A05 Solar Energy Viability Model
Team Project

This assignment includes (1) milestone.

Purpose of this project

Engineering requires consideration of environmental, economic, social and technical factors as each play an important role in design and modeling decisions. Often these decisions are not straightforward and require ethical and professional judgement.

Your Task

Due to rising energy costs and a need to reduce greenhouse gas emissions (CO_2), the city of Indianapolis, Indiana, is looking for a way to reduce energy usage in their municipal buildings.

The Mayor's office has commissioned your engineering firm to review options for a public library, to complete an **economic and environmental** analysis of the library's energy use, and to make a recommendation, comparing two scenarios:

1. **Proposed new system:** Installing an array of *solar panels* on the library roof to reduce the purchase of commercial electricity produced with fossil energy.

2. **Implementing no new solution and continuing the current use of fossil energy.**

Justify your recommendation based on:

1. **An economic analysis** (compare costs, savings and the payback period of the proposed new system), and
2. **An environmental analysis** (compare CO_2 emissions of both systems).

Relevant Course Resources:

Assignment Resources	• Critical information is provided in this document. • You will create an "Excel Spreadsheet" • The "Technical Brief template" outlines sections of your technical brief and specific expectations
Video Modules	All modules related to Data Analysis, Modeling, and Solar Energy

Organizing Your Work

Pay attention to how you format and organize your work in your technical report and Excel spreadsheet. Below are some general instructions:

Technical Brief: [Note- your grade will be more heavily based on this document]

- Follow the "Technical Brief Template".

Excel Spreadsheet:

- Make sure your tables have captions and titles, and your columns have clear labels & units
- Format your cells with reasonable decimal places and data type (In Excel right click, format cells).
- Include details on your calculations using **text boxes** located near the calculations you are describing. Have detailed explanations in your text boxes so that a user can easily follow along with your work presented in the spreadsheet. Insert a text box by choosing "Text Box" on the "Insert" tab in Excel.
- Follow instructions on how to name each sheet in your Excel document.

Submission Instructions:

- Complete this assignment **as a team.** One member of your team must submit your work on Brightspace, but all team members should review and approve the submission.

  Deliverables:
  - Technical Brief:
    Name your Word file: **ENGR131_ A05 _teamnum.docx**
  - Spreadsheet showing model calculations:
    Name your Excel file: **ENGR131_ A05_ teamnum.xlsx**
    Label your spreadsheets as appropriate

- Submit your work through the designated **Brightspace Assignment Dropbox at** https://purdue.brightspace.com

Background/Technical Content:

Indianapolis Library

This public library, located in Indianapolis, Indiana, has a demand for **electricity** to run computers and electronics, provide lighting, and power ventilation systems (similar to other commercial buildings in the area). The furnaces use **natural gas** to run the heating systems in winter as well as provide hot water year round.

This library is a two-story building with the usable floor space being approximately 2,600 m^2 on both floors and a total usable roof area of 1,000 m^2. The distribution of energy consumption for the library is shown in Figure 1.

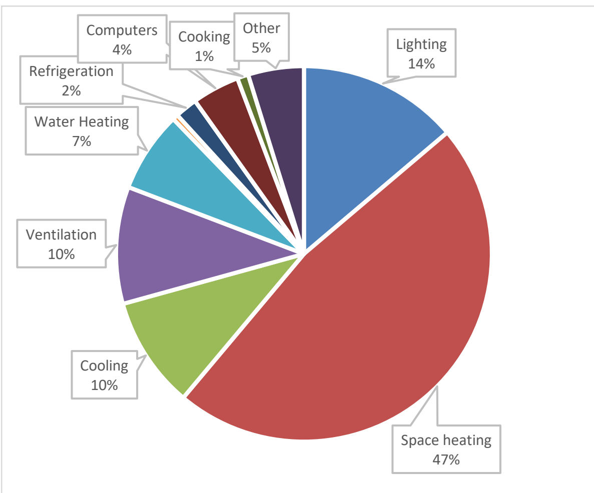

Figure 1. Percentage of Total Energy Usage by Category

The **electricity consumption** for this library is measured as 393,434 kWh per year; however, the daily consumption for this commercial building varies considerably depending on the season. Currently, the library purchases electricity at a commercial rate of 9.77 cents per kWh.

Indianapolis is in a temperate climate with good sunlight at a latitude of 39.73°. Table 1 describes the average monthly library energy use and provides solar insolation data. **Solar insolation** is the average amount of energy (in kWh/day·m^2) that strikes a surface. The actual instantaneous amount of solar energy will vary by season, cloud cover, time of day, and the direction and angle of tilt of the surface away from horizontal. Under perfect circumstances (sun directly overhead — noon on an equinox day at the equator — with no clouds), incident power from the sun is 1,370 W/m^2. There are many variables to consider when designing a solar power facility. Some of these are detailed at the end of this document under ***Solar Panels: Additional information (optional)***. For the purposes of this assignment, *only consider flat panel installation*.

Solar Panels

A solar panel (or photovoltaic panel) is a packaged interconnected assembly of solar cells. Solar panels only generate electricity during daylight hours, but surplus electricity can be stored in special batteries (we will not consider the use of batteries for this assignment). Many installations of solar panels contain several panels, known as a photovoltaic array. In addition to electrical energy savings, solar panels also help reduce the CO_2 emissions produced by fossil energy-burning electrical power plants.

Figure 2: Installation of a solar panel. Retrieved from: http://www.sigearth.com/solar-

Table 1: An Indianapolis Library - Monthly Energy Use and Solar Insolation

Month	Natural Gas Consumption (cubic ft)	Electricity Consumption (kWh)	Average daily solar insolation (kWh/day·m^2) for panels lying flat on the roof
January	174,618	28,888	2.0
February	156,791	28,901	2.8
March	112,141	29,037	3.7
April	66,066	29,984	4.9
May	40,628	33,812	5.9
June	23,777	39,399	6.5
July	23,696	39,480	6.3
August	23,207	39,994	5.6
September	31,022	35,868	4.6
October	63,380	30,173	3.3
November	109,495	28,996	2.1
December	134,323	28,901	1.6

Cost and Specifications of Solar Panels

Typical initial and operational costs of solar panel arrays include materials, pre-installation fees for structural analysis, installation and labor, government incentives and maintenance costs. The anticipated life of the solar panels is 20 years. Table 2 contains cost information for the Sunmodule SM 245 solar panels and related materials. Table 3 provides information on the physical properties and efficiency of the solar panels.

Table 2: Solar Panel and Materials Costs

Item	Cost per solar panel
SM 245 (Solar Panel)	$238
System hardware and wiring	$150
Pre-installation, and installation and labor fees	$200
Maintenance*	$12
Total cost per panel	$600

** One-time premium price includes a lifetime annual cleaning service contract*

Table 3: Solar Panel Specifications of the SM 245 solar panel

Energy Efficiency	22% of solar insolation
Area	1.675 m^2 per panel
Weight	48.5 lbs per panel

Calculating the monthly solar electricity production

- Perform your economic and environmental analysis for an installation of a solar array comprised of **500** Sunmodule SM 245 solar panels **lying flat** on the roof of the Indianapolis Library. Be sure to include the solar panel **energy efficiency** in your calculations.

- Make your economic calculations using constant value of money and cost of the solar array system. Do not consider the time-value of money, interest, or inflation and do not include any financial incentives for investment in renewable energy. Your economic calculations do not need to include the cost of natural gas.

- This information sheet does not provide all the information necessary to complete your report to the Mayor. **A reliable online source for the CO_2 emission data must be found and utilized.**

- Fossil fuels are the predominant energy sources for Indiana. In 2018, the energy sources for generating Indiana electricity were 68.3% coal and 23.6% natural gas (5.1% wind & solar) (EPA).

The essential calculation is simply about units:

$$\begin{matrix}Monthly\ Solar\\ Electricity\ Production\end{matrix}\left(\frac{kWh}{month}\right) = \begin{matrix}Mean\ Daily\\ Insolation\end{matrix}\left(\frac{kWh}{m^2 d}\right)\cdot\begin{matrix}Panel\\ Efficiency\end{matrix}\cdot\begin{matrix}Pannel\\ Area\end{matrix}(m^2)\cdot\frac{Days}{Month}$$

Given in monthly table | Given 0.22 (22%) | Given 1.675 m^2 | Must find

Solar Panels: Additional information (optional)

Tilting solar panels optimizes solar insolation. Tracking systems to do this are very expensive. Many non-tracking installations use tilted panels that are set to maximize winter insolation. However, tilted panels cast shadows. Even partial shadows falling across a solar panel will greatly decrease the electricity output. Therefore, rows of tilted panels must be spaced so shadows are not cast on the next row. Using tilted panel improves individual panel performance but significantly reduces the number of panels that can be installed on a given space. Laying panels flat increases the number of panels that fit onto a space but reduces individual panel performance in the winter. Thus, there is a trade-off between optimizing individual panel performance and maximizing the total number of panels. Solar circumstances are rarely perfect: it is only noon once per day, the sun is higher in summer than winter, most cities are not on the equator, many days are cloudy, etc. The average total insolation, therefore, is significantly less than 1,370 W/m^2; for Indianapolis. If the solar panels are lying flat on the roof, instead of tilted south, the daily insolation is considerably less in the winter, but greater in the summer. Overall, for this proposed system, the amount of electricity generated by tilting does not justify reducing the number of panels.

Check Your Work with the Learning Objectives:

Assignment 05: Report/Technical Brief
Learning Objectives
DV02: Select appropriate graphical representation of dataset based on data characteristics such as numerical (discrete or continuous) or categorical (ordinal or nominal)
DV04: Prepare a table for technical presentation with proper formatting
DV05: Prepare a chart for technical presentation with proper formatting, including title, axes labels, appropriately scaled axes, units and appropriate markers
EB02: Identify assumptions made in cases when there are barriers to accessing information.
EE01: Justify decision based on cultural, economic, environmental and other applicable factors recognizing how engineering practice is not only based on technical information but is shaped by cultural, economic, environmental and other factors.
IL01: Ask questions to determine what new information is needed to scope and solve a problem.
IL02: Gather information from reliable sources
IL04: Include citations within the text (in-text citations) that show how the references at the end of the text are used as evidence to support decisions
IL05: Format reference list of used sources that is traceable to original sources (APA)
PC02: Make statement to communicate result found in analysis.
PC05: Fully address all parts of the assignment by following instructions and completing all work.
PS01: Explain the problem based on synthesis of client, user, and other stakeholder needs.
PS02 - Justify why problem is important to solve by making reference to relevant global, societal, economic, or environmental issues.
PS04: Recognize potentially competing or conflicting needs.
SQ01: Use accurate, scientific, mathematical, and/or technical concepts, units, and data in final solution
SQ02: Justify design solution based on how well it meets criteria and constraints.
TW02: Document all contributions to the team performance with evidence that these contributions are significant.

Assignment 05: Excel Spreadsheet
Learning Objectives
DV01 - Efficient use of engineering tools for basic statistics. Use of automated solutions, such as cell referencing and built in functions.
DV02 - Select appropriate graphical representation of dataset based on data characteristics such as numerical (discrete or continuous) or categorical (ordinal or nominal)
DV04 - Prepare table for technical presentation with proper formatting, including title, row labels, column labels, units and correct decimal places.
DV05 - Prepare a chart for technical presentation with proper formatting, including title, axes labels, appropriately scaled axes, units and appropriate markers.
SQ01: Use accurate, scientific, mathematical, and/or technical concepts, units, and data in final solution