122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #14130

Feasibility Study of Renewable Energy Sources for Energy Efficiency

Dr. Ahmed Cherif Megri, North Carolina A&T State University

Dr. Ahmed Cherif Megri, Associate Professor of Architectural Engineering (AE). He teaches capstone, lighting, electrical, HVAC and energy design courses. He is the ABET Coordinator for the AE Program. His research areas include airflow modeling, zonal modeling, energy modeling, and artificial intelligence modeling using the support vector machine learning approach. Dr. Megri holds a PhD degree from INSA at Lyon (France) in the area of Thermal Engineering and a "Habilitation" (HDR) degree from Pierre and Marie Curie University - Paris VI, Sorbonne Universities (2011) in the area of Engineering Sciences. Prior to his actual position, he was an Associate Professor at University of Wyoming (UW) and prior to that he was an Assistant Professor and the Director of the AE Program at Illinois Institute of Technology (IIT). He participated significantly to the development of the current architectural engineering undergraduate and master's programs at IIT. During his stay at IIT, he taught thermal and fluids engineering (thermodynamics, heat transfer, and fluid mechanics), building sciences, physical performance of buildings, building enclosure, as well as design courses, such as HVAC, energy, plumbing, fire protection and lighting. Also, he supervises many courses in the frame of interprofessional projects (IPRO) program. Dr. Megri wrote over 100 journal and conference papers. Overall, Dr. Megri taught more than 30 different courses at University level in the AE area.

Areas of Interests: - Zonal modeling approach, - Integration zonal models/building energy simulation models, - Zero Net Energy (ZNE) building, - Airflow in Multizone Buildings & Smoke Control, - Thermal Comfort & Indoor Air Quality, - Predictive modeling and forecasting: Support Vector Machine (SVM) tools, - Energy, HVAC, Plumbing & Fire Protection Systems Design, - Computational Fluid Dynamic (CFD) Application in Building, - BIM & REVIT: application to HVAC and Electrical/Lighting Design systems.

Feasibility Study of Renewable Energy Sources for Energy Efficiency

Ahmed Cherif Megri, PhD, HDR
North Carolina A&T State University

Abstract:

The purpose of this study is to assess the roof of an industrial building and its adjacent land for possible solar PV, thermal solar or geothermal installations and to estimate the cost, performance and site impacts of these three systems. The economics of the potential systems were analyzed using an electric rate suggested by the utility company, as well as incentives that are offered by the federal, State, and by the serving utility.

The electrical rate increases over the next three years need to be anticipated. A rate increase of this magnitude would greatly improve the economics of a renewable system, such as solar PV generation plant. The system economics with the anticipated rate increase information and job creation estimates if the building roof and its adjacent land were used for one of the three systems.

As well, the purpose of the work is to provide students with the opportunity to apply the design theories and techniques they have learned in earlier classes to the full design of a building including its structural, HVAC and electrical systems. Students also review and deepen their understanding of architecturally related topics including special layout and building codes requirements.

Most importantly, project methodology will be discussed. We discuss the capstone design program from students' point of view, and the experience earned in design, integration, and also in written and oral communication skills. Methodology used to evaluate the effectiveness of the capstone design program in term of learning outcomes is also described.

Introduction:

The Architectural Engineering Senior Project Capstone Class (AREN 485/486) proposes to use an actual industrial facility as the basis for the senior project. The purpose of the class is to provide students with the opportunity to apply the design theories and techniques they have learned in earlier classes to the full design of a building including its structural, HVAC and electrical systems. Students also review and deepen their understanding of architecturally related topics including spatial layout, building codes and building shell requirements.

The industry group has asked that the project include a design analysis of the installation of PV solar panels for the facility. This will be incorporated into an integrated design assignment for the students. The proposed steps are as follows:

- Students reviewed the existing building as a case study. This included review of the building program, building code and zoning requirements and a conceptual review of the structural, HVAC and electrical systems including loads, system type and overall layout of each system. The industrial representative provided the building program, building plans, elevations and some building details that describe the existing building. This information is intended to be general in nature and can be scrubbed of any proprietary information prior to its delivery. The students through this review solidify their understanding of how the current building meets its design requirements.
- Students divided into small groups to investigate various alternatives to the existing design that incorporated a variety and mix of options including various scales and locations of PV panels, geothermal energy, alternative heating and cooling systems, daylighting and other technologies that may be of interest to the industry group. The students prepared a description of their design including plans, specifications, a BIM model and costs and an analysis of the feasibility of their design including technical, economic and operational factors.
- Students presented the results of their work to industry staff at the end of the Fall Semester.
- During the Spring Semester students developed their designs in more detail. This will include preparing plans and details typically associated with Construction Documents. It will also include a more detailed cost estimate. The students presented their work at the end of the semester to industry staff and as part of the Senior Capstone Expo conducted by our College of Engineering.

The purpose of this study is to assess the roof of an industrial building and its adjacent land for possible solar PV, thermal solar or geothermal installations and to estimate the cost, performance and site impacts of these three systems. The economics of the potential systems were analyzed using an electric rate suggested by the utility company, as well as incentives that are offered by the federal, State, and by the serving utility.

Most importantly, project methodology will be discussed. We discuss the capstone design program from students' point of view, and the experience earned in design, integration, and also in written and oral communication skills. Methodology used to evaluate the effectiveness of the capstone design program in term of learning outcomes is also described.

Literature review:

Multiple feasibility studies have been conducted in USA and Canada, as well as in Africa, with the objective to use renewable energy (PV solar or solar thermal) to save energy and improve the environment. Samples of these works will be summarized here for illustration purposes.

In 2006, a 300 MW solar PV plant, generator interconnection feasibility study was conducted. The purpose of this Feasibility Study (FS) is to evaluate the feasibility of the proposed interconnection to the New Mexico (NM) transmission system. In 2007, a feasibility study of PV for the city of Easthampton, MA was conducted. Of the six municipal sites assessed for solar photovoltaics potential, three demonstrate enough promise to warrant further consideration by the City of Easthampton: the Highway Garage, Water Treatment Plant and Waste Water Treatment Plant.

Lisell and Mosey (2010) conducted a feasibility study of economics and performance of solar photovoltaics in Nitro, West Virginia. Citizens of Nitro, city planners, and site managers were interested in redevelopment uses for brownfields in Nitro, and the site is particularly well suited for solar photovoltaic (PV) installation. Eight sites in or near Nitro were considered, all of which were found suitable for PV systems. The economics of the potential systems were analyzed using an electric rate of $0.08/kWh, as well as incentives that are offered by the State of West Virginia and by the serving utility, American Electric Power (AEP). No incentives were offered for commercial size solar power systems in West Virginia, or by AEP. The conclusion was that not all sites would need to be developed; beginning with a smaller demonstration system and increasing capacity as funds become available may make more sense. Calculations for this analysis assume the 30% federal tax credit incentive would be captured for the system.

In 2012, the City of Pomona Municipal Facilities conducted a Solar Photovoltaic Feasibility Study. Recently, Somers conducted a rooftop solar PV feasibility study on twenty facilities, belonging to the Mesa Fire Department (MFD), to partially obviate the need for grid-supplied electricity. The conclusions were that converting some MFD facilities to solar power is technologically feasible, and may even have positive environmental and fiscal impacts for the city of Mesa.

Feasibility Study:

The purpose of this study is to assess the sites designated by an industrial Company for possible solar PV, thermal solar or geothermal installation and to estimate the cost, performance and site impacts of these three systems.

Different PV options: crystalline silicon (fixed-tilt), crystalline silicon (single-axis tracking), and thin film (fixed-tilt) have been tested. Each option represents a standalone system that can be sized to use an entire available site area. Two sites are considered: part of the building roof and the adjacent area, represented in the Figure 1.

Figure 1: The roof of the building and the adjacent area.

The economics of the potential systems were analyzed using an electric rate suggested by the utility company (Duke Energy), as well as incentives that are offered by the federal, State of South Carolina, and by the serving utility. Calculations for this analysis assume the 25% federal tax credit incentive would be captured for the system.

The electrical rate increases over the next three years need to be anticipated. A rate increase of this magnitude would greatly improve the economics of a renewable system, such as solar PV generation plant. The system economics with the anticipated rate increase information and job creation estimates if the industrial Company location were used for one of the three systems.

The feasibility study has been performed using the software SAM (System Advisor Model), as well as PVWatt. The System Advisor Model (SAM) is a performance and financial model designed to facilitate decision making for people involved in the renewable energy industry. SAM makes performance predictions and cost of energy estimates for grid-connected power projects based on installation and operating costs and system design parameters that you specify as inputs to the model.

As a first step, the students are guided to perform the following:

- Familiarize themselves with the SAM software
- Introduce the incentives collected into the case study (using SAM)
- Identify the list of inputs needed for the study
- Collecting data for the case studies
- Identify the parameter for the parametric study

There are a couple of reasons that SAM's payback calculation is not as simple as the following equation:

Payback Period (years) = Project Investment ($) / Annual Cash Flows ($/year)

1. Annual cash flows are not constant. For example, a project with a 30-year life may have tax-deductible debt interest payments in the first 15 years, periodic O&M costs every 7 years (e.g., for inverter replacements), and incentive payments in the first 10 years).

2. SAM calculates metrics besides the payback period (levelized cost of energy, NPV, etc.) that are based on a cash flow that includes debt costs, so it uses a different cash flow to calculate those metrics. In the base case cash flow table on the Results page, SAM shows the "after-tax cash flow" that it uses for the LCOE and NPV calculations, and the "payback cash flow" that it uses to calculate the payback period.

To address Items 1 and 2, SAM defines the payback period as the time in years that it takes the cumulative payback cash flow to equal the project investment cost.

The energy demand of the building is provided by the industrial for last three years. As example, the energy demand of the building over 2013 is represented in Figure 2.

The input regarding the location of the building and the adjacent area, the square footage, as well as the PV solar characteristics are introduced in the program, PVWatts.

- **Roof**: ~5799m2 (870 kWdc). In the rest of our calculation, we used only **400 kWdc** as max, since the roof cannot be used entirely for safety, and building codes reasons.
- **Land**: ~ 1 acre = 4046 m2 (607 kWdc). For the rest of the calculation, we only use **300 kWdc** as max, for the same reasons mentioned previously.

The input data that used by SAM for PV Solar are:

- Balance of systems, equipment: $2.50/ watt DC
- Installation labor: $1.00 / watt DC
- Installer margin and overhead: $.20/ Watt DC
- Contingency (%): 15%
- **Indirect Capital Cost**: **$ or $/Wdc or $/m^2**
  - Permitting, environmental studies: Depends on AHJ
  - Engineering: $1,400
  - Grid interconnection: $200.00, unless new transformers are needed at site.
- **Operation and maintenance costs**: $/year or **$/kW-yr or $/MWh**: $350 per year.
- **Financial**:
  - Loan rate: 5%
  - Inflation: 3%

- **Tax and Insurance Rates**
    - Federal Income Tax Rate: 30%
    - State Income Tax Rate: 25%

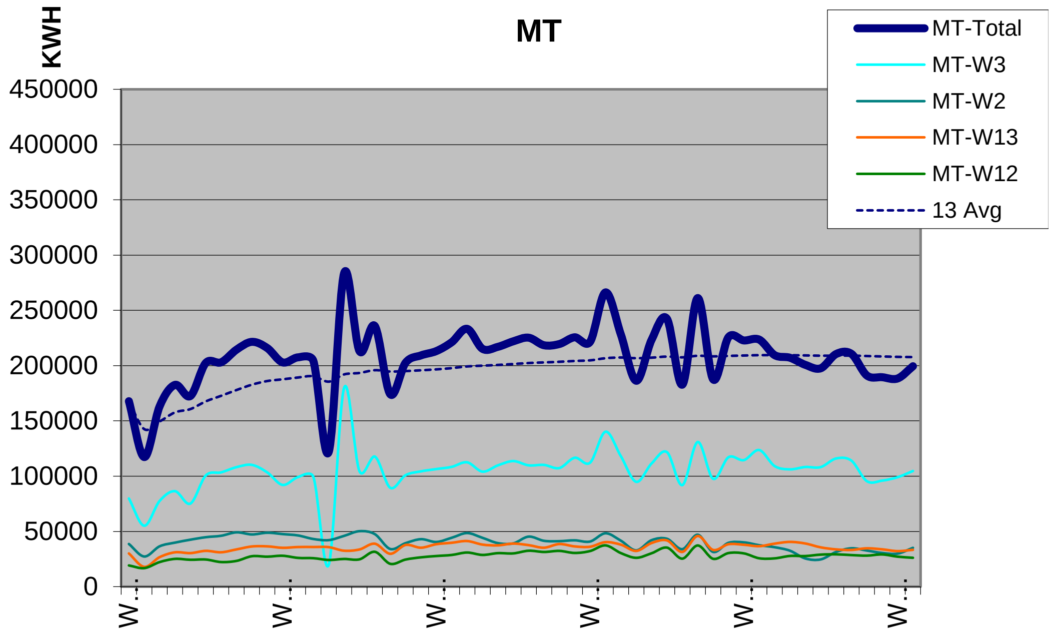

Figure 2: The energy demand of the building over 52 weeks (2013)

Net Present Value:

The difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyze the profitability of the project, shown in Table 1.

The payback period is in the year when the cumulative payback switches from negative to positive. The Year Zero value shows the initial investment amount (a negative number). The Year One value shows the sum of the Year One cash flow and the initial investment, Year Two is the sum of the Year One cumulative cash flow and the Year Two cash flow, etc. As the years progress, the project's cash flow pays off more and more of the initial investment. When the cumulative payback turns positive, the initial investment is paid off. The economic study shows that Flat Plate PV UIPP had the highest net present value (Table 1).

As conclusion, the PV solar and even thermal solar systems are too costly, and the recommendation of the students was to perform a comprehensive building auditing to save energy from the existing equipment, HVAC Systems and upgrade the lighting systems to LED, rather than installing costly PV systems, based on the following:

- The current energy consumption is too high,
- Multiple Lighting fixtures (Metal Halide, T12 and fluorescent) are used.
- The integration between the two HVAC systems (general HVAC system and localized HVAC system for each cell) needs to be improved
- The energy consumption for each system: motors, controls, HVAC need to be monitored and improved (commissioning study).

Table 1: Net Present Value for each Model tested.

Module	**Net Present Value**
PVWatts Commercial	$357,793
PVWatts Commercial PPA	$109,555
PVWatts UIPP	$378,874
Flat Plate PV Commercial	-$1,181,191
Flat Plate PV Commercial PPA	$312,708
Flat Plate PV UIPP	$388,140

Students' Assessment:

The students have as objective to size the PV solar on two areas: the building roof and on one acre land by conducting a performance and financial analysis.

In parallel with the self-evaluation of each course by the instructor, we also conduct a course evaluation by students. The course objectives introduced earlier in the course are again provided to the students at the end of the semester. The students' input on whether the materials offered have met the objectives is then complied and used in the program outcome assessment process. Results of instructor course evaluations (conducted by students) are reviewed by the department chair and the dean and shared with the faculty.

Indirect Assessment Results

Using the indirect course evaluation form, students were asked, anonymously, to self-assess their ability in specific areas identified by the instructor in connection with the course learning objectives. The compilation of the results of the student self-assessment of course learning objectives questions for AREN 485 are presented in Table 2. The student responses of "A" through "E" were converted to a 4.0 GPA scale in the standard way, with an "E" being considered equivalent to an "F". In this way, an equivalent class GPA was obtained for each question. The results of the students' assessment show that for all the questions, students generally feel like they are able to perform the task requested. The next step is to check if the assignments performed by the students will show the same positive answers.

Direct Assessment Results

The four course learning objectives were measured using exam questions. The average grading of such exam are shown in Table 3. One or multiple exam questions were associated with each learning objective, permitting that learning objective to be measured by direct assessment. The points scored per question were converted to a percentage scale and then to an "A" through "F" scale, using the traditional grade assignments. Table 3 shows the breakdown of letter grades received for each exam question. The equivalent class GPA is shown for each question, based on a 4.0 scale.

Direct assessment provides the most accurate measure of a student's knowledge in a given course. In this course, less than 50% of students were able to have a grade of "A". The other 50% are subdivided between "B", "C", "D", and "F". One student was not able to answer the questions successfully, obtaining grades of "F".

Table 2: Results of Indirect Assessment for AREN 485 (twenty two students in the course)

Indirect Assessment						
Student Self-Assessment of Course Learning Objectives	**Number of A's**	**Number of B's**	**Number of C's**	**Number of D's**	**Number of E's**	**Equivalent GPA (4 to 0 scale)**
PV sizing	12	6	3	3		3.41
Performance Analysis	12	4	3	3	0	3.13
Financial Study	11	4	3	4	0	3.00
Take into consideration of the federal, state, and utility incentives	13	5	4	0	0	3.41

Table 3. Results of Direct Assessment for AREN 485 (twenty two students in the course)

Direct Assessment						
Course Learning Objectives	**Number of A's**	**Number of B's**	**Number of C's**	**Number of D's**	**Number of E's**	**Equivalent GPA (4 to 0 scale)**
PV sizing	10	7	3	1	1	3.09
Performance Analysis	12	6	3	0	1	3.27
Financial Study	9	6	4	2	1	2.91
Take into consideration of the federal, state, and utility incentives	9	5	5	2	1	2.86

The direct assessment of the four learning objectives needs improvement, especially those related to financial and economic aspects. Among the improvement, during the capstone we invited people from the industry and university centers, with dual specialization in finance and solar energy.

Each faculty member also conducts an evaluation of performance of students in his/her courses as part of the Program Objectives (PO) and outcome assessment process. A summary report on the performance of students (to meet the program objectives) and compliance with the program outcomes is prepared and submitted to the department chair for the assessment purposes.

A more rigorous process in assessing the learning outcomes of this capstone course will be implemented, which are in parallel with the program outcomes. The following outlines process will be used for this capstone course assessment.

- Individual instructor evaluation of the degree of learning achievement of individual students on a capstone team, which includes consideration of the collective achievements of the team.
- Peer evaluation (optional by instructor).
- Grading of deliverables by the instructors (project plan, mid-term review, final report, exhibit (and abstract), oral presentation, team minutes, web site if applicable).
- Teamwork survey.
- Self-assessment.
- Senior Design Symposium judging (with evaluation criteria explicitly indexed to the learning objectives and articulated via rubrics for all measures).

Conclusions:

Teaching a design courses for undergraduate students is challenging and require real applications, where students need to perform real engineering application. The main objective is to familiarize students them with both energy efficiency and financial studies. For that a comparative study is performed between three PV Solar systems: on the roof, on the adjacent area and both on the roof and adjacent area.

The implementation of a PV solution work on reducing energy consumption, in conditions that a better price from utility company is negotiated and more state incentives are available. Since, very few incentives are available in such location, the PV solar and even thermal solar systems are too costly, and the recommendation of the students was to perform a comprehensive building auditing to save energy from the existing equipment, HVAC Systems and upgrade the lighting systems to LED, rather than installing costly PV systems, based on the following:

- The current energy consumption is too high,
- Multiple Lighting fixtures (Metal Halide, T12 and fluorescent) are used.
- The integration between the two HVAC systems (general HVAC system and localized HVAC system for each cell) needs to be improved

- The energy consumption for each system: motors, controls, HVAC need to be monitored and improved (commissioning study).

References:

Lars Lisell and Gail Mosey, “Feasibility Study of Economics and Performance of Solar Photovoltaics in Nitro, West Virginia”, 2010, Technical Report, NREL/TP-6A2-48594.

Scott Somers, “roof top solar PV feasibility study for the Mesa Fire Department”, City of Mesa Fire Department, Mesa, Arizona.

Precision decisions LLC, “Solar photovoltaics feasibility study for the city of Easthampton Massachusetts” (2007).

El Paso Electric Company System Planning (August 2006), “300 MW Solar Photovoltaic Plant, Generator Interconnection Feasibility Study”.

City of Pomona Municipal Facilities Solar Photovoltaic Feasibility Study, Pomona, CA (URS).