical, and pond/lake—are closed-loop systems. The fourth type of system is open-loop. Which system is best for a particular site depends on the climate, soil conditions, available land, and local installation costs. All of these approaches can be used for residential and commercial building applications (DOE 2011b).

Installing geothermal heat pumps in building retrofit projects impose an added level of complexity of locating the loops on site and tying the geothermal heat pump system to the existing building heating, ventilating, and air-conditioning system. These and other design factors should be carefully considered early in the process when geothermal heat pump systems are being considered to determine if installing such a system can be done cost effectively.

2.4. Wind

Wind energy is created by uneven solar heating of the Earth's surface. This wind flow, or motion energy, can be harnessed by modern wind turbines to generate electricity. Wind turbines use rotating propeller-like blades to harness the energy in the wind and drive a turbine that generates electricity.

Before installing a wind turbine, it must be established that the wind resource in a specific location is adequate. Wind resource is classified according to its potential to produce electricity over an annual basis (Table 2). Wind resource maps can determine if an area of interest should be further explored, but wind resource at a micro level can vary significantly. Therefore, it is important to evaluate the specific area of interest before deciding to invest in wind systems.

Table 2. Wind Resource Classifications.

Wind Power Class	Resource Potential	Wind Speed at 50m (m/s)
1	Poor	<5.6
2	Marginal	5.6–6.4
3	Fair	6.5–7.0
4	Good	7.0–7.5
5	Excellent	7.5–8.0
6	Outstanding	8.0–8.8
7	Superb	>8.8

If the site has a class 3 wind resource, consider small wind turbine (100 kW or less) or large, low-wind speed turbine opportunities. If the site has a class 4 or greater wind resource, wind may be a good option and even larger, utility-scale turbines may provide economic options.

Lower wind resources are less likely to be economically feasible, but should be reviewed if the site is in a class 2 area and there are nearby pockets of class 3 resources (DOE 2011c).

Most wind turbines are designed for an operating life of up to 20 years and require little maintenance during this period. Wind turbines require land area, so on-site wind power generation usually occurs for projects having space for installing the turbines (Figure 9). Roof-mounted wind systems are beginning to be used in some building projects. However, building designers should carefully consider issues such as maintaining the building's structural integrity, noise, and the added cost before determining if building-mounted systems are appropriate for a specific project.



Figure 9. The City of Medford, Massachusetts, USA owns a Northern Power Systems Northwind 100 wind turbine sited at McGlynn Elementary and Middle School.
Source: Photo from Northern Power Systems, NREL/PIX 16729

2.5. Bioenergy

There are many types of biomass—organic matter such as plants, residue from agriculture and forestry, and the organic component of municipal and industrial wastes—that can be used to produce fuels, chemicals, and power. Wood has been used to provide heat for thousands of years. This flexibility in materials has resulted in increased use of biomass technologies (DOE 2011d).

Biomass technologies break down organic matter to release stored energy from the sun. The process used depends on the type of biomass and its intended end use. For example, biofuels and biopower can be used to provide heat or electricity for buildings.

Biofuels are liquid or gaseous fuels produced from biomass. Most biofuels are used for transportation, but some are used as fuels to produce electricity (DOE 2011e). Biofuels include ethanol and biodiesel.

Biopower is the production of electricity or heat from biomass resources. Biopower technologies include direct combustion, co-firing, and anaerobic digestion (DOE 2011f).

2.6. Connecting to the Electrical Grid

Building-sited renewable energy systems generating electricity and connected to the electrical utility grid (known as "grid-tied" systems) are known as distributed generation (DG) systems. It is important to consider all issues of connecting the DG system to the grid when such systems are part of a building project. Project leads should communicate with the utility on topics such as technical design requirements, which the utility may mandate for interconnection and net metering agreements, including rates the utility will pay for excess renewable energy power generations supplied back to the grid.

Net metering allows for the flow of electricity from a grid-connected DG system both to and from the customer typically through a single, bi-directional meter. When a customer's generation exceeds usage, electricity flows back onto the grid. This effectively offsets electricity consumed by the customer at a different time during the same billing cycle or is carried over as a credit on future billing cycles. Net metering policies vary widely. Some net metering programs reimburse customers for excess generation at

the wholesale rate, while others reimburse at the retail value. Some policies specify a limit on the capacity of renewable energy systems that can participate in the net metering program.

Interconnection standards specify the technical and procedural process by which a customer connects a renewable energy system to the grid. Such standards include the technical and contractual arrangements by which system owners and utilities must abide.

Utilities can be reluctant to allow interconnection of DG systems. The reasons for this are often associated with concerns over ensuring high-quality, reliable power to all customers, load management when considering the intermittency of renewable energy power generation, safety of those maintaining the utility distribution systems, and other similar issues. Even with the increased number of DG systems being added to grid systems, many utilities still have limited experience with these systems. As a result, these utilities address the interconnection questions on a case-by-case basis, which can result in a significant amount of time needed to develop interconnection agreements.

For those pursuing grid-connected renewable energy systems for buildings projects, consider the following steps to ensure effective relations and solutions with the utility:

- Meet up-front and often with utility representatives and develop a strategy for potential rate structure changes as well as taking advantage of incentives the utility may be offering for renewable energy system installations
- Work with a reputable installer/contractor with proven interconnection experience
- Size the DG system to be less than the minimum electrical load so there is no back feeding onto the grid
- Ensure anti-islanding capabilities, which means the renewable energy system stops providing power to the electrical grid when power from the electrical utility is no longer present (depending on application)
- Undertake engineering studies and negotiate who pays for utility line upgrades
- Submit the interconnection proposal early.

3. INTEGRATING RENEWABLE ENERGY SYSTEMS IN HISTORIC BUILDINGS

Maintaining the architectural aspects of existing buildings, especially historic buildings, is often a priority of existing building retrofit projects. In addition, reusing historic and existing buildings is considered by many to be a sustainable design strategy, especially when renewable energy technologies are included with the project. The embodied energy of a building—the energy consumed by all of the processes associated with the production of building materials and components—is equal to approximately 20% of the energy that the building consumes, on a life-cycle basis (UNEP 2007). Grants, tax credits, or other incentives are available to encourage historic preservation in many areas, which further urge investment into existing building retrofit projects. However, without proper planning, installing a renewable energy system on or near the building can comprise both the architectural aesthetics and structural integrity of the building.

Historic preservation entities from the national to the local levels exist in many nations. These entities are often responsible for designating historic properties, providing guidance and resources for historic preservation projects, and imposing regulatory restrictions with which historic projects must comply. Therefore, it is important to understand what regulations apply to historic building projects before investigating renewable energy installation options.

In general, when embarking on an historic building project, it is advised to first determine what energy efficiency features included in the building's original design can be rehabilitated, such as daylighting, natural ventilation, and thermal storage features. The next step is to consider how to incorporate on-site renewable energy installations. Some technologies can be hidden from view, such as installing a bio-fuel generator or geothermal heat pump. Solar electric and solar thermal systems can be integrated into the building "skin", such as the roofing material or shading devices (Figure 10). These systems can also be installed out of the view of building visitors, such as on a roof, facing away from where visitors view the building, behind roof parapets, on other structures located on the site such as a parking structure, or ground-mounted away from the historic building.

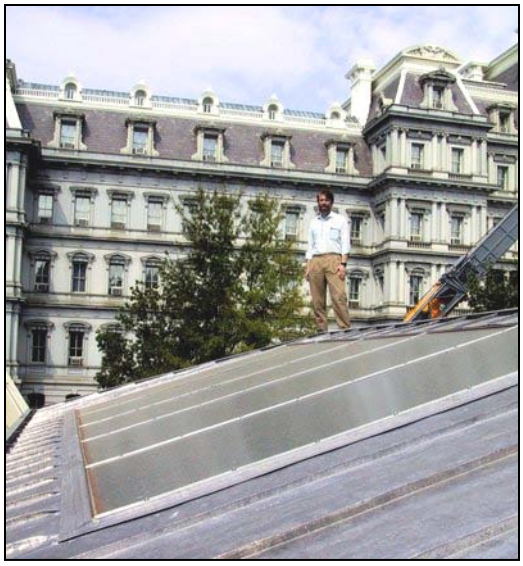


Figure 10. Building-integrated solar water heating array incorporated into the historically correct, teme-coated copper, standing-seam roof of the U.S. White House in Washington, DC.
Source: Photo from Solar Design Associates, Inc., NREL/PIX 15663

4. IMPLEMENTATION PROCESS

The process for implementing renewable energy projects for existing buildings is described in the following steps (Figure 11).

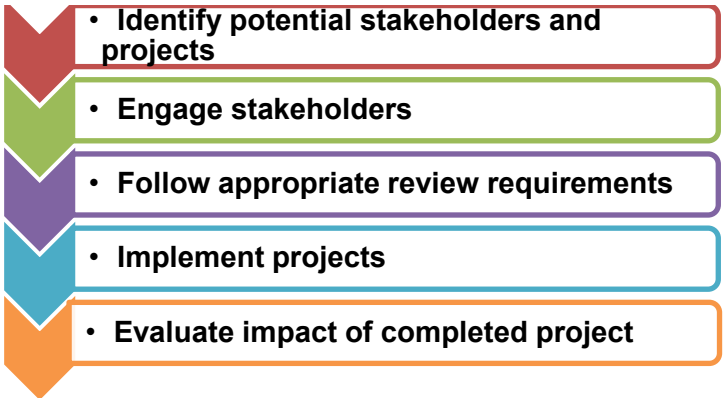


Figure 11. Process for implementing energy efficiency and renewable energy projects.
Source: (NREL 2011)

4.1. Step 1: Identify Potential Stakeholders and Projects

When considering a renewable energy project for an existing building, it is essential to identify relevant stakeholders and potential project locations.

Identifying Stakeholders. Early identification and engagement of all relevant stakeholders is a large determinant of project success. Stakeholders may include facilities engineers and renewable energy system installation companies who can assist with the implementation of the project. Easement holders and private and commercial property owners will be important stakeholders due to their control over the property or land where renewable energy installations might be possible. Other stakeholders include

government organizations that may have funding and renewable energy targets that need to be met, as well as financiers with knowledge of rebates, grants, third-party financing, and tax credits.

The project goals, type, and financing mechanism dictate the type of people who should be involved as stakeholders. Although not an exhaustive list, stakeholders may include the following:

- Adjacent property owners
- Technical assistance providers such as equipment vendors
- Public recipients of grants or funding
- Planners
- Contractors
- Engineers
- Property owners
- Federal agencies
- Non-profit preservation and environmental groups
- Local government.

Entities in the construction process, such as manufacturers, contractors, and others with a vested interest in the promotion, sale, or installation of energy efficient or renewable energy products may be consulted for technical information relevant to the discussion, but not labeled as stakeholders.

***Identifying Projects*.** The identification of potential projects ideally begins with an initial goal-setting exercise. Determining, with appropriate stakeholders, what the motivations for and goals of the project are will help define and drive the project development throughout the entire implementation process. Goals could be related to municipality energy reduction or renewable energy use goals, building or neighborhood environmental requirements, and building owner or tenant motivations, for example. Project identification may include an analysis of building stock to determine which buildings have the most feasible renewable energy installation potential, an assessment of the potential impact to the building's character-defining features, consideration of electricity costs or incentives available for energy projects, and understanding energy efficiency measure that have been implemented as part of previous building retrofit projects.

High costs of energy combined with the incentives and rebates for renewable energy installations, along with legislation and the need for energy security, are all drivers for considering installing renewable energy projects on existing properties. Alternate solutions for siting the renewable energy system should be considered such as installing solar on a carport over a parking area or a ground-mounted array elsewhere on the property instead of limiting solutions to just available roof area. There will be times when it is not possible to roof-mount a solar system without negatively impacting a building's character-defining features, so one of these out-lying locations may be a viable alternative or another renewable energy technology should be considered.

Siting renewable energy systems may not be limited to locating the systems on a single site or structure. There is potential for "district renewable energy" and/or more distant locations than the site allows. These types of systems could make sense in some district situations, such as grouping solar installations on a large institutional rooftop, open field, or over a parking lot, where locating the system in a hidden area could be a better solution than placing all the systems on visible rooftops. It should be noted that there are technical issues related to distance, as well as legal and regulatory issues when more than one property is involved.

4.2. Step 2: Engage Stakeholders

After stakeholders and projects have been identified, it is important to engage stakeholders to ensure that requirements of architectural preservation are met, resources are fully utilized, and more informed decisions are made. This will ultimately increase the likelihood of project success.

The process for engaging stakeholders depends on the project location and scale. Different stakeholders will be involved in different phases of the process. Legal requirements or local code could partially stipulate which stakeholders are involved. The process of engagement could be done through third-party advocates, public notices, statutes and mandates, Web announcements, conferences, workshops, awards, newsletters, solar advertisements, funding announcements, or public hearings. By exploring all available avenues and considering various entities and stakeholders, a project will have a greater chance for success.

4.3. Step 3: Follow Appropriate Review Requirements

The review process for renewable energy installations will vary according to the type of project and the property. Properties that have been designated as historic may be protected through local historic preservation or landmark preservation ordinances. As a result, review processes can differ greatly depending on local and national policies for historic buildings and/or districts. To acquire more information regarding the review process for a specific project, contact local historic building authorities for guidance.

Locally applicable environmental protection processes should also be examined. For example, some properties are protected by preservation or conservation easements. The easement holding entity should be involved in the renewable energy installation from the earliest phase.

4.4. Step 4: Implement Project

The project is ready to be implemented once stakeholders have been engaged, the project location, renewable energy technology, and renewable energy system size have been identified, and all requirements have been considered and met. Implementation may involve a number of stakeholders and will require open communication between the installers of the renewable energy system, the stakeholders, and the local community. Consideration should be given to the impact of project implementation and construction on the function of the building or district and its occupants. Also, renewable energy projects must be implemented in a way that not only maintains structural and architectural integrity, but ensures maximum energy generation.

4.5. Step 5: Evaluate Project Effects

Evaluating a renewable energy project can help to increase the rate of success of future projects. Review is recommended of what was successful in the project implementation process as well as what could have been done differently. This review should take place during the process and after installation to analyze the coordination of planners, installers, property owners, utilities, and energy bill payees. The review should also consider impacts on policies, neighbors, appeal boards, and the like. Case studies or best practices can be created to share the experiences with other entities trying to replicate similar projects as well as with the public.

CONCLUSION

European studies suggest that buildings are responsible for around 45% of global carbon dioxide emissions over the entire life cycle (UNEP 2007). Given this large contribution to global emissions, buildings are ripe for retrofits that result in reduced energy consumption and associated emissions. There are many synergies between existing buildings and energy-efficient and renewable energy technologies. Conserving and rehabilitating existing buildings to operate more efficiently and cleanly can reduce energy use, energy cost, and GHG emissions. Retrofitting an existing building rather than building a new building also optimizes the energy previously expended that is associated with the embodied energy in the building's materials and past construction. Many existing buildings are prime candidates for energy efficiency and renewable energy technologies. In fact, older, historic buildings often have energy-efficient features, such as natural daylighting, ventilation, and thermal storage, included in the building design.

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REFERENCES

ASHRAE 2010. "Sustaining Our Future by Rebuilding Our Past" – President's Address. American Society of Heating, Refrigerating, and Air-Conditioning Engineers. http://www.slideshare.net/ashrae6/presidents-address.

DOE 2011a. "Geothermal Technologies." U.S. Department of Energy Office of Energy Efficiency and Renewable Energy (EERE). http://www.eere.energy.gov/basics/renewable_energy/geothermal.html. Accessed 17 July 2011.

DOE 2011b. "Geothermal Heat Pumps." EERE. http://www.eere.energy.gov/basics/renewable_energy/geothermal_heat_pumps.html. Accessed 17 July 2011.

DOE 2011c. "Integrating Renewable Energy in Federal Construction." EERE. http://www2.eere.energy.gov/femp/reconstructionguide/preliminary_screening.html. Accessed 17 July 2011.

DOE 2011d. "Biomass Technologies." EERE. http://www.eere.energy.gov/basics/renewable_energy/biomass.html. Accessed 17 July 2011.

DOE 2011e. "Biofuels." EERE. http://www.eere.energy.gov/basics/renewable_energy/biofuels.html. Accessed 17 July 2011.

DOE 2011f. "Biopower." EERE. http://www.eere.energy.gov/basics/renewable_energy/biopower.html. Accessed 17 July 2011.

EIA 2010. *International Energy Outlook 2010*, World Energy Demand and Economic Outlook. Energy Information Agency. Report #DOE/EIA-0484(2010). Release Date: July 27, 2010. http://www.eia.gov/oiaf/ieo/world.html.

EurOberv'ER. (2009). "Photovoltaic Barometer." *Le Journal du photovoltaique.* Updated 11/05/2009. http://www.eurobserv-er.org/pdf/baro190.pdf.

European Union 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. *The Official Journal of the European Union*. May 2009. http://www.energy.eu/directives/pro-re.pdf.

European Union 2009. Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings. *The Official Journal of the European Union*. April 2003. http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm. Accessed 25 July 2011.

GENI 2007. Renewable energy resource maps. Global Energy Network Institute. http://www.geni.org/globalenergy/library/renewable-energy-resources/index.shtml. Accessed 17 July 2011.

IEA 2006. *The World Energy Outlook 2006 Maps Out a Cleaner, Cleverer and More Competitive Energy Future*. Press Release. International Energy Agency. November 7, 2006, London. http://www.iea.org/press/pressdetail.asp?press_rel_id=187.

NREL 2009. Learning About Renewable Energy, Solar Photovoltaic Technology. National Renewable Energy Laboratory. http://www.nrel.gov/learning/re_photovoltaics.html. Accessed 17 July 2011.

NREL 2011. Kandt, Walker, Hotchkiss. *Implementing Solar PV Projects on Historic Buildings and in Historic Districts.* NREL. Draft Technical Report. NREL/TP-7A40-51297. May 2011.

UNEP 2007. Buildings and Climate Change. Status, Challenges and Opportunities. United Nations Environment Programme. ISBN: 978-92-807-2795-1. http://www.unep.fr/shared/publications/pdf/DTIx0916xPA-BuildingsClimate.pdf.

WBCSD 2009. Energy Efficiency in Buildings. World Business Council for Sustainable Development. http://www.wbcsd.org/DocRoot/Ge2Laeua8uu2rkodeu7q/91719_EEBReport_WEB.pdf. Accessed 17 July 2011.

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