

Effective Selection of Renewable Energy Projects in Constructed Facilities

Taylor Andrews and Hazem Elzarka
University of Cincinnati
Cincinnati, Ohio

The interest in renewable energy projects in recent years is growing. Although renewable energy technologies offer many benefits, such as reduced energy demand and costs and lower environmental impact, their level of performance and success is dependent on the thoroughness of their selection and their adequate design. Governmental policies and mandates have increased renewable energy systems' appeal, while advancements in technology have helped to bring down their costs. It is crucial to the success of projects utilizing renewable energy systems that careful consideration goes into the design and planning of the project. Educating the construction industry in best practices for selecting these technologies will further encourage their use and growth in the industry. The purpose of this paper is to demonstrate to the construction industry the successful process of selecting RETs. The paper also describes how a commercially available analysis tool was used to evaluate a promising RET; Solar air Heating.

Key Words: Renewable Energy Technology (RET), Energy Use Reduction, Renewable Energy Analysis, Energy Efficiency, Solar Air Heating

Introduction

The use of Renewable Energy Technologies (RET) in constructed facilities is growing. Recent federal energy policies are encouraging or requiring federal agencies to implement strategies toward reducing energy demands and environmentally harmful emissions. These policies motivate federal agencies and organizations to actively seek out effective strategies and methods for utilizing RETs (FEMP, 2010). Furthermore, governments and utilities throughout the world have developed economic incentives to promote widespread utilization of RETs. In spite of these efforts, owners, contractors and developers are often reluctant to use RETs because they (1) are unfamiliar with all the alternatives and (2) lack an assessment tool to evaluate their economic feasibility. Therefore, it is important that successful implementation of RETs be demonstrated and reported to the construction industry. In addition to cost considerations, proper assessment of RETs requires knowledge of available incentives, government regulations, best practices for implementation, and environmental benefits. The assessment process and tools should consider all this information in its decision making process.

Selection Process

The process of analyzing an RET is often grouped into three phases: Preliminary Screening, Screening, and Feasibility Study (FEMP, 2010). The preliminary screening phase is an initial look into what types of RETs are practical for a given project. During the screening phase, more detailed calculations and analysis are performed to evaluate the RET selected in the preliminary screening phase. These calculations often require a renewable energy expert and complex software, but give more exact estimations of performance levels and savings based on the project's conditions. The feasibility study phase is a continuation of the screening phase and is a more in depth study in which the goal is to eliminate the problems that could arise on a particular project (FEMP, 2010). This paper focuses on the preliminary screening phase which is typically used during a value engineering process to select among RET alternatives.

Influential Factors

There are many different factors that influence a RET's performance and that must be considered in the preliminary screening phase. These factors can be categorized into 4 categories: (1) energy use characteristics, (2) building's characteristics, (3) site characteristics and (4) financial characteristics.

Energy Use Characteristics

A project's energy use characteristics include detailed information on how much energy a project is using, when is it used and how much it costs. Knowing these characteristics is essential for identifying the most suitable RET. The energy use characteristics of a new project can be determined from energy modeling or from historical data for similar projects. For an existing project, the energy use characteristics can be determined from the evaluation of utility bills. Utility bills should be collected to analyze monthly and annual energy usage and cost trends. An example of a monthly energy use profile for a vehicle service repair facility in Ohio that the authors developed as part of an ongoing research project is shown in Figure 1. Other characteristics that should be determined include identifying the building systems that consume the most energy as well as the time of peak energy demand and unit costs. For example, a building's primary energy consumption may result from heating needs that peak in the winter months and this may increase the unit cost of electricity ($/kWh) during the winter season. Such a building would benefit from a passive heating RET system that reduces the winter heating demand. Knowing the on-peak and off-peak energy rates is also important. Solar Photovoltaic electricity production for example may work well in the summer when on-peak rates are charged since the value of the electricity produced (during on-peak periods) may be considerably more than the calculated yearly average cost (FEMP 2010). Another important characteristic that should be determined is whether the project utilizes on-gird or off-grid energy. Some RETs such as solar sources are better suited to off-grid projects (FEMP, 2009). In addition, the conventional energy source that the RET is replacing (i.e. electricity, natural gas, etc.) needs to be identified. Solar hot water for example is more economically feasible when electricity instead of natural gas is currently being used for water heating in an existing building.

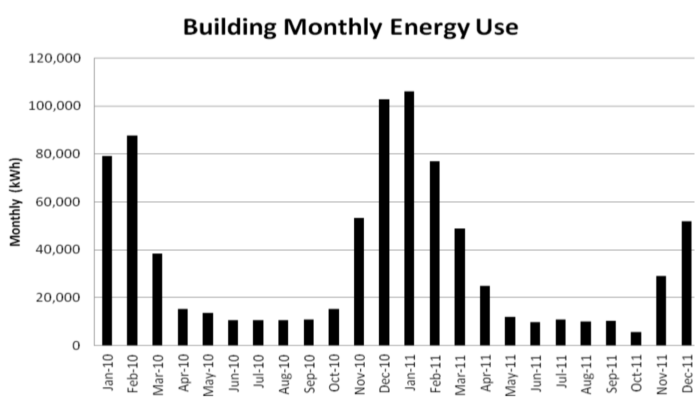

Figure 1: A sample monthly energy use trend for a vehicle service/repair facility.

Building Characteristics

Existing building characteristics that may have an impact on RET selection include building age, size, configuration, intended usage, and condition of its various components. In terms of age and condition for example, if a project is considering installing rooftop photovoltaic (PV) modules, it is important to know the age and condition of the roof before proceeding; PV modules service life is typically 20 years and it won't be economical to install new modules on a roof that needs to be replaced in 5 years. The size and type of building can also give clues as to how the energy is used. For instance, for a large warehouse structure with high ceilings, it is likely that a large amount of energy is used for heating and cooling applications. The building's configuration and intended usage can be utilized as input to energy modeling tools to determine how energy is consumed when that information is not readily available from sub-metering data. Careful evaluation of building characteristics will establish a good understanding of the projects unique conditions.

Site Characteristics

Site characteristics that may have an impact on RET selection include site location, weather and climate data, building orientation, and the availability of renewable resources. The geographical location, along with a building's orientation, can rule out certain RETs as impractical, or establish them as potential candidates. For example a project that is in a location with significant solar radiation and proper building orientation will be a good candidate for daylighting and/or roof-top photovoltaic. It is also important to determine the availability of renewable resources. The National Renewable Energy Laboratory (NREL) provides resources maps that define the availability of different resources for specific regions and locations (FEMP, 2010). These maps show the availability of renewable energy sources in different locations. An example of an NREL map is shown in Figure 2.

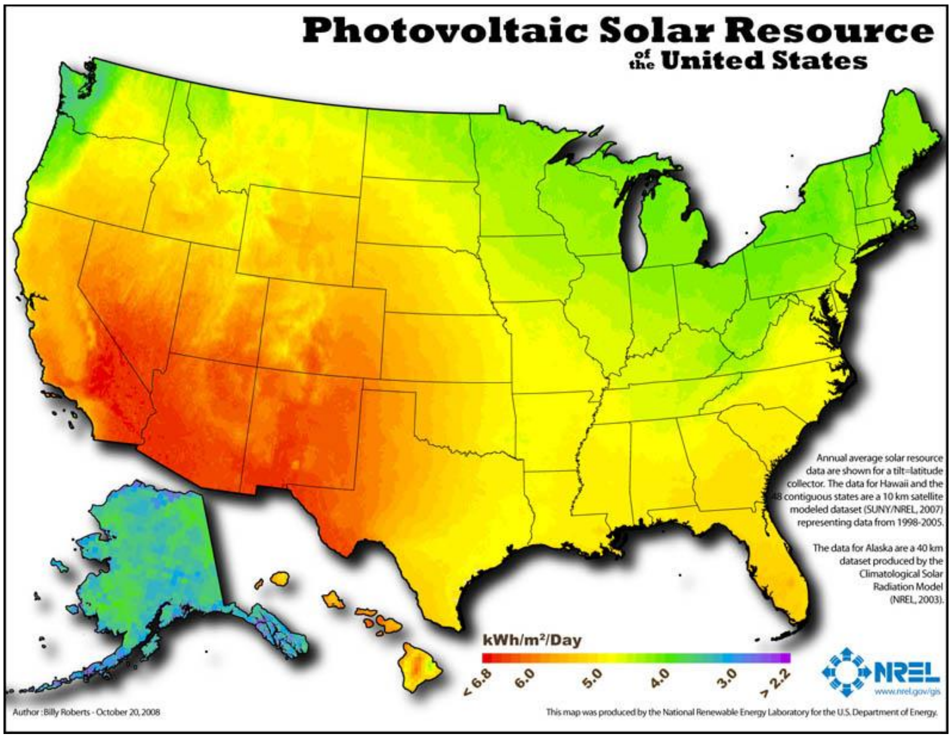

Figure 2: Available photovoltaic solar energy in the United States (NREL).

Financial Characteristics

Financial characteristics that may have an impact on RET selection include expected costs, potential savings, and payback time. As with any construction project, an RET project must evaluate its available funding before starting. Financial analysis is done by comparing the cost of a project with the potential savings in energy costs. The cost-savings relationship is evaluated in terms of the project payback time. The payback time is one of the most important aspects in selecting a RET. RETs are frequently considered impractical or too costly due to their perceived long payback times, but this is not always true and especially so when projects have been well planned and designed. Payback times are decreasing in recent years as the costs of RETs continue to decrease and the costs of traditional energy sources such as fuel and natural gas increase. Furthermore, numerous incentives and grants have been established by government agencies, utility companies, and different organizations that when utilized will reduce upfront costs and by extension reduce payback time. These incentives will vary in different locations, but there are a large number of them available to a wide range of projects. The US Department of Energy has established the Database of State Incentives for Renewables and Efficiency (DSIRE) with details and specifics on incentives. This Database is freely available on the DSIRE website (dsireusa.org) (Department of Energy, 2012).

Analysis Tools

As outlined in the previous sections, a multitude of factors unique to any given project will always play a role in the proper selection of RETs. No two projects are exactly the same and so it is important to establish which factors and details will be most influential in the selection of a proposed RET project. Analysis of factors is best done through assessment tools. One of these assessment tools is the Canadian based software RETScreen. RETScreen is a leading international analysis tool for clean energy decision-making and can be downloaded for free (RETScreen, 2012). Another free assessment tool is the In My Backyard (IMBY) tool from NREL (NREL, 2012). IMBY is used for the analysis of solar based technologies and allows the user to select locations and technology features to visualize the level of performance that could be achieved at a particular site. RETScreen was used to conduct the research described in this paper and is further described in the next section.

RETScreen

RETScreen conducts detailed financial analysis for projects and compares a base scenario that uses traditional energy sources to a RET scenario when calculating energy savings and payback estimates. The RETScreen program includes an extensive database of templates and previous sample projects, which provide a good starting point for analysis. To analyze a new RET project, it is usually simpler to modify a RETScreen sample project to meet the project's specific conditions then to start from scratch. It is important when using a RETScreen sample project as a starting point, to look for a project that has as many similarities to the proposed RET project as possible. A sample RETScreen analysis sheet is shown in Figure 3.

RETScreen Financial Analysis - Heating project

Financial parameters		
General		
Fuel cost escalation rate	%	3.0%
Inflation rate	%	2.0%
Discount rate	%	10.0%
Project life	yr	30
Finance		
Incentives and grants	$	6,051
Debt ratio	%	75.0%
Debt	$	45,385
Equity	$	15,128
Debt interest rate	%	9.00%
Debt term	yr	15
Debt payments	$/yr	5,630
Income tax analysis		☑
Effective income tax rate	%	34.0%
Loss carryforward?		No
Depreciation method		Straight-line
Depreciation tax basis	%	100.0%
Depreciation period	yr	5
Tax holiday available?	yes/no	No
Annual income		
Electricity export income		

Project costs and savings/income summary			
Initial costs			
Heating system	100.0%	$	60,513
Balance of system & misc.	0.0%	$	0
Total initial costs	**100.0%**	**$**	**60,513**
Incentives and grants		$	6,051
Annual costs and debt payments			
O&M		$	500
Fuel cost - proposed case		$	16,107
Debt payments - 15 yrs		$	5,630
Total annual costs		**$**	**22,237**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		$	26,972
Total annual savings and income		**$**	**26,972**

Yearly cash flows			
Year	**Pre-tax**	**After-tax**	**Cumulative**
#	$	$	$
0	-9,077	-11,135	-11,135
1	5,051	5,051	-6,084
2	5,377	5,377	-707
3	5,712	5,712	5,005
4	6,058	6,058	11,062
5	6,414	6,414	17,476
6	6,780	3,666	21,142
7	7,158	3,843	24,986
8	7,548	4,021	29,006
9	7,949	4,199	33,205
10	8,362	4,378	37,583
11	8,788	4,556	42,139
12	9,227	4,734	46,873
13	9,679	4,910	51,783
14	10,145	5,084	56,867
15	10,625	5,256	62,123
16	16,749	11,055	73,178
17	17,259	11,391	84,569
18	17,784	11,737	96,306
19	18,324	12,094	108,400
20	18,881	12,462	120,861
21	19,455	12,840	133,702
22	20,046	13,231	146,932
23	20,655	13,633	160,565
24	21,283	14,047	174,611
25	21,929	14,473	189,085
26	22,596	14,913	203,998
27	23,282	15,366	219,364
28	23,989	15,833	235,196
29	24,717	16,313	251,510
30	25,468	16,809	268,318

Figure 3: Sample RETScreen analysis.

Solar Air Heating

Solar air heating (SAH) is a promising RET that is further evaluated in this paper. Solar air heating, also called solar ventilation air preheating and/or solar wall, is based on solar thermal energy and uses a solar heated surface to preheat air which is then used in ventilating a building (EIA, 2012). The most common style of collector for SAH is the transpired solar collector that is usually installed on the south facing wall in the form of a rain screen

(RETScreen, 2004). The solar wall panels that act as the thermal collectors allow the outside air to pass through the screen into an air gap where the air becomes heated between the building's exterior wall and solar collector cover. Through convection, the heated air then rises and is pulled into the buildings ventilation system and is delivered by the duct system to heat the interior spaces (NREL, 1994). An example of a commercially available SAH system, the SolarWall manufactured by Conserval Engineering is shown in Figure 4. Solar air heating is an RET with many appeals, and has already demonstrated high levels of success in various case studies. It is a relatively low cost and easily implemented technology, and systems have demonstrated high levels of efficiency (FEMP, 2011). SAH was selected for a detailed example of how to best analyze and select a RET as detailed in the remainder of the paper. The authors believe that demonstrating a low cost and easily attainable technology will help change the construction industry's perception that RETs are all complicated and costly projects with low rewards.

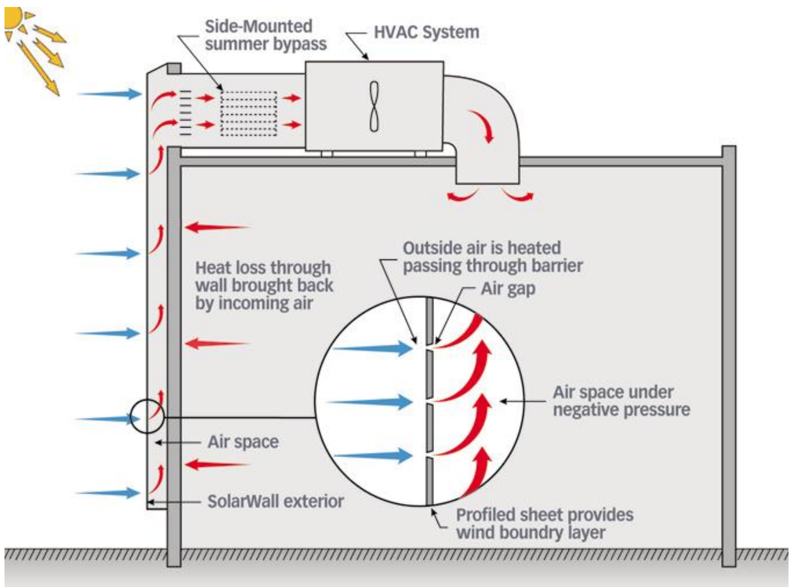

Figure 4: Solar air heating process used by Conserval Engineering. (Conserval Engineering)

Factors That Affect SAH Projects

When considering solar air heaters, there are several factors that influence success. These can be broken into performance factors and financial factors. The performance factors are those that influence what levels of energy savings can be achieved, and the financial factors are those that influence cost savings and payback times. For solar air heaters the main performance factors include: the size of the area to be heated, the size and orientation of the solar collector, the design air flow rate, the collectors' thermal resistance, the building location and weather data, the desired indoor temperature, and the base case's cost of heating air with conventional energy sources. A successful analysis relies on knowing or estimating these factors as closely as possible. For those factors that are not known or need to be decided, such as the collector area, the use of an assessment tool such as RETScreen becomes important. Adjusting factors in RETScreen helps show how changes influence the results and to what extent. As further detailed in the paper, it was determined that some of the most influential factors affecting the economic feasibility of solar air heaters are the collector size, design air flow rate, and building size.

Best Applications for SAHs

While there are opportunities for small-scale solar air heating systems and collectors to be installed in residential and small commercial projects, large scale systems offer the best benefits and results. Buildings with high walls and large amounts of open space, such as storage and maintenance facilities, gymnasiums, warehouses, and industrial facilities particularly benefit from the reduced heating demands (RETScreen, 2004).

The orientation and size of the collector surface wall, along with the available solar energy, influence how much thermal energy can be used for heating the air that enters the system. Buildings located in areas with high levels of solar radiation will perform better than those located in areas where the solar radiation is restricted (RETScreen, 2004). Other factors such as the design air flow rate may be influential but are governed by the demands and size of the building and may not always be altered in attempts to create best case scenarios. The careful consideration of influential factors allows for identifying the scenarios that will most likely be successful. For solar air heating systems, a project that has a large open space, high heating demands, specifically in winter months, and that is located on a site that receives a large amount of sunlight and solar radiation year round, is a good candidate.

Impact of Financial Requirements

After considering the main performance factors and establishing that a specific technology is relevant to a project, the main concern becomes financial feasibility. The financial factors for solar air heaters are similar to those of most RETs. They include: the cost of the project, the cost of the standard fuel or electricity used in the base case, and any incentives or opportunities for alternative funding. Compared to some other RETs, SAH has relatively low upfront costs. From examining several SAH case studies it was found that moderately sized projects' costs range from 10,000 to 60,000 dollars. It has also been reported from manufactures that the costs are approximately 30 to 40 dollars per square foot of solar collector area (FEMP, 2009). As with all RETs, depending on the project location, it is possible to find incentives and grants to reduce the upfront costs. Furthermore, several case studies (FEMP 2009) reported that the solar air heating systems saved 20 percent on average of the annual energy costs, backing up claims by manufacturers that they could reduce energy demands from 20 to 50 percent (Conserval Engineering, 2012). The case studies considered showed an average payback period of less than seven years, with paybacks being achieved in as little as two years. Results such as these contradict the popular opinion that RET projects take too long to recoup the initial investment, and can help change the perception of RETs as too costly or inefficient.

Case Study

The case study examined is for a solar air heating project located in Denver, Colorado, experiencing high heating demands in the cooler winter months. This case study is based on one of the RETScreen sample projects provided with the software (RETScreen, 2000), and was utilized to evaluate the impact of varying project conditions on the economic feasibility of a SAH. The building is a large warehouse distribution center for Federal Express with a floor area of 5,574 m^2. The installed solar air heater has a collector area of 465 m^2 installed on the southeast facing wall and utilizes a design air flow rate of 76,500 m^3/h. The desired indoor air temperature is 21°C and the base case for meeting the heating demand uses conventional natural gas costing \$0.17/m^3.

This project's governing characteristics were found to be the same as previously discussed for solar air heaters. To see the influence of the various factors on the outcome of the project's feasibility, each factor was adjusted to several values and the resulting percent savings of fuel consumption and payback time were compared. Fuel consumption savings are calculated by comparing the annual fuel costs for the base case using traditional fossil fuels sources, with the RET case using a SAH. The SAH project, as described in the RETScreen database has an estimated payback period of 2.1 years and saved 40.3 percent of the natural gas consumption. First, the authors studied the impact of changing the project location on the economic outcomes. Such a scenario may be applicable if FedEx is considering constructing a similar warehouse in another location. Table 1 shows the variation of SAH performance if the only variable changed is the geographical location of the project. Table 2 compares different collector areas and shows how a slightly larger upfront cost doesn't always mean a longer payback time. Different design air flow rates are compared in Table 3. In this sample project, lowering the air flow rate decreases the efficiency of the solar air heating system by reducing the amount of heated air that is introduced to the building. Table 4 shows how a lower level of absorptivity reduces the efficiency of the SAH system by decreasing the amount of thermal energy that is available to heat the air. A project's cost is not always a factor that can easily be controlled, but by utilizing different incentives and grants the upfront cost can be reduced. The importance of making use of available incentives is shown in Table 5, and as illustrated, decreasing the upfront cost of a project is a key component to decreasing the payback time. The other major cost factor influencing payback times is the cost of the energy source that would be used without the introduction of an RET. In this example the energy source is natural gas and it can be seen in Table 6 how slight fluctuations in the price of gas can affect the payback time.

Table 1

Performance levels with variation of location

	Original	Variation Cases			
Location	Denver, CO	San Francisco, CA	Baltimore, MD	Chicago, IL	Burlington, VT
Fuel Consumption Savings (%)	40.3	65.8	44.0	32.7	29.2
Payback Time (Years)	2.1	2.8	3.1	3.3	3.1

Table 2

Performance levels with variation of collector area

	Original	Variation Cases			
Collector Area (m^2)	465	350	400	500	600
Fuel Consumption Savings (%)	40.3	35.4	37.8	41.4	44.3
Payback Time (Years)	2.1	2.8	2.4	2.0	1.8

Table 3

Performance levels with variation of design air flow rate

	Original	Variation Cases			
Design Air Flow Rate (m^3/h)	76,500	85,000	70,000	65,000	50,000
Fuel Consumption Savings (%)	40.3	38.4	41.9	43.2	48.2
Payback Time (Years)	2.1	1.9	2.3	2.6	3.8

Table 4

Performance levels with variation of collector absorptivity

	Original	Variation Cases			
Solar Collector Absorptivity	0.85	0.7	0.75	0.8	0.9
Fuel Consumption Savings (%)	40.3	36.5	37.7	39.0	41.6
Payback Time (Years)	2.1	2.6	2.4	2.3	2.0

Table 5

Payback time with variation of project upfront cost

	Original	Variation Cases			
Project Cost ($)	60,513	50,000	55,000	65,000	70,000
Payback Time (Years)	2.1	1.4	1.7	2.5	3.0

Table 6

Payback time with variation of fuel costs

	Original	Variation Cases			
Fuel cost ($\$/m^3$)	0.17	0.15	0.16	0.18	0.20
Payback Time (Years)	2.1	2.8	2.4	1.9	1.6

Conclusions

In spite of policies and economic incentives that encourage the use of renewable energy technologies in constructed facilities, owners, contractors and developers are often reluctant to use RETs because they (1) are unfamiliar with all the alternatives and (2) lack an assessment tool to evaluate their economic feasibility. The paper attempts to overcome these barriers by describing a structured approach for the proper selection of RETs and presenting a case study where a commercially available assessment tool was utilized to conduct a feasibility study for a project utilizing solar air heating. As described in the paper, to properly select an RET project, the project team should:

- Determine the project needs and conditions by considering the energy use characteristics and building's characteristics.
- Consider the project's site features to determine the practicality of different RETs.
- Look at the financial requirements to determine the feasibility of RETs.
- Utilize available tools such as RETScreen to perform preliminary analysis and calculations.
- Evaluate similar past projects that have been successful for guidance.

It is important to remember that although each RET project is unique, following the structured approach for proper RET selection as described in the paper will increase the project's potential for success. Each successful RET project will help grow their use in the construction industry.

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