[redacted] | ENVS 492

Final Project Report

[redacted]

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The purpose of this report is to provide [redacted] and the [redacted] with an in-depth analysis of several publicly available green building tools on a University of Illinois campus building. These tools are ENERGY STAR, WELL Certification, the BETTER tool, PVWatts, and IFC EDGE respectively. [redacted] is working in conjunction with [redacted] and a Historically Black College and University (HBCU) to develop a course to train students on green building design and auditing to support green building workforce training needs. In this regard, the ENVS 492 team carried out a case study to understand how each tool is best used, then compiled the results and recommendations. Under the guidance of [redacted], the students assessed the tools and suggested improvements, roadblocks, and final takeaways from the usage of these tools.

INTRODUCTIONS

ENVS 492 Team:

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1 - PROJECT DESCRIPTION, OBJECTIVES, AND SCOPE

It's no secret that our surroundings have a significant influence on our health. Green design aims to improve building performance by reducing negative impacts on the environment as well as optimizing the health and comfort of building occupants. We have evaluated five digital tools and rating systems that can be applicable to an existing UIUC building for opportunities to improve sustainability through installation of energy efficiency, water conservation and on-site renewable energy measures as well as improvements in health, wellness, and resiliency.

More specifically, PVWatts targets cost estimation of photovoltaic energy systems, while the BETTER Tool identifies the highest cost-saving energy efficient measures, ENERGY STAR measures and tracks energy and water consumption, as well as greenhouse gas emissions, and the IFC EDGE and WELL Building certification both work with analysts to determine a building's energy efficiency measures and energy in conjunction with health and wellness, respectively.

[redacted] is looking to design and establish a curriculum for undergraduate students interested in sustainable building design. In consideration of the project objectives, ENVS 492 students will provide [redacted] and [redacted] with a final report documenting the project activities, results, and recommendations. This report includes a demonstration of the use of the tools on a campus building, gives sustainability recommendations for the building evaluated based on the use of the tools, estimates the time to complete analysis once data was obtained, describes the benefits of each tool, and notes the roadblocks encountered.

What we have done:

Table 1: Summary of range and constraints of project

Range:	Constraints:
Understand and study publicly available tools	Will not be studying multiple buildings due to data limitations and time constraints
Assess useability of the tools taking in factors such as interface, data required for output, and time taken to get results	HBCU is undetermined, so will not be collaborating with a faculty member to understand what best suits their needs or recommendations from an academic perspective
Create outline of best practices for tools	

To maintain and further carry on this project once ENVS 492 students have graduated from the course, [redacted] may work in conjunction with the HBCU professor (once decided) to integrate feedback from students using these tools into the course design.

The wider implications of this project are such that professors across the country may be able to apply the information from this report in their classrooms. Fields of study potentially include architecture, various engineering disciplines, and sustainable/green entrepreneurship. Furthermore, it can also be used as a training module for those in the corporate or non-profit sector that are involved in green energy and building design.

Lastly, within this project we hope to provide a holistic overview of the many resources available for those interested in sustainable building to utilize.

2 - SIDNEY LU MECHANICAL ENGINEERING BUILDING PROFILE

Introduction:

The Mechanical Engineering Building at the University of Illinois at Urbana-Champaign opened its doors in 1950 and featured 113 rooms for departmental use, including 32 classrooms and 16 laboratories. In the six decades since, the needs of mechanical engineering students have changed significantly.

Now, the building has expanded to include a five-level, 25,000 sq. ft. addition to the east of the original building, a 3,000 sq. ft. space increase on the north end of the building, and a total of over 60,000 sq. ft. transformation to be optimized for the new generation of mechanical engineers that will leave its walls.

Why are we carrying out our case study at the LUMEB?

The Sidney Lu Mechanical Engineering Building (LUMEB) is a comprehensive space that has classrooms, common areas, food service facilities, and other components that the team felt would allow for greatest application of the studied tools. It is an older building, but also has an extension that was opened in 2021. This balance of old and new allows for a wide range of data sets to be used. Additionally, a WELL Certification process was already being carried out for this building, and thus access to procedures and resources was less limited.

Floor Plans for the facility:

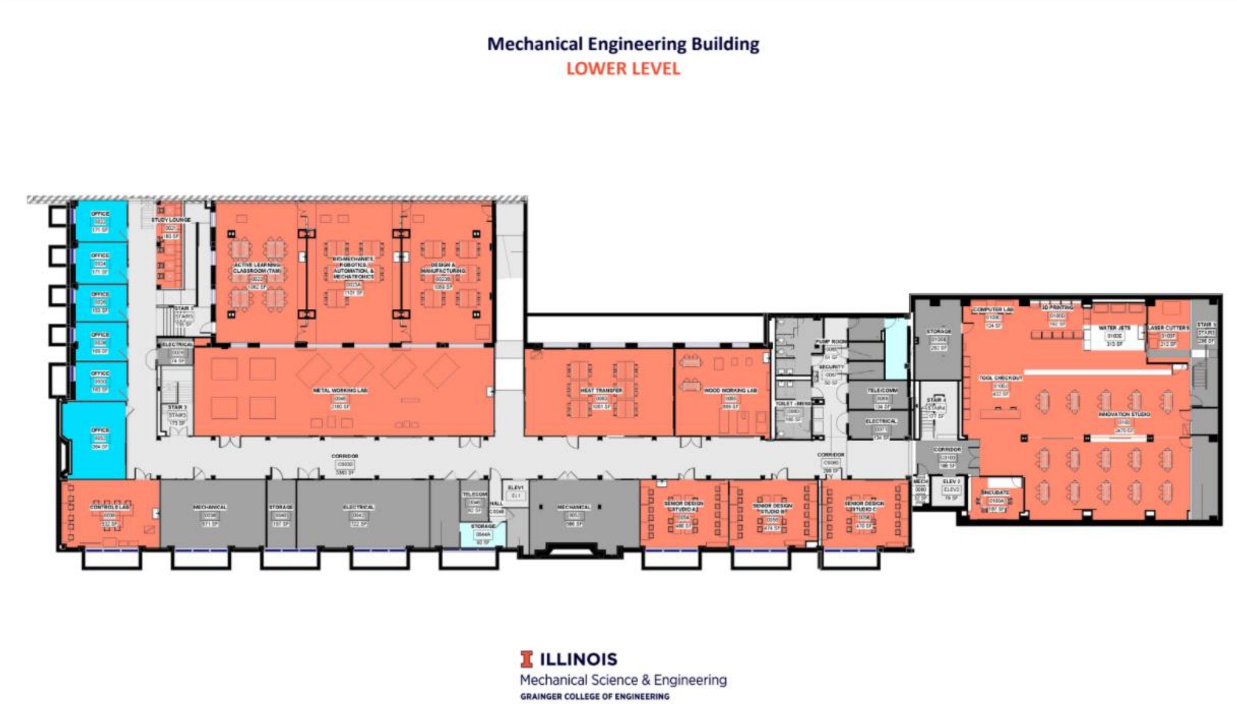


Table 2: Space Breakdown of Lower Level of LUMEB

Space Type	*Area (ft^2)*
Offices	1182
Lab Space/Study Space	13,151
Corridor	3869
Stairs	783
Bathrooms	165
Elevators	136
Mechanical/Electrical/Storage	2987
Total	*22,273*

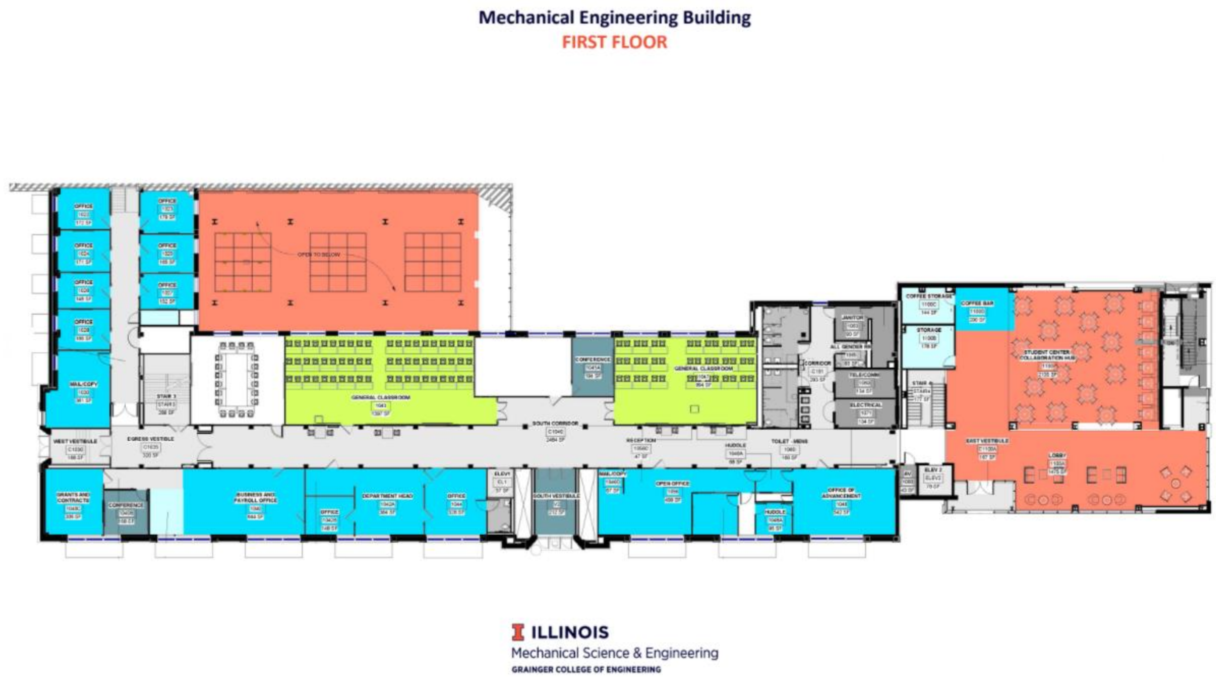


Table 3: Space Breakdown of First Floor of LUMEB

Space Type	*Area (ft^2)*
Offices	4375
Classrooms	2391
Bathrooms	385
Corridors	3380
Conference Space	564
Lab/Study Space	3610
Elevators	136
Mechanical/Electrical/Storage	723
Food	200
Stairs	733
Total	*16,497*

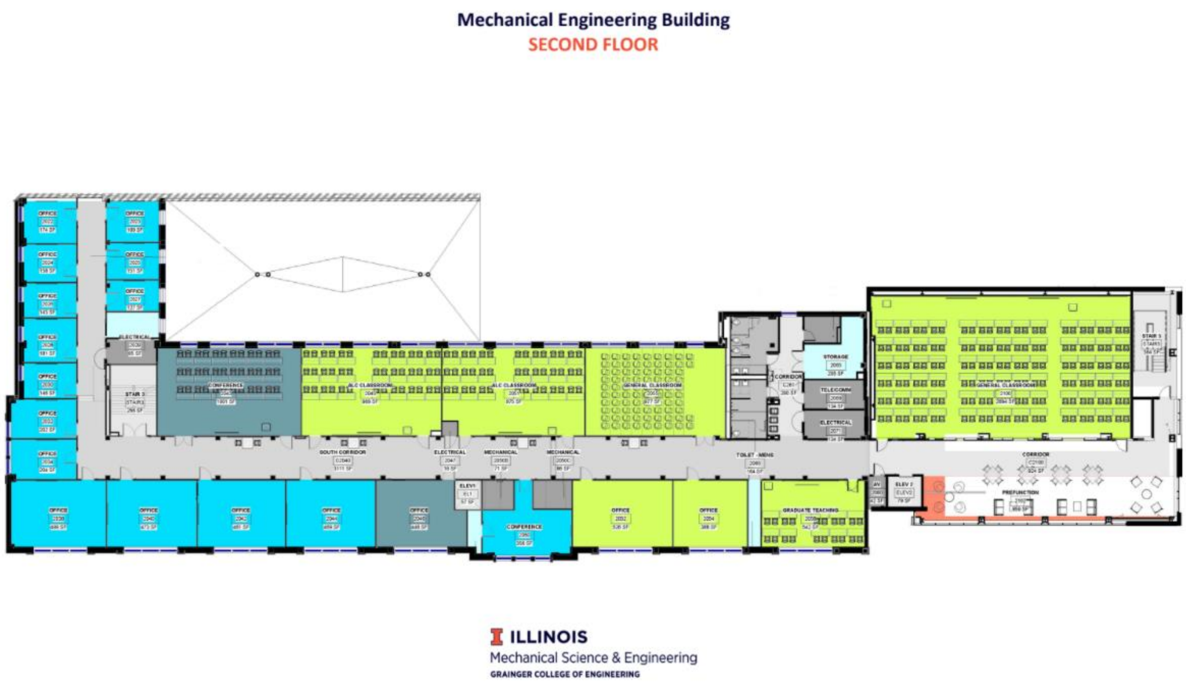


Table 4: Space Breakdown of Second Floor of LUMEB

Space Type	Area (ft^2)
Offices	4905
Classrooms	6357
Bathrooms	328
Corridors	5184
Conference Space	1357
Elevators	136
Mechanical/Electrical/Storage	783
Stairs	620
Total	*19,670*

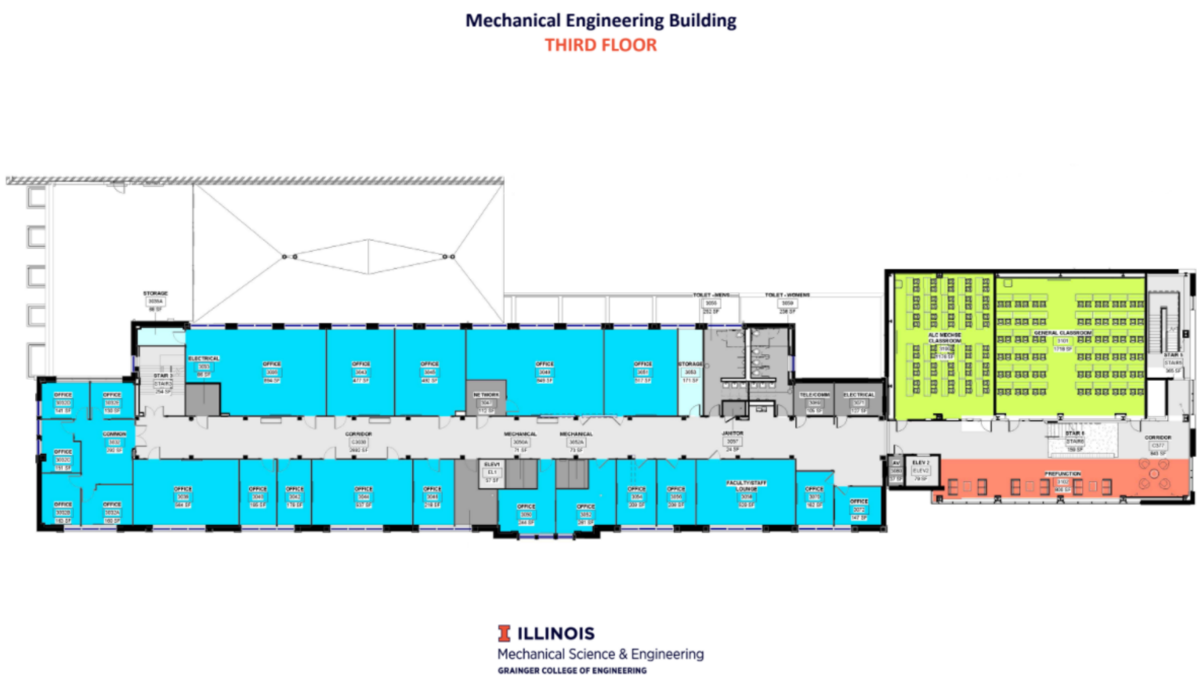


Table 5: Space Breakdown of Third Floor of LUMEB

Space Type	*Area (ft^2)*
Offices	6896
Classrooms	2894
Bathrooms	490
Corridors	3535
Conference Space	1684
Elevators	136
Mechanical/Electrical/Storage	874
Stairs	778
Total	*17,287*

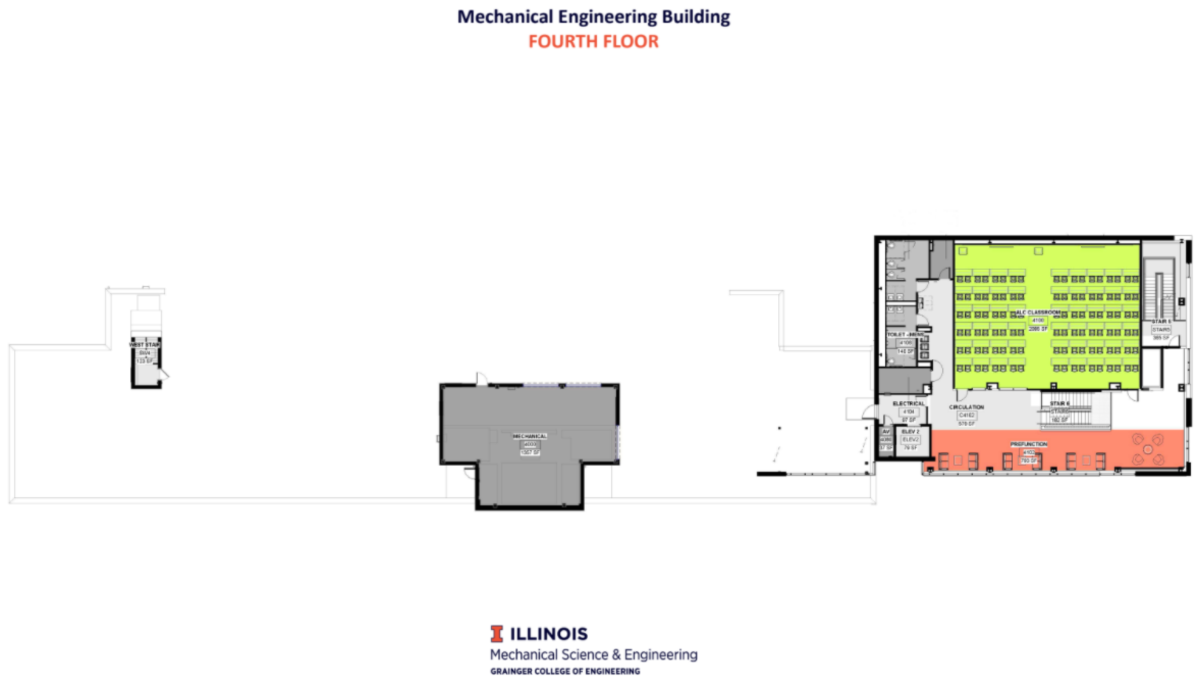


Table 6: Space Breakdown of Fourth Floor of LUMEB

Space Type	*Area (ft^2)*
Classrooms	2095
Bathrooms	280
Corridors	579
Elevators	79
Mechanical/Electrical/Storage	1570
Stairs	670
Total	*5273*

Table 7: Total LUMEB Space and Square Footage

Space Type	*Area (ft^2)*
Multipurpose	*81,000*

3 - Tool 1: ENERGY STAR/Energy Billing System

What is ENERGY STAR Portfolio Manager?

ENERGY STAR is a government-backed voluntary program helping individuals, schools, businesses, colleges and universities, and other organizations protect the environment through superior energy performance. It provides simple, credible, and unbiased information that consumers and businesses rely on to make well-informed decisions that affect the future of our world. The ENERGY STAR program is administered by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE).

Impact:
The ENERGY STAR mark is recognized by more than 75 percent of the public. The ENERGY STAR label appears on products such as lighting, computers, appliances, and electronics when they meet government specifications for superior energy performance. Americans, with the help of ENERGY STAR, save 5 trillion kilowatt-hours of electricity, avoid more than $450 billion in energy costs, and achieve 4 billion metric tons of greenhouse gas reductions. Over the lifetime of the program, every dollar EPA has spent on ENERGY STAR resulted in $350 in energy cost savings for American business and households. In 2019 alone, ENERGY STAR and its partners helped Americans save nearly 500 billion kilowatt-hours of electricity and avoid $39 billion in energy costs.

Portfolio Manager:
Portfolio Manager is an interactive energy management tool that allows you to track and assess energy and water consumption across your entire portfolio of buildings in a secure online environment. Whether you own, manage, or hold properties for investment, Portfolio Manager can help you set investment priorities, identify under-performing buildings, verify efficiency improvements, and receive EPA recognition for superior energy performance. It is available at no-cost to all users.

ENERGY STAR is a useful tool for all types of industries and building types to benchmark and improve energy performance. College campus buildings are a specific subset within the Education branch and the tool stores pointed information on each building subset. Many colleges and universities have already successfully taken steps to improve energy efficiency and protect the environment thanks to the use of ENERGY STAR Portfolio Manager.

Tool Functionality and Scoring:

The main tool for benchmarking buildings that ENERGY STAR provides is the ENERGY STAR Portfolio Manager. This tool can be used to rate the energy performance of operating residence halls, campus administrative buildings, and hospitals. This tool can also provide a centralized view of all campus facilities by calculating a combined energy usage metric based on combined floor space. In order to use the tool, building managers must enter building operating characteristics and a year of utility bills into EPA's online benchmarking tool, Portfolio Manager, to receive a score indicating how the building compares to similar buildings nationwide.

Scores range from 1-100. A score of 50 equivocates to the industry average performance. A building with a score above 75 is eligible to earn the ENERGY STAR label. The ENERGY STAR energy performance scale accounts for the impact of weather variations as well as changes in key physical and operating characteristics of each building. Based on the information you enter about your building such as size, location, number of occupants and number of personal computers, the energy performance score compares your building's energy use to the actual energy use of similar buildings around the country.

EPA developed the energy performance scale as a screening tool to help organizations assess performance and identify those buildings that offer the best opportunities for improvement and recognition. The tool's 1–100 scale is easily understood and can facilitate communication between facility managers and senior executives regarding building performance.

LIST OF REQUIRED DATA:

Almost all types of energy, water, and waste data can be benchmarked using Portfolio Manager. The more accurate and larger the data set, the more accurate the report and therefore the ENERGY STAR score.

Information required for ENERGY STAR Portfolio Manager Use
Not all data points apply to each building. The more specific information input into ENERGY STAR the more accurate the score.

- Property name
- Property Address
- Total Gross Floor Area of Property
- Irrigated Area
- Year Built/Planned for Construction Completion
- Occupancy
- Number of Buildings
- 12 consecutive months of Energy, Water, and Waste Data

- Energy Options
    - Electric
    - Natural Gas
    - Propane
    - Fuel Oil (No. 2)
    - Diesel
    - District Steam
    - District Hot Water
    - District Chilled Water
    - Fuel Oil (No. 4)
    - Fuel Oil (No. 5 and No. 6)
    - Coal (anthracite)
    - Coal (bituminous)
    - Coke
    - Wood
    - Kerosene
    - Fuel Oil (No. 1)
- Water Options
    - Municipally Supplied Potable Water
    - Municipally Supplied Reclaimed Water
    - Well Water
- Waste/Material Options
    - Trash
    - Mixed Recyclables
    - Compostable - Mixed/Other

Additional Data Required for College/University Buildings

- Gross Floor Area
- Weekly Operational Hours
- Enrollment
- Number of Full-Time Equivalent Workers
- Number of Computers
- Grant Dollars

PROCESS OVERVIEW:

Create a Portfolio Manager account.

- User creates an account using a username and password.
- One must input personal information including name, job title, email, phone, reporting units, as well as street address into the system.

- Information about your organization is input next. The organization name as well as the service of the organization must be provided. In the case of our study, 'Education' was selected as the service of our organization.
- One must answer whether the organization is an ENERGY STAR partner, meaning the university has signed a partnership agreement with the EPA's ENERGY STAR program to make a fundamental commitment to protecting the environment through continuous improvement of energy performance. In our case study, the University of Illinois is not an ENERGY STAR partner.
- You then activate your account using an email link.

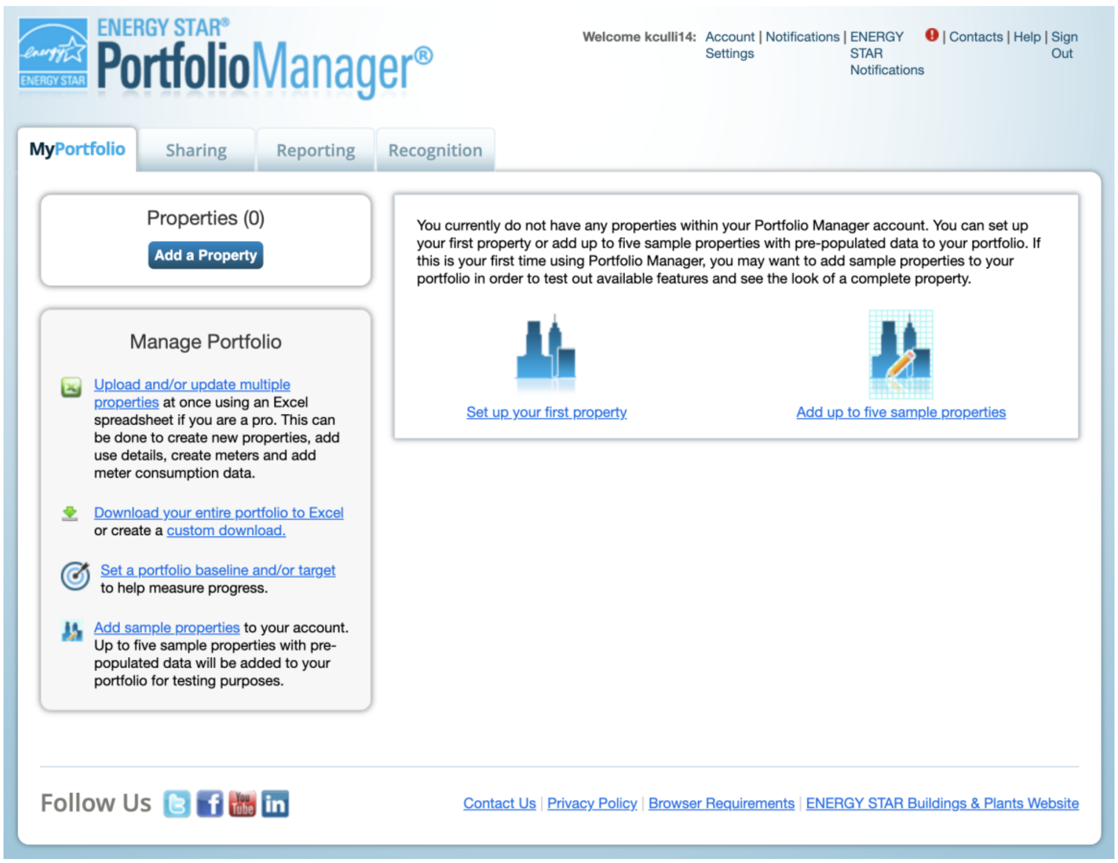
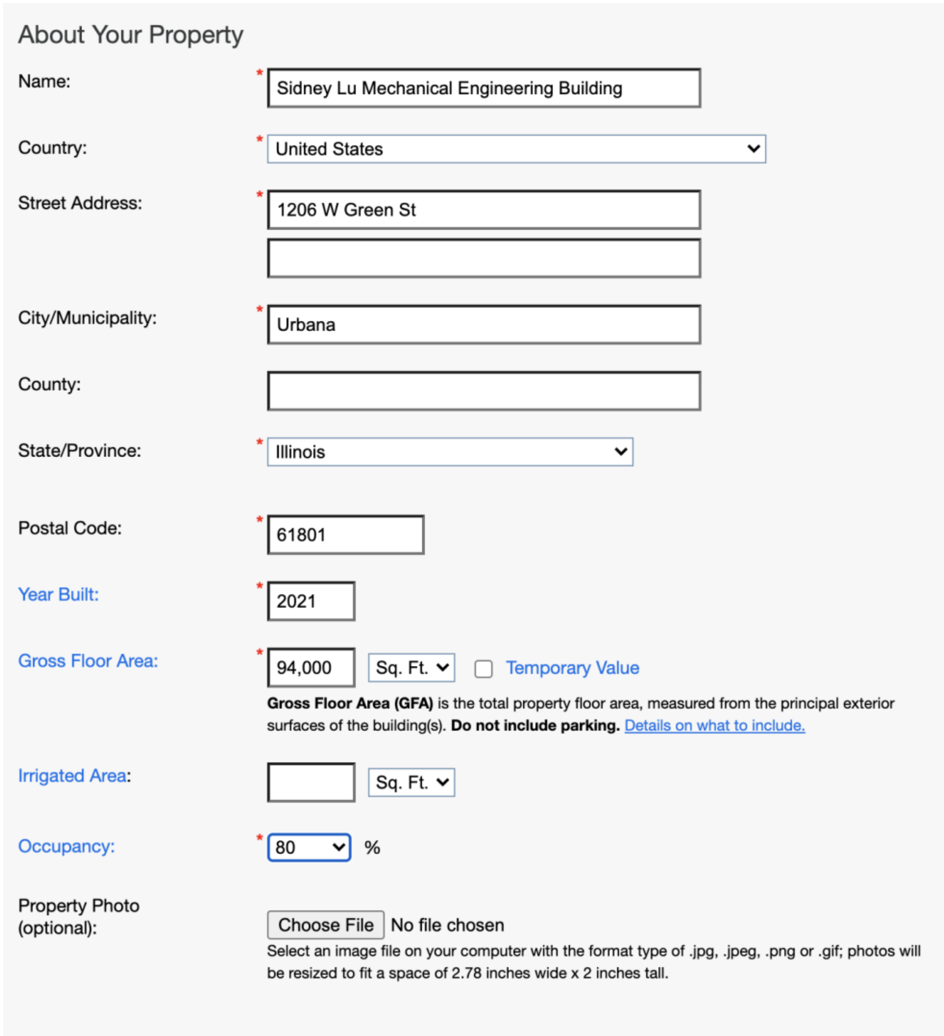


Figure 1: ENERGY STAR Portfolio Manager Interface

Add a property.

- To set up your first property, you must select a property type. For our example, College/University was selected.
- You must differentiate how many physical buildings are considered part of the property.
- Finally, the property's construction status (existing, design project, or test property) is questioned.
- Information about the property, including name, country, address, year built, gross floor area, irrigated area, and occupancy are input.

- A Standard ID (an identification tool used for data collection and benchmarking assigned by many state and local governments) is collected, if applicable. In our case, the University of Illinois does not apply to any Standard ID issuance.


About Your Property

Name: * Sidney Lu Mechanical Engineering Building

Country: * United States

Street Address: * 1206 W Green St

City/Municipality: * Urbana

County:

State/Province: * Illinois

Postal Code: * 61801

Year Built: * 2021

Gross Floor Area: * 94,000 Sq. Ft. Temporary Value

Gross Floor Area (GFA) is the total property floor area, measured from the principal exterior surfaces of the building(s). **Do not include parking.** Details on what to include.

Irrigated Area: Sq. Ft.

Occupancy: * 80 %

Property Photo (optional): Choose File No file chosen

Select an image file on your computer with the format type of .jpg, .jpeg, .png or .gif; photos will be resized to fit a space of 2.78 inches wide x 2 inches tall.

Figure 2: ENERGY STAR Data Addition

- The final step in adding a property requires inputs of building use data. This includes gross floor area, weekly operating hours, enrollment, number of full-time equivalent (FTE) workers, number of computers, as well as grant dollars.
    - Each input must be estimated as a temporary or current value. If the building is a multi-use case, you must input this data for each use case.

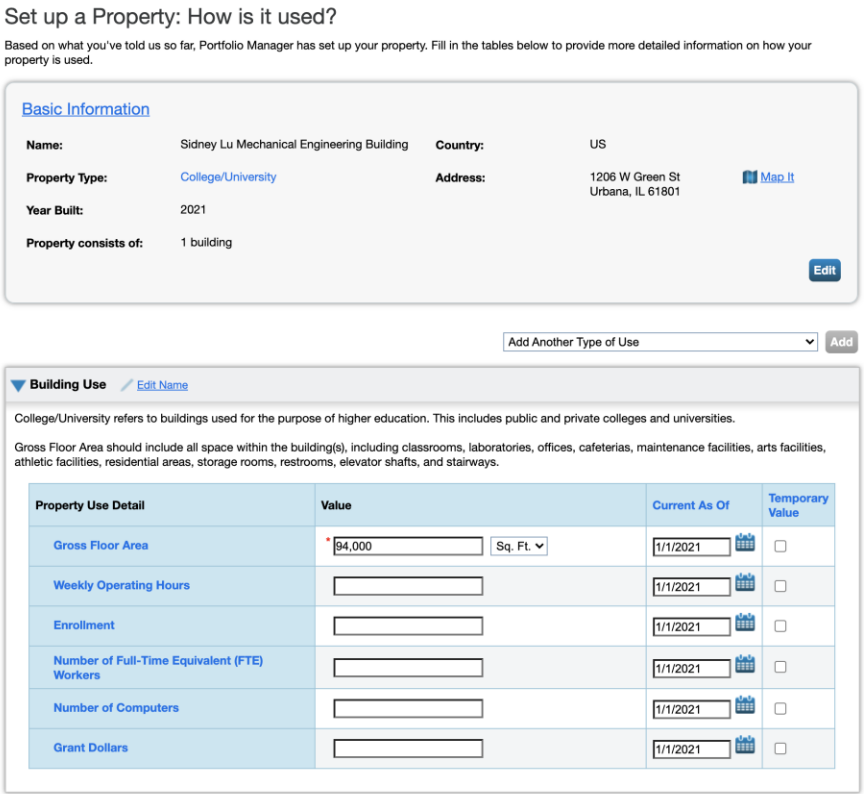


Figure 3: ENERGY STAR Property Set-up

Enter Energy, Water, and Waste & Materials Data.

Once the property is added into the system, a new interface is available in which the user can input metrics. One must gather at least 11 consecutive months of utility bills for all fuel types used in the building. There are 5 ways to input Bill Data:

1. Manually (Instructions here)
2. Use a simple spreadsheet (on the bottom of each meter's Manage Bills page) to upload or Copy/Paste
3. Use a complex spreadsheet (multiple meters + multiple properties)
4. Hire an organization to electronically enter the data
5. See if the utility company offers this service

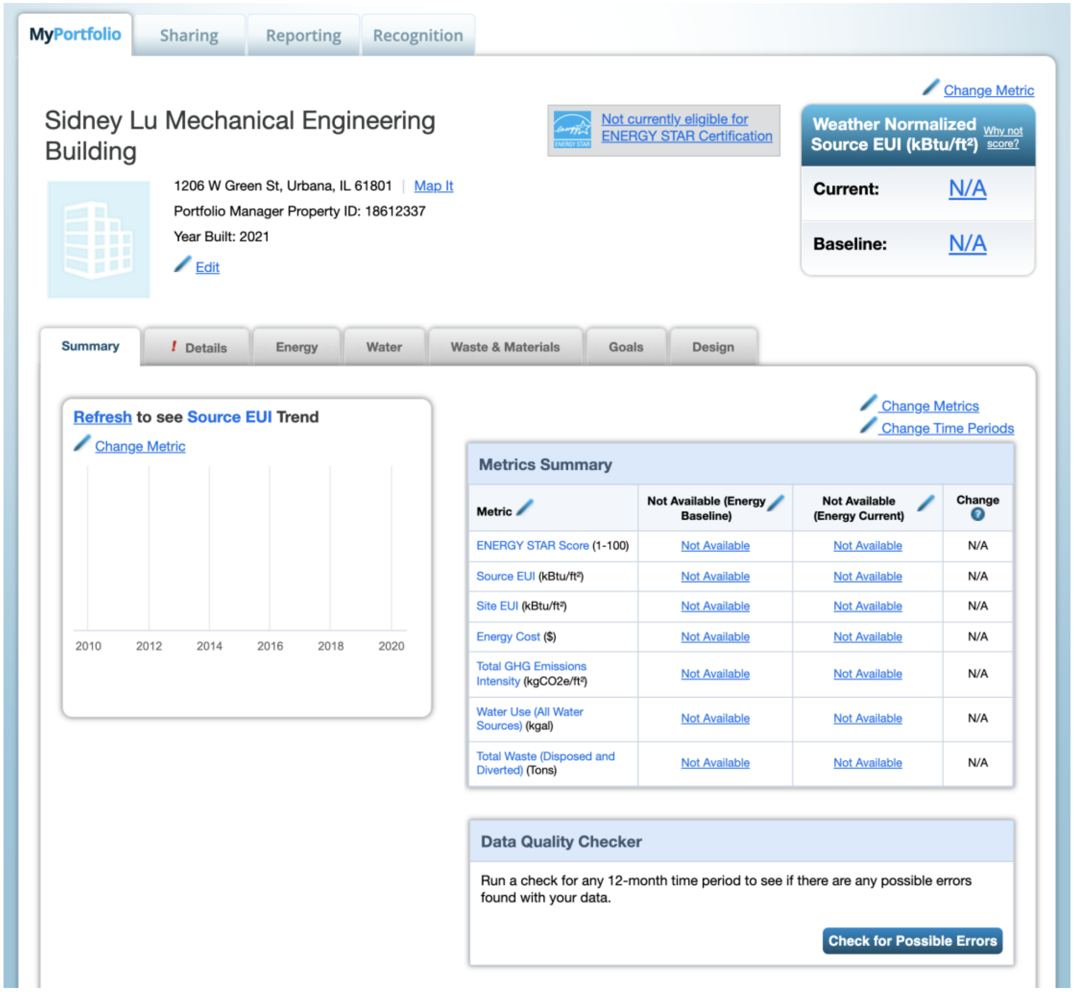


Figure 4: ENERGY STAR Energy, Waste, Water, and Materials Data

Metrics include:

Source EUI (kBtu/ft²): The total amount of raw fuel that is used to operate the property. Source EUI (Energy Use Intensity) is calculated when Source Energy is divided by the Gross Floor Area.

Site EUI (kBtu/ft²): The annual amount of all the energy the property consumes on-site, regardless of the source. Site EUI is calculated when Site Energy Use is divided by the property square footage.

Energy Cost ($): Total cost for each energy meter for the selected 12-month period. This can be a combination of energy cost metrics for each individual energy type (Grid Electricity, Onsite Solar/Wind Electricity, Natural Gas, Fuel Oil (No. 1), …) and as aggregated values for all fuel sources combined (Energy Cost, Energy Cost Intensity, National Median Energy Cost)

Total GHG Emissions Intensity ($kgCO_2e/ft^2$): Greenhouse Gas (GHG) Emissions are the carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) gases released into the atmosphere because of energy consumption at the property. Total emissions are calculated as the sum of Direct Emissions and Indirect Emissions.

Water Use (All Water Sources) (kgal): Sum of all water meters, both indoor and outdoor.

Total Waste (Disposed and Diverted) (Tons): Total of all the waste and materials that are being tracked. It includes everything that is disposed of, composted, recycled, and donated/reused.

View Results & Progress.

Figure 5: ENERGY STAR Data Output Example

This final step allows the user to trend and track improvements across an entire portfolio of buildings with a variety of standard graphs. If the building scored a 75 or higher, it may be eligible for ENERGY STAR certification. Pictured above in Figure 5 is a Portfolio Manager results screen.

FINDINGS AND TOOL RECOMMENDATIONS:

Why ENERGY STAR?

Leading organizations take a strategic approach to energy management. Most importantly, through benchmarking against similar buildings, organizations can identify opportunities to improve energy performance and gain financial benefits. By looking at performance at the whole building level, building managers can identify opportunities for savings through operational improvements and system optimization as well as capital upgrades.

Overall, this tool is recommended to be used for these main purposes:

1. Set goals for energy performance.
2. Establish a baseline energy performance for each building (and the campus as a whole) using Portfolio Manager.
3. Conduct ongoing measurement and verification of improvements - both financial and environmental.
4. Prioritize investments.
5. Earn recognition from EPA, BOMA, ASHE, and other organizations for environmental and operational excellence.

This tool is best used when wanting to compare:

1. Similar buildings in a portfolio
2. Past building performance
3. Target building performance for energy efficiency

Regarding recommendations for the University of Illinois specifically, I would suggest further education around ENERGY STAR certification with our campus sustainability experts. The University does not have ENERGY STAR certified buildings on campus. The University of Illinois Facilities and Services require the use of ENERGY STAR equipment when applicable, but that is a different aspect of the ENERGY STAR system. ENERGY STAR even has implemented a national call-to-action to improve the energy efficiency of America's commercial, industrial, and campus buildings by 10 percent or more.

USABILITY

The website and overall application were very user friendly. ENERGY STAR has populated their website and produced numerous documents with information on how to use the tool, how to input data, and what the data means. Any question that I had about the application was solved by referencing these documents, linked in the references section of this report. They have even crafted a document specifically for college students looking to make their college campus more energy efficient, clearly detailing how ENERGY STAR and the Portfolio Manager can help in the process.

ESTIMATED TIME FOR COMPLETION:

First, one must familiarize with the ENERGY STAR platform before beginning to input data. In my experience, this process takes at least 4 hours. The overall estimated time for completion varies greatly depending on the method of data input. Once the data is input, the graphs are instantly populated with the data. Along with the graph output, the building is given a score that correlates with the energy efficiency of the building data. If this score is above a 75, an application can be submitted to gain ENERGY STAR certification. During the application process, the DOE verifies the data and score. According to the website, it takes anywhere from 1-2 weeks to review and either approve or reject an ENERGY STAR certification application.

ROADBLOCKS ENCOUNTERED:

Before using the tool, one must be cognizant of the variety of parameters that ENERGY STAR puts in place to qualify for ENERGY STAR certification. Thanks to the lack of cost to use the Portfolio Manager tool, there was no financial barrier of entry. One must be able to understand and input mass quantities of data sets to accurately use the tool, which could be a barrier to some.

Knowing distinct occupancy totals for a building on a college campus is difficult as well, especially when considering hybrid class schedules.

4 - Tool 2: WELL Certification

What is the WELL Certification?

The WELL Building Standard v2 is a way for organizations to deliver more intentional and thoughtful spaces that enhance human health and well-being. This standard is a performance-based system for certifying, measuring, and monitoring features of the built environment. The features that are studied impact human health and wellbeing via air, water, light, comfort, mind, fitness, and nourishment. The strategies used to determine whether these factors are up to par are backed by scientific research that aims to advance human health through design interventions and implementing operational protocols and policies that will optimize health and well-being.

WELL is managed and administered by the International WELL Building Institute (IWBI), a public benefit corporation whose mission is to improve human health and wellbeing through the built environment. The WELL Building Standard® is third-party certified by the Green Business Certification Incorporation (GBCI), which administers the LEED certification program and the LEED professional credentialing program.

FINDINGS AND TOOL RECOMMENDATIONS:

WELL can be implemented either before or after the building is constructed. However, for maximum effectiveness, WELL considerations should be taken into account before the building is constructed and that way a higher level of certification can be achieved. Otherwise, modifications may need to be made to the building structure or operation to meet the WELL requirements, and this would mean the need for more funds after construction.

To complete the WELL process, there are several people that play a major role in doing this successfully. First and foremost is the building owner, or the person that has taken on the role of implementing WELL Certified procedures. The project owner will then hire an architect with whom they will register the project with WELL and find a suitable WELL assessor. In addition to the project owner and architect, there are other people that will contribute heavily to the design such as the HVAC Engineer, Electrical Engineer, and those in charge of interior aesthetics.

With the architect, the project owner must outline the necessary qualities the building should possess, a priority list, and the cost of each quality (for example, accessible entrance ramps will cost x amount of dollars).

WELL requires that each quality be maintained in order to keep the status as WELL Certified. For this, a policy was written up for each quality outlining a process that would allow for the quality to remain consistent (i.e. ramps will be made sure to not be blocked at any time so that entrances are always ADA accessible).

Lastly, depending on the number of points the building can get based on WELL criteria, the building is assigned Bronze, Silver, Gold, or Platinum status. The LUMEB is currently at a silver status due to some components remaining incomplete.

PROCESS OVERVIEW:

1) **Registration**
   WELL Certification begins with registration through WELL Online. Upon registration, a WELL contact is assigned to the project. The WELL contact supports the project administrator to help navigate the WELL Certification process in a timely and smooth fashion.

2) **Documentation**
   Any documentation submitted in the initial review as well as after the project is registered is looked over by the WELL Assessor. They will ensure that the submitted documentation meets the requirements.

3) **Performance Verification**
   Once the project passes the documentation review phase, the project may move on to Performance Verification, where a series of post-occupancy performance tests are performed.

4) **Certification**
   Once it is demonstrated through these two steps that the project has achieved all the applicable Preconditions and desired Optimizations, the project achieves WELL Certification. Recertification ensures that the project maintains the same high level of design, maintenance, and operations over time.

ESTIMATED TIME FOR COMPLETION:

In general, the following summary of the WELL Process takes about 1 year for Platinum certification according to the Sidney Lu MEB project manager. This is due to ensuring the presence of as many qualities as possible.

Taking everything into consideration, the building can be either Bronze, Silver, Gold, or Platinum certified. WELL Certification is valid for three years. To maintain a current certification, WELL Certified projects must undergo Performance Verification again and apply for recertification to verify that the building continues to perform in accordance with the requirements of the WELL Building Standard before the end of the three-year Certification period. During the Certification period, annual data must also be submitted for the features that require more frequent reporting.

In terms of assessing the building itself, it is less feasible for a student to come in and grade the building against the WELL Categories unless they were to go along with the project owner step by step. For example, unless a student is trained to know what to look for, it is unlikely that they will know what 'Enhanced Ventilation', or 'Enhanced Thermal Performance' will look like. An estimation of this process may range from a solid several hours over one day (assuming all the categories have been checked) to a spread-out time frame over the course of several weeks. Some qualities a student may go in and notice themselves, such as 'Handwashing' and 'Access to Nature' but the majority of the WELL points require a certain level of expertise.

REQUIRED DATA FIELDS:

HED

Project Name: UIUC ME Building
Client: University of Illinois at Urbana-Champaign
Project Number: 2016-01087-000

WELL v2
2019 | Q2
8/16/2019

Y	?	N		Air
X			A01	Fundamental Air Quality
X			A02	Smoke-Free Environment
X			A03	Ventilation Effectiveness
X			A04	Construction Pollution Management
0	3	1	A05	Enhanced Air Quality
0	1	2	A06	Enhanced Ventilation
0	0	2	A07	Operable Windows
0	1	1	A08	Air Quality Monitoring and Awareness
1	0	0	A09	Pollution Infiltration Management
1	0	0	A10	Combustion Minimization
0	0	1	A11	Source Separation
1	0	0	A12	Air Filtration
0	0	1	A13	Active VOC Control
1	0	1	A14	Microbe and Mold Control
4	5	9	4	*4-12 points

Y	?	N		Water
X			W01	Fundamental Water Quality
X			W02	Water Contaminants
X			W03	Legionella Control
0	1	0	W04	Enhanced Water Quality
1	0	1	W05	Water Quality Consistency
0	0	1	W06	Drinking Water Promotion
1	2	0	W07	Moisture Management
2	0	0	W08	Handwashing
4	3	2	4	*2-12 points

Y	?	N		Nourishment
!!!			N01	Fruits and Vegetables
!!!			N02	Nutritional Transparency
0	0	3	N03	Refined Ingredients
1	0	1	N04	Food Advertising
0	0	1	N05	Artificial Ingredients
0	0	1	N06	Portion Sizes
1	0	0	N07	Nutrition Education
2	0	0	N08	Mindful Eating
0	1	0	N09	Special Diets
1	0	0	N10	Food Preparation
0	0	1	N11	Responsible Food Sourcing
0	0	2	N12	Food Production
1	0	0	N13	Local Food Environment
6	1	9	6	*2-12 points

Y	?	N		Light
-			L01	Light Exposure and Education
X			L02	Visual Lighting Design
	1	2	L03	Circadian Lighting Design
	1	2	L04	Glare Control
	3		L05	Enhanced Daylight Access
	1		L06	Visual Balance
	2		L07	Electric Light Quality
1		1	L08	Occupant Control of Lighting
1	8	5	1	*2-12 points

Y	?	N		Movement
X			V01	Active Buildings and Communities
-			V02	Movement Network and Circulation
	1	2	V03	Visual and Physical Ergonomics
2		1	V04	Active Commuter and Occupant Support
2	1		V05	Site Planning and Selection
		3	V06	Physical Activity Opportunities
		2	V07	Active Furnishings
1	1		V08	Physical Activity Spaces and Equipment
1			V09	Exterior Active Design
		1	V10	Enhanced Ergonomics
		1	V11	Physical Activity Promotion
		1	V12	Self-Monitoring
6	3	11	6	*2-12 points

Y	?	N		Thermal Comfort
X			T01	Thermal Performance
1	2		T02	Enhanced Thermal Performance
	1	1	T03	Thermal Zoning
1		2	T04	Individual Thermal Control
		2	T05	Radiant Thermal Comfort
		1	T06	Thermal Comfort Monitoring
		1	T07	Humidity Control
2	3	7	2	*2-12 points

Y	?	N		Sound
X			S01	Sound Mapping
	3		S02	Maximum Noise Levels
	3		S03	Sound Barriers
	1	2	S04	Sound Absorption
		2	S05	Sound Masking
0	7	4	0	*2-12 points

Y	?	N		Materials
X			X01	Fundamental Material Precautions
-			X02	Hazardous Material Abatement
-			X03	Exterior Materials and Structures
		1	X04	Waste Management
2			X05	In-Place Management
		2	X06	Site Remediation
	1		X07	Pesticide Use
	1		X08	Hazardous Material Reduction
	2		X09	Cleaning Products and Protocol
1	2		X10	Volatile Compound Reduction
		3	X11	Long-Term Emission Control
	2	1	X12	Short-Term Emission Control
		2	X13	Enhanced Material Precaution
	2		X14	Material Transparency
3	10	9	3	*2-12 points

Y	?	N		Mind
X			M01	Mental Health Promotion
X			M02	Access to Nature
3			M03	Mental Health Support
	2		M04	Mental Health Education
	2		M05	Stress Support
1			M06	Restorative Opportunities
		1	M07	Restorative Spaces
1			M08	Restorative Programming
1			M09	Enhanced Access to Nature
1			M10	Focus Support
		2	M11	Enhanced Access to Nature
1			M12	Business Travel
3			M13	Tobacco Prevention and Cessation
3			M14	Substance Use Education and Services
	3		M15	Opioid Emergency Response Plan
14	7	3	12	*2-12 points

Y	?	N		Community
X			C01	Health and Wellness Awareness
X			C02	Integrative Design
X			C03	Occupant Survey
3			C04	Enhanced Occupant Survey
3			C05	Health Services and Benefits
2	1		C06	Health Promotion
	2		C07	Community Immunity
	3		C08	New Parent Support
		3	C09	New Mother Support
	2		C10	Family Support
		1	C11	Civic Engagement
		2	C12	Organizational Transparency
3			C13	Accessibility and Universal Design
1	1		C14	Bathroom Accommodations
1		2	C15	Emergency Preparedness
1			C16	Community Access and Engagement
14	9	8	12	*2-12 points

Y	?	N		Innovations
		10	I01	Innovate WELL
1			I02	WELL Accredited Professional (WELL
1			I03	Educate WELL
		1	I04	Gateways to Wellness
5			I05	Green Building Rating Systems
7	0	11		

Y		N	
17	4		Preconditions
54	56	67	Optimizations (Total)
50	56	14	**Optimizations (Towards WELL certification)**
7	0	11	**Innovations**
57	56		113

TOTAL: 57 - 113

Current certification
SILVER

Potential certification:
PLATINUM
3 points to Gold
23 points to Platinum

WELL Silver Certification: 50 points | WELL Gold Certification: 60 points | WELL Platinum Certification: 80 points

Figure 6: Summary of all the factors considered for a WELL Project

USABILITY:

Functionality wise, WELL is a process carried out by studying the building and implementing systems that will satisfy the requirements. Usability is not so much a tool, but rather an undertaking by several people. In this case, WELL is accessible for those with the funds and passion to pursue it. Otherwise for students, it is a study in understanding the ways buildings impact human bodies and minds.

ROADBLOCKS ENCOUNTERED:

To understand the process of WELL Certification, there are many online resources available, which promote the usage of WELL and how to go about it. However, for students researching this process, it is unlikely that a WELL expert will exist on the campus they are at. Of the many buildings and projects on the UIUC campus, only one building is currently pursuing WELL. In this regard, there were accessibility hurdles that needed to be overcome in the pursuit of carrying out this case study. First, Facilities and Services needed to be contacted, who then referred the project owner of the WELL Certification at the Sidney Lu MEB. Furthermore, as a student it was difficult to gain cooperation from staff to assist in the thorough understanding of WELL. Although not everyone may face this hurdle, it is likely that there will be some lack of regard for the student's time.

Some recommendations may be for the next student to study and understand the process of WELL to ultimately start thinking about different parameters that promote health and wellness. For example, parameters such as light exposure and humidity control affect a person's mood and comfort. For someone studying architecture, they may take into account these factors in future projects. For someone studying Food Science and Nutrition, they may take into consideration portion sizes, and local food environment. WELL is not necessarily a tool that students will implement themselves, rather it can be a gateway to start thinking about energy and wellness in an intersectional manner.

5 - Tool 3: BETTER

BETTER BUILDING EFFICIENCY TARGETING TOOL FOR ENERGY RETROFITS U.S. DEPARTMENT OF ENERGY

What is the BETTER tool?

BETTER is a software toolkit used to quickly identify the highest cost-saving energy efficient measures in buildings and portfolios. BETTER benchmarks a building's energy use against peers; quantifies energy, cost, and GHG reduction potential; and recommends specific energy efficiency measures.

FINDINGS AND TOOL RECOMMENDATIONS:

Overall, the BETTER tool is very user-friendly. It is designed as an easy-to-use, open-source tool that allows building owners and managers to rapidly convert readily available, monthly building energy consumption data into specific recommendations for improvement. Though the tool requires minimal inputs, it is critical that the correct energy consumption metrics and energy costs are entered accurately to receive beneficial recommendations.

This graph is an example of the output that BETTER creates to determine appropriate energy efficiency based on weather conditions.

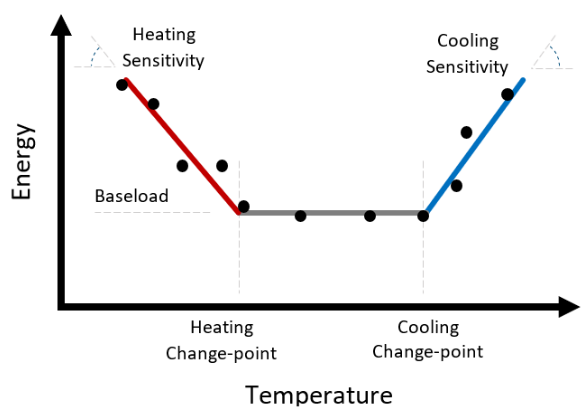


Figure 7: Change-point model example

BETTER uses regression techniques to analyze a building's monthly energy use in response to weather conditions in order to determine how much energy is weather-sensitive (heating and cooling), and weather-independent (lighting, plug loads, etc.). Normalized energy use data is fit to temperature patterns to determine whether heating and cooling set points are appropriate and whether equipment is performing for optimal energy efficiency (Li).

The figure below is an example of the benchmarking aspect of BETTER, which determines how your building or portfolio compares against peers or industry standards to further evaluate energy savings. The BETTER tool creates benchmarking charts specific to energy type as well, such as electricity consumption benchmarking and water consumption benchmarking.

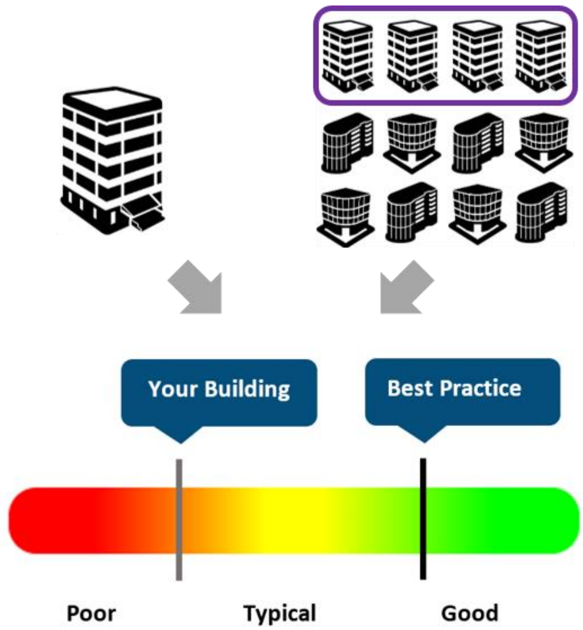


Figure 8: Standard example of the energy consumption benchmarking graph

With this information, a building operator can adjust heating setpoints, add insulation, or perform an energy audit that focuses on heating equipment. The process of benchmarking allows users to see how their buildings compare to others, which allows them to make the best strategic decisions to increase energy efficiency and cost savings across their portfolio.

Specific to the Mechanical Engineering Building at the University of Illinois Urbana-Champaign, the following figure shows the savings breakdown and recommendations that were produced by the BETTER tool.

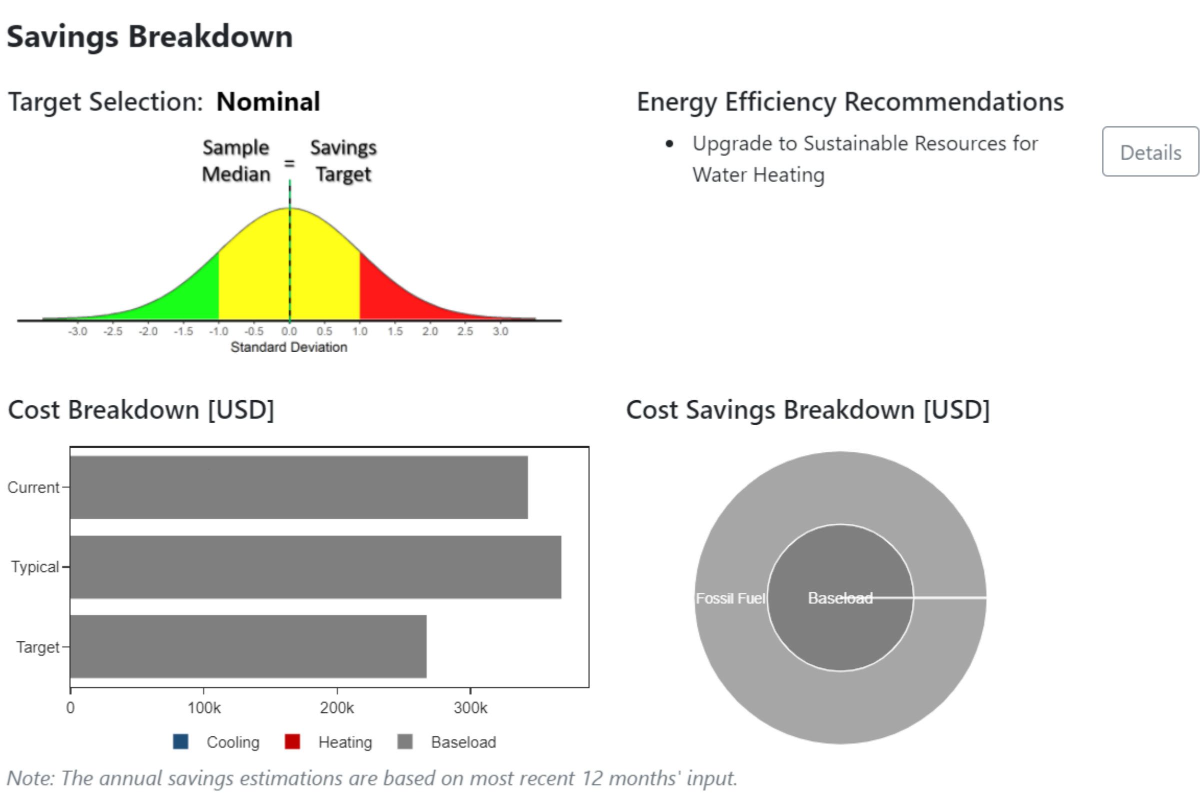
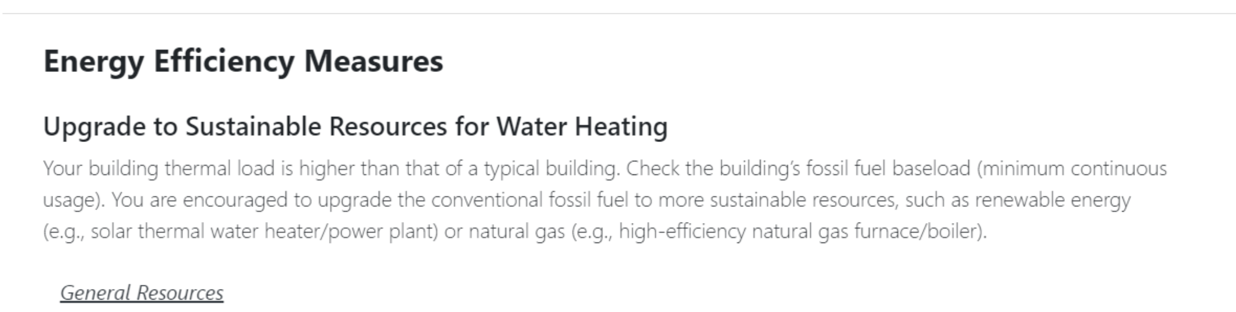


Figure 9: Savings breakdown graphs based on UIUC's Mechanical Engineering Building

As seen here, the current energy spending for the Mechanical Engineering Building is already $25,000 less than industry average, but cost savings measures must be implemented despite this fact to reach the target savings amount of $267,630.

The BETTER tool had one recommendation for the Mechanical Engineering Building, according to the inputted data. The following recommendation was created by the BETTER tool based on the building's inputs:



Energy Efficiency Measures

Upgrade to Sustainable Resources for Water Heating

Your building thermal load is higher than that of a typical building. Check the building's fossil fuel baseload (minimum continuous usage). You are encouraged to upgrade the conventional fossil fuel to more sustainable resources, such as renewable energy (e.g., solar thermal water heater/power plant) or natural gas (e.g., high-efficiency natural gas furnace/boiler).

General Resources

Figure 10: BETTER tool recommendations for UIUC's Mechanical Engineering Building

This recommendation is a starting point for the user to determine which source(s) of energy to prioritize and adjust compared to others to best manage and optimize energy efficiency. As a building uses a variety of energy sources, BETTER provides a fast and convenient way to determine which energy source(s) to target for the greatest energy efficiency measures. Since BETTER's recommendations are fairly general, this tool may be used in combination with other green building tools, such as IFC Edge or PVWatts for greater impact.

PROCESS OVERVIEW:

1) Create a free account at https://better.lbl.gov/
2) To start a new project, click "create new portfolio" or "create new building"
3) Enter required data fields for the building
4) Enter required data fields for utility consumption
5) Click save
6) Navigate to the building analytics tab and click "run" to receive the output

REQUIRED DATA FIELDS:

1. Building ID or name
2. Location (country, city, zip code)
3. Gross floor area (excluding parking)
4. Primary building space type (i.e., ≥ 50% of the gross floor area)
5. 12 consecutive months of energy use and costs for all fuels used in the building
    a. Energy type
    b. Bill start date
    c. Bill end date
    d. Energy consumption amount
    e. Energy consumption unit

Note: Energy cost (USD/$) is not a required field but inputting this data will result in a more accurate building summary report and higher quality energy efficiency recommendations. If the field is left blank, an estimated cost will automatically be generated.

USABILITY:

The tool was very user-friendly and comfortable to use upon first approach. For best results, I recommend using the tool on a computer or laptop, rather than a mobile device. If certain data is missing from the required data fields, it will be very difficult to receive accurate outputs and recommendations, as all the recommendations are based on accurate historical consumption metrics and cost in order to determine energy efficiency measures. However, the tool is specifically designed to require minimal data inputs, therefore the data required to use the tool should be easily accessible. While it is not required to understand and navigate the BETTER tool, there are tutorials available on the BETTER Lawrence Berkeley National Laboratory website.

ESTIMATED TIME FOR COMPLETION:

If all the required data is available and ready to input into the BETTER tool, it will instantly analyze the data and create recommendations. There is no lead time to receive the output from this tool, as it only requires minimal, readily available data.

However, there is a learning curve to use the tool. I found minimal information online, so I conducted a self-analysis of the tool with different types of inputs to examine its capabilities. I found the interface to be immediately easy to navigate, but it took about two hours to explore the platform and become familiar with it. The data entry portion is straightforward, but the building analytics part of the tool took some research to understand. As someone who is not closely familiar with energy benchmarking or energy consumption building patterns, I conducted some research to understand the output from the BETTER tool, especially the change-point models, as pictured above. I estimate that it took two hours for me to examine and understand the building analytics for one building's output.

The following are three resources I found particularly useful when familiarizing myself with the functionality and analysis of the BETTER tool.
LBNL BETTER Tool, Webpage
BEST Center's BETTER Project, YouTube
WRI's Introduction to the Building Efficiency Targeting Tool for Energy Retrofits, YouTube

ROADBLOCKS:

To use the tool efficiently, the user must know the utility costs per energy consumption metric for the building(s) they choose. Without the correct consumption metrics, the tool may fail to produce accurate recommendations. Additionally, because the dataset I was referencing for the required data fields had units in both SI and IP, it was required that I do the metric conversions to be consistent with one type of unit system, either SI or IP. This made the process slightly more confusing, but with the correct units of measure, this can be avoided.

The following are types of inputs needed for the first part of the tool. If these are unknown, the tool is unusable.

- Energy type
- Bill start and end date
- Energy consumption/unit
- Energy cost

6 - Tool 4: PVWatts

What is NREL PVWatts?

The National Renewable Energy Laboratory (NREL) developed a calculator that estimates the energy production and cost of energy of grid-connected photovoltaic (PV) energy systems. It's a free online photovoltaic (PV) system performance and cost calculator that makes it simple for homeowners, small building owners, installers, and manufacturers to evaluate the performance of prospective PV installations.

REQUIRED DATA FIELDS:

- Building location
- PV system requirements (can use default inputs)
- Current power rate

PROCESS OVERVIEW:

Step 1: Enter the location

To use the PVWatts calculator, the address is needed for where solar panels will be put. This is necessary because the amount of sunlight (solar radiation) that reaches the panels is affected by the building's location and orientation. PVWatts uses the supplied location to access local weather and solar data from NREL's National Solar Radiation Database, rather than looking at national averages.

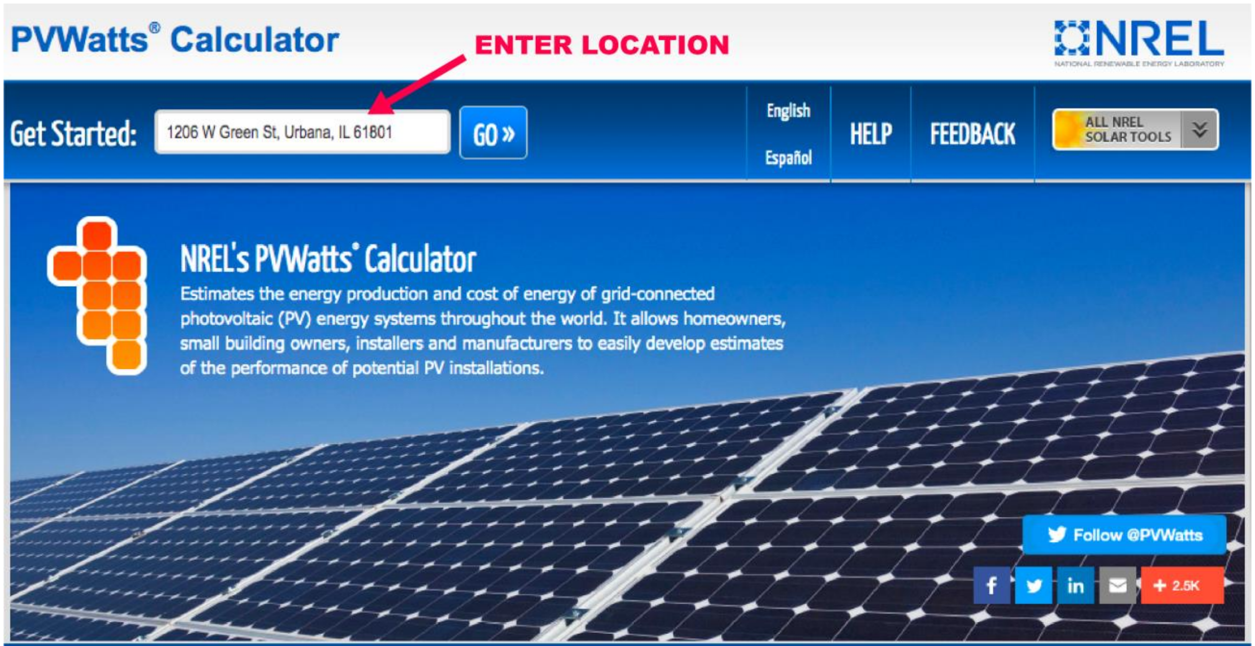


Figure 11: PVWatts Calculator Homepage

Step 2: Enter system information

PVWatts is preloaded with assumptions about the size of the system, the equipment being utilized, and the current power rate. These assumptions can be used, or information can be inputted manually.

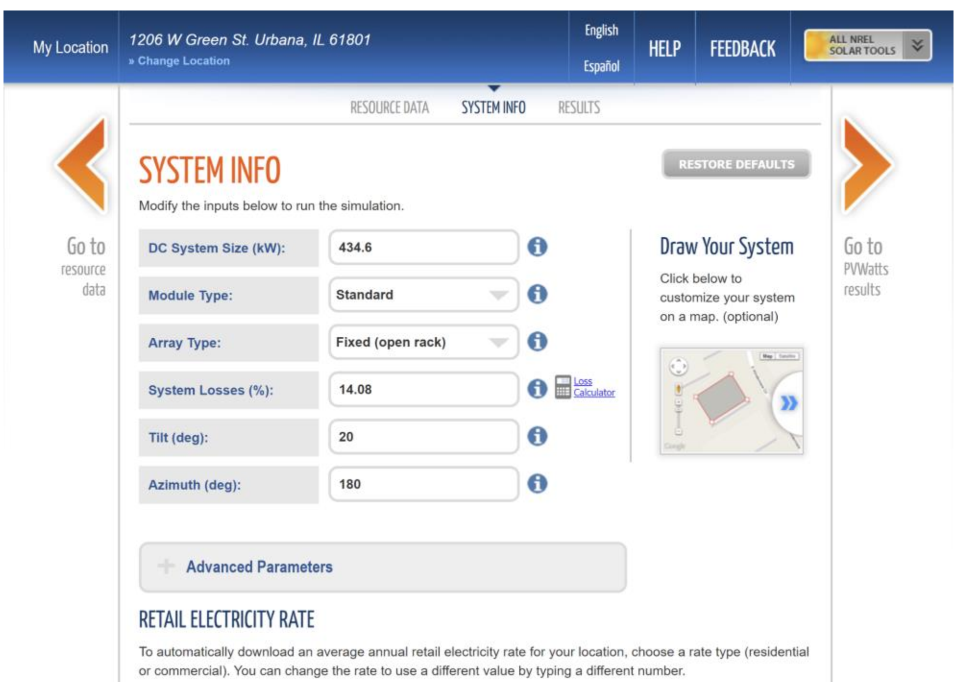


Figure 12: PVWatts System Info

DC System Size

The DC system size is the PV array's DC (direct current) power rating in kilowatts (kW) under conventional test conditions. The DC system size will have the most impact on the numbers returned by the calculator. The size of the solar power system will be established by a professional in the end. The default size of a PV system is 4 kW. This equates to an array area of roughly 25 m^2 for a system with 16 percent efficient PV modules. If unsure what size to use, the map tool can be used to get a rough estimate based on the amount of roof or ground space available. The map tool determines the size and enters it into the System Size field. The system size can be estimated based on the area available for the array or calculated from the module nameplate size at standard test conditions and the number of modules in the array:

$$\text{Size (kW)} = \text{Array Area } (m^2) \times 1\ kW/m^2 \times \text{Module Efficiency } (\%)$$

or

$$\text{Size (kW)} = \text{Module Nameplate Size (W)} \times \text{Number of Modules} \div 1{,}000\ W/kW$$

Module Type

There are three options available for module types: standard, premium, and thin film. Standard is the most common style of solar panel used in the market, made of crystalline silicone, which has a 15 percent efficiency. The premium type is also made of crystalline silicon, but it is more efficient, at about 19 percent efficiency. Thin film is a different type of technology that has about 10 percent efficiency and is made mostly of tellurium, a rare metal that absorbs solar rays better than silicon crystalline modules.

Array Type

The array type specifies whether the PV modules in the array are fixed or move with one or two axes of rotation to monitor the sun's movements throughout the sky. The default value is for a fixed array. There are two alternatives for systems with fixed arrays: an open rack or a roof mount. Ground-mounted equipment should use the open rack option. Trackers are solar panels that shift their position during the day to keep as much direct sunlight as possible when the sun's position in the sky changes. As a result, trackers are more efficient, but they are also more expensive. There are three tracker options: one-axis tracking, one-axis backtracking and two-axis tracking. A one-axis tracker moves the panels along a single axis, which is commonly north and south. In a two-axis tracking array the panels can move on two axes, north-south and east-west. This system is meant to capture as much solar energy as possible throughout the year. In addition to regular everyday motion, it can detect seasonal differences in the height of the sun.

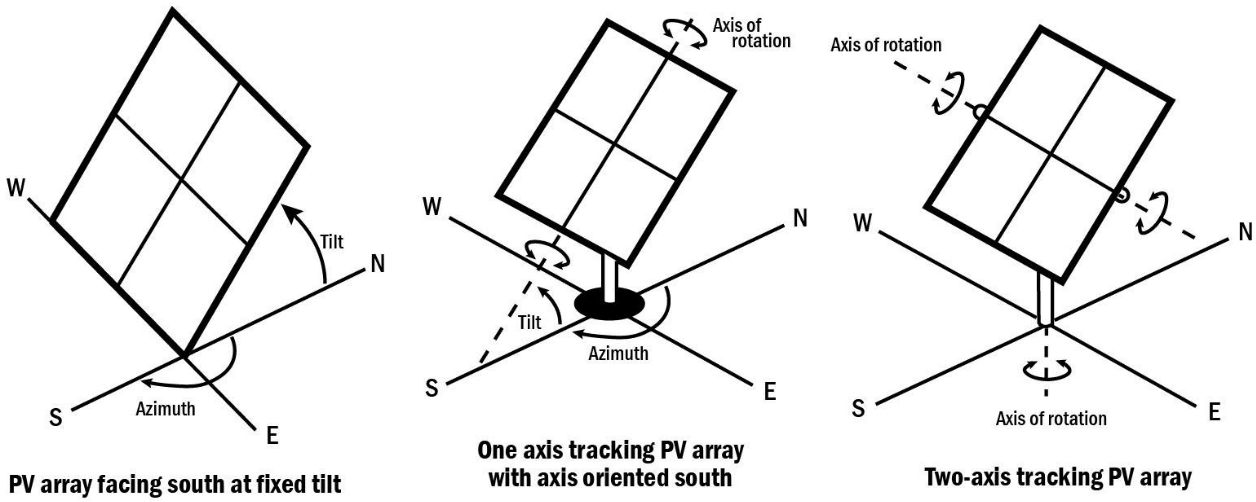


Figure 13: Array Type Diagram

Tilt

The angle of the solar panels in relation to the ground is known as tilt. The tilt of panels sitting flat on a flat roof is 0º. Depending on the pitch of the roof and the latitude of the building on the ground, most roof-mounted panels have angles between 20º and 40º. It's all about getting as much direct sunshine as possible. This is another reason why some use trackers. The tracker keeps the solar panels directly in line with maximum sunlight when the sun's position in the sky varies by both day and season. The default tilt angle for the PVWatts calculator is 20º. It's preferable to just leave it at that if the tilt is uncertain at this time. If the panels are to be mounted flat on the roof, the rise and run of the roof can be calculated to determine the tilt.

Azimuth

The angle of the panels from the sky is known as azimuth. In the morning, an east-facing solar panel will receive more sunshine, while a west-facing panel will receive more in the afternoon. The azimuth of a fully south-facing solar panel is 180º. When facing west, the angle is 270º, and when facing east, the angle is 90º.

System Type

The system type is either residential or commercial.

Average Cost of Electricity

The average cost of electricity aids in determining how much money can be saved by using solar energy. Looking at the energy bill and finding the per-kWh pricing will help figure out what the average cost of electricity is. This is the rate that people desire to lower or eliminate with solar panels. The PVWatts calculator assumes that individuals will recoup 100% of their energy expenditures, however it does not take into account net metering or other similar services that certain states and cities provide.

Advanced Parameters:

DC to AC Ratio
The DC to AC ratio is related to power output. The ratio, as well as the cost, increases with a larger system. The average range is 1.10 to 1.25. This figure may be higher for extremely large commercial systems. Higher is preferable. The PVWatts calculator uses a 4-kW system with a 1.10 ratio, which is typical of a residential installation. For the time being, it is advisable to leave it at 1.10 unless individuals have access to technical data indicating otherwise.

Inverter Efficiency
The inverter turns DC solar energy into AC current, which is used by the power outlets. An inverter is required for any solar power system. The efficiency of DC to AC conversion is used to grade each inverter. The PVWatts calculator estimates a 96 percent efficiency, however efficiency can vary a lot more above 90 percent.

Ground Coverage Ratio
This concept does not apply if solar panels are installed on the roof or on the ground. This ratio is only important if trackers are utilized. Consult the technical manuals if this is the case.

Step 3: Results

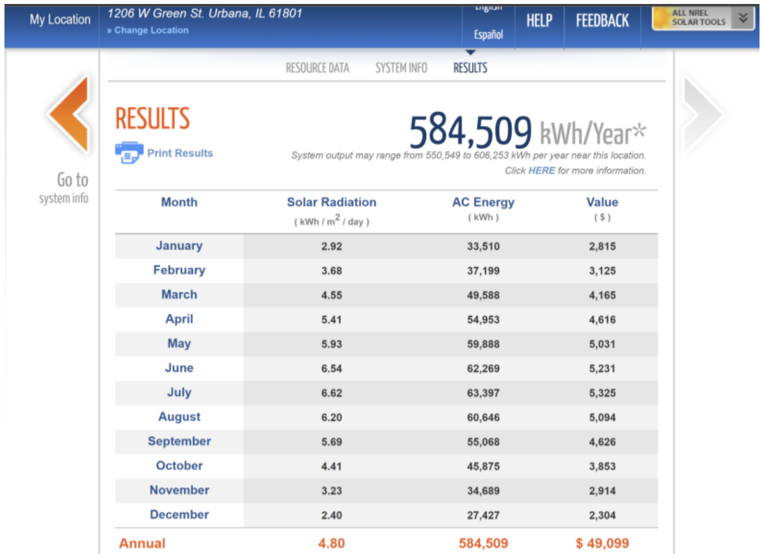
The PVWatts calculator provides three columns, each one broken down by the month. Monthly and yearly solar radiation, energy output, and the monetary worth of power produced by the system are all displayed on the results page.

Solar Radiation
The solar radiation is derived from monthly and yearly values using hourly plane-of-array irradiance readings in the weather file for the location, considering the sun's position and the module's orientation.

AC Energy
Monthly totals are computed by adding together the hourly figures for each month to get the total amount of electricity produced by the PV system for each month. Because these figures are based on average year solar resource data, they indicate the system's normal monthly generation across several years rather than the monthly generation for specific months.

Energy Value
The result of total electricity generated in each month (kWh) and the average annual retail electricity rate ($/kWh) determines the value of electricity. This number is simply a rudimentary representation of the value of the electricity generated by the system, and it is effective for basic

comparisons of system sizes, locations, and other design factors.


My Location | 1206 W Green St. Urbana, IL 61801 | » Change Location | Español | HELP | FEEDBACK

RESOURCE DATA | SYSTEM INFO | RESULTS

RESULTS

Print Results

584,509 kWh/Year*

System output may range from 550,549 to 606,253 kWh per year near this location.
Click HERE for more information.

Go to system info

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Value ($)
January	2.92	33,510	2,815
February	3.68	37,199	3,125
March	4.55	49,588	4,165
April	5.41	54,953	4,616
May	5.93	59,888	5,031
June	6.54	62,269	5,231
July	6.62	63,397	5,325
August	6.20	60,646	5,094
September	5.69	55,068	4,626
October	4.41	45,875	3,853
November	3.23	34,689	2,914
December	2.40	27,427	2,304
Annual	4.80	584,509	$ 49,099

Figure 14: PVWatts Results Page

FINDINGS AND TOOL RECOMMENDATIONS:

After inputting the address of the Sidney Lu Mechanical Engineering Building into the PVWatts calculator, specific system information had to be inputted to determine which solar array design provided the best payback. Using the map tool to outline the building, the system size of 434.6 kW was estimated based on the roof area available for the array. The current electricity rate was determined to be $0.084/kWh from the university's Facilities & Services website. The different options for module and array types allowed for various simulations to be run to understand which system design would have the greatest outcome. Focusing on the array of the system, the standard module type was chosen for each of the following array types: fixed (roof mount), one-axis tracking, one-axis backtracking, and two-axis tracking. After running each simulation it was determined that the two-axis tracking performance was the strongest, seen in Table 8.

Table 8: Standard Module Type Results

	AC Energy (kWh/year)	Value ($)
Fixed (roof mount)	584,644	49,109
One-Axis Tracking	675,557	56,746
One-Axis Backtracking	675,171	56,714
Two-Axis Tracking	822,346	69,076

Next, the three module types (standard, premium, and thin film) were chosen along with a two-axis tracker. Through this process it was determined that the thin film module type had the highest AC Energy per year and monetary value, seen in Table 9.

Table 9: Two-Axis Tracking Results

	AC Energy (kWh/year)	Value ($)
Standard	822,348	69,076
Premium	834,692	70,115
Thin Film	849,653	71,372

A system with a thin film module and two-axis tracking array provided the best payback. Based on the location, system information, and current electricity rate, a 434.6 kW DC system with a thin film module type and 2-axis tracking array type installed on the Sidney Lu Mechanical Engineering Building is estimated to produce 849,653 kWh/year of AC energy and an annual value of electricity of $71,372. Figure 15 gives a breakdown of the monthly and annual solar radiation, AC energy and electricity value of the system.

RESULTS

849,653 kWh/Year*

System output may range from 784,994 to 898,423 kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	4.49	49,569	4,164
February	5.27	52,163	4,382
March	6.15	66,663	5,600
April	7.10	74,603	6,267
May	7.97	85,622	7,192
June	8.96	92,274	7,751
July	9.20	96,995	8,148
August	8.31	88,272	7,415
September	7.86	81,167	6,818
October	6.33	68,386	5,744
November	4.94	52,659	4,423
December	3.70	41,280	3,468
Annual	6.69	849,653	$ 71,372

Figure 15: Two-Axis Thin Film Tracking Results

It is understandable why a system with a two-axis tracker and thin film modules would perform the best since they have two axes of movement that optimize the amount of solar energy captured and the materials that best absorb the sun rays.

Using the university's Energy Billing System (EBS) the 2021 monthly and yearly energy consumption of the building was found, as seen in Figure 16.

	FY 2021
	Consumption (KWH)
JUL	142,997.000
AUG	161,152.000
SEP	160,834.000
OCT	161,386.000
NOV	161,236.000
DEC	152,105.000
JAN	154,931.000
FEB	140,108.000
MAR	126,595.000
APR	144,666.000
MAY	144,898.000
JUN	144,820.000
Overall	1,795,728.000

Figure 16: Mechanical Engineering 2021 Electricity Consumption

While the system designed does not produce enough energy to completely cover the total electricity consumption of the building, it would save about $71,372 annually. At the current rate of electricity consumption for the mechanical engineering building, a system that would allow for total renewable energy would have to be much larger, perhaps at least twice the size of the current system.

ESTIMATED TIME FOR COMPLETION:

To become familiar with the tool adequate time had to be spent understanding the components that go into generating a PV installation. About 10-20 minutes of time was spent researching each component of the system information in order to understand how it pertains to the PV system and find the value that would be inputted. The PVWatts calculator interface provides detailed information for each parameter under the documentation tab which can be found by the information buttons next to each system information component. Once the values are inputted the results are generated automatically into three easy to read columns that break down the values of solar radiation, AC energy and energy value. The process of analyzing the results generated from the different test configurations took about 5 minutes. Each results page was read over to look at the monthly and annual outputs and then the annual performances of each system were compared to determine the best output. If adequate research into the system parameters is done in the beginning of the process, the analysis of the results will be a faster process as the numbers generated will make sense in relation to the values inputted. If the default assumptions from NREL are used to calculate the performance potential of PV installations, the process is fairly simple and would take no more than 10 minutes to generate and analyze the reports.

USABILITY:

PVWatts is simple to use because the user experience is straightforward, and they provide more information to aid comprehension. It does, however, necessitate some knowledge if accuracy is required. These are, of course, projections. It's impossible to make perfect predictions. However, their pre-purchase calculation is about as specific as you can get. It considers the most crucial aspects to help visualize what makes a PV energy system.

The platform can be used in its default state to provide a basic introduction into PV energy systems. Additionally if specific information is obtained about the building, a more customized approach can be used in order to truly understand how certain factors can affect the much kWh of AC energy can be expected for the system size chosen or how much money does the energy value save.

ROADBLOCKS:

Users can simply construct estimations of the performance of potential PV installations using the PVWatts Calculator. It's a great way to begin with basic PV system performance estimates, but specialists would use software platforms for projects that require more detailed reports. There are a lot of default options that aren't always the most accurate. Using local weather patterns, environmental circumstances, and average solar equipment specs, many default settings are precise to the broad location. However, default settings may not always apply to the specific system, causing computations to be incorrect. The energy estimate for LUMEB is based on an hourly performance simulation using a typical-year weather file that represents a multi-year historical person for Springfield, IL. Additionally the default value for the power rate is from 2012. To have a more accurate reading, the electric bill for the building should be used, however if that cannot be obtained, the commercial rate for the area can be used. In the results, the estimated value for the energy is the product of the AC energy and the average retail electricity rate. This value is useful for basic comparisons but does not account for financial considerations in a cash-flow based analysis.

7 - Tool 5: IFC EDGE

What is IFC Edge?

An innovation of IFC, a member of the World Bank Group, EDGE ("Excellence in Design for Greater Efficiencies") includes a cloud-based platform to calculate the cost of going green and utility savings. The state-of-the-art engine has a sophisticated set of city-based climate and cost data, consumption patterns and algorithms for predicting the most accurate performance results. The EDGE software compares the building's utility savings and decreased carbon footprint to a basic model. It shows how much more it costs to construct green, as well as how quickly it pays for itself through operational savings. To be certified, the building must have a resource efficiency of 20% in the categories of energy, water, and embodied energy in materials.

FINDINGS AND TOOL RECOMMENDATIONS:

Using data obtained from the Energy Billing System through the UIUC Facilities and Services department, many necessary fields were identified and filled in in the EDGE app. Thus, the EDGE application generated a final report outlining the improved measures that could be implemented to optimize the building. Each of the following figures displays a 'base case' which is made with our initial data, along with an 'improved case' which is made using the optimizations that EDGE has put in place. These optimizations are further described in the EDGE report (Supplemental Data).

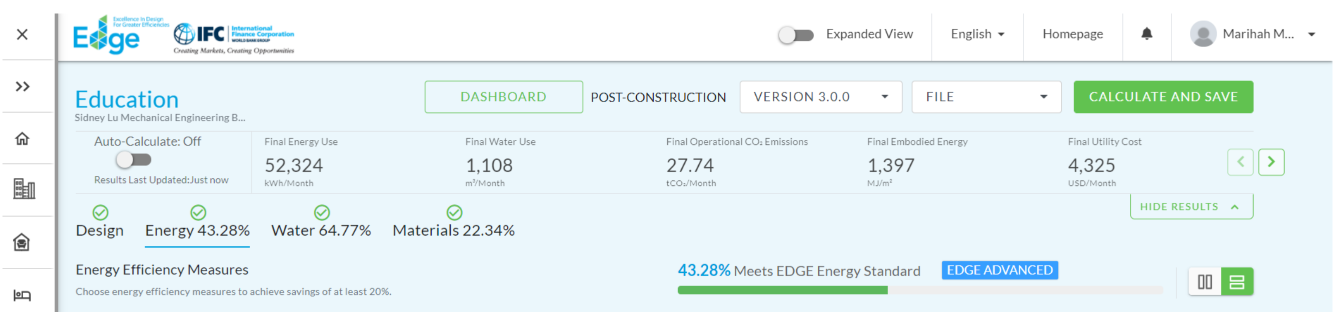


Figure 17: EDGE App Interface Example

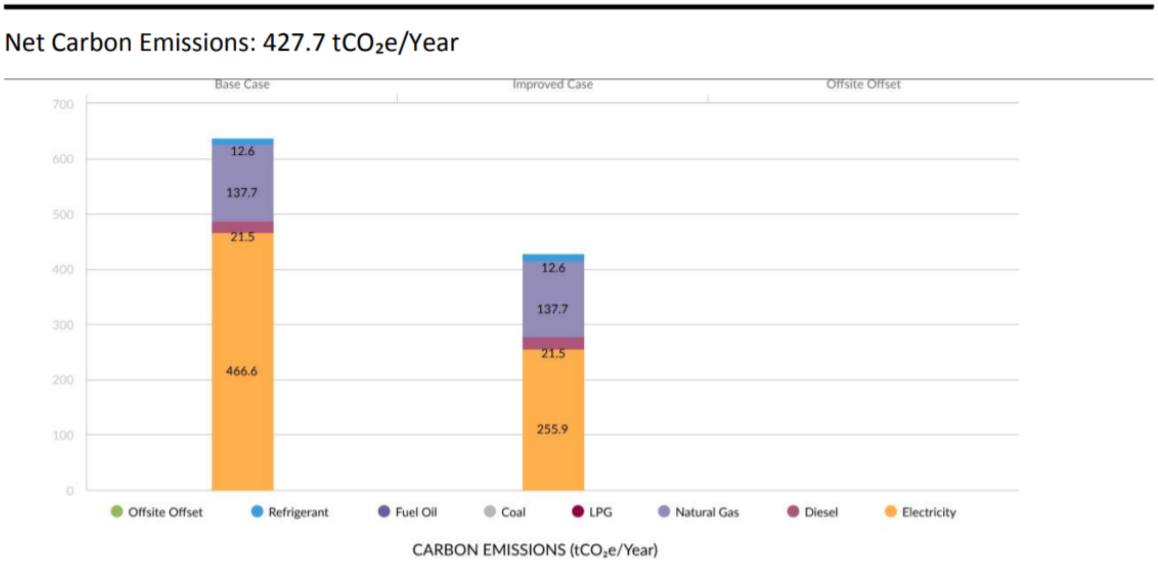


Figure 18: Carbon Emissions Improvements

This first graph displays the optimizations made in terms of Carbon Emissions. Going through the EDGE report, this is achieved by mainly reducing the electricity usage of the building. Through observation, many lights remain on even during times that rooms, or the building are not in use, and this adds to the electricity usage.

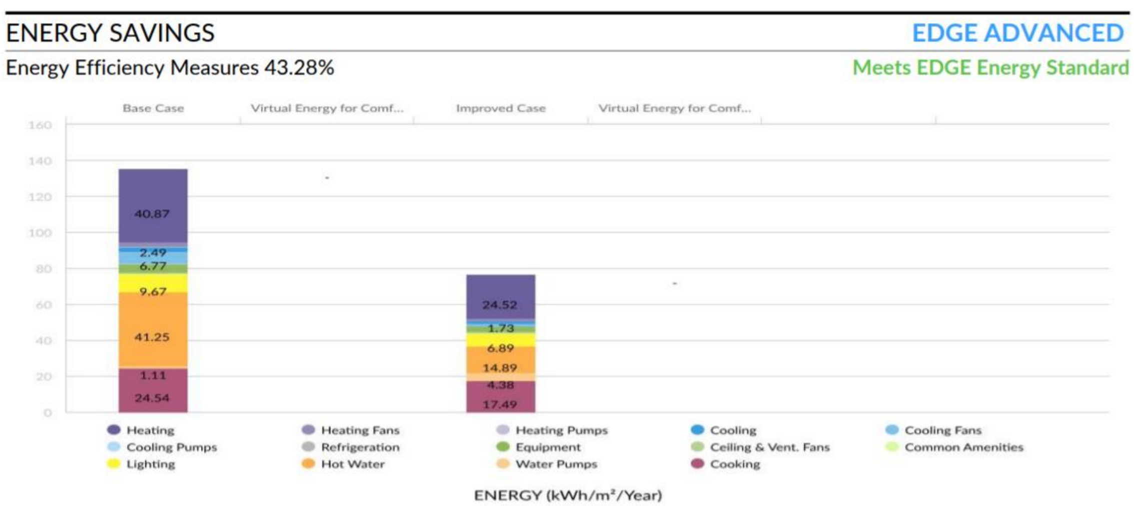


Figure 19: Energy Efficiency Improvements

The energy efficiency measures outputted a result of 43.28% improvements from the base case scenario if certain changes were made, including: changes to cooling system efficiency, increasing insulation of roofs and exterior walls, as well as installing smart meters for energy, and shifting to a minimum of 25% renewable energy sources for the building.

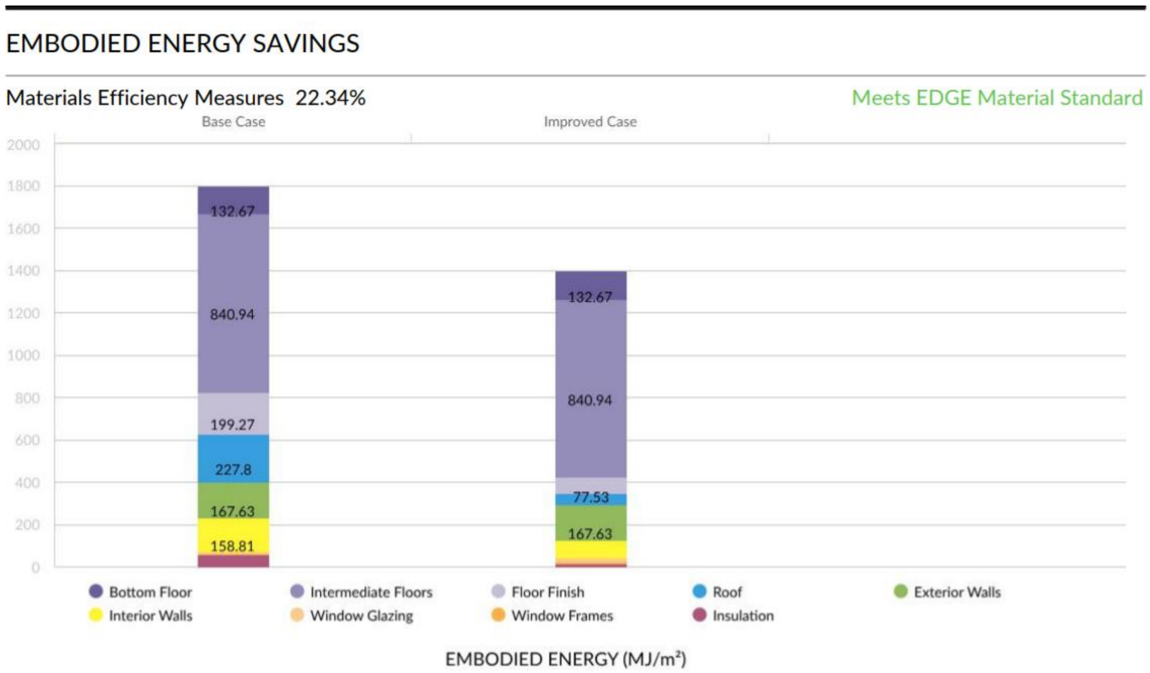


Figure 20: Materials Efficiency Improvements

For materials efficiency improvements, the improved case shows a 22.34% better efficiency. However, this section is the most inaccurate of the bunch, as default materials were utilized by EDGE. If access to genuine materials used in the construction of the building were known, a better output more specific to the building could have been achieved.

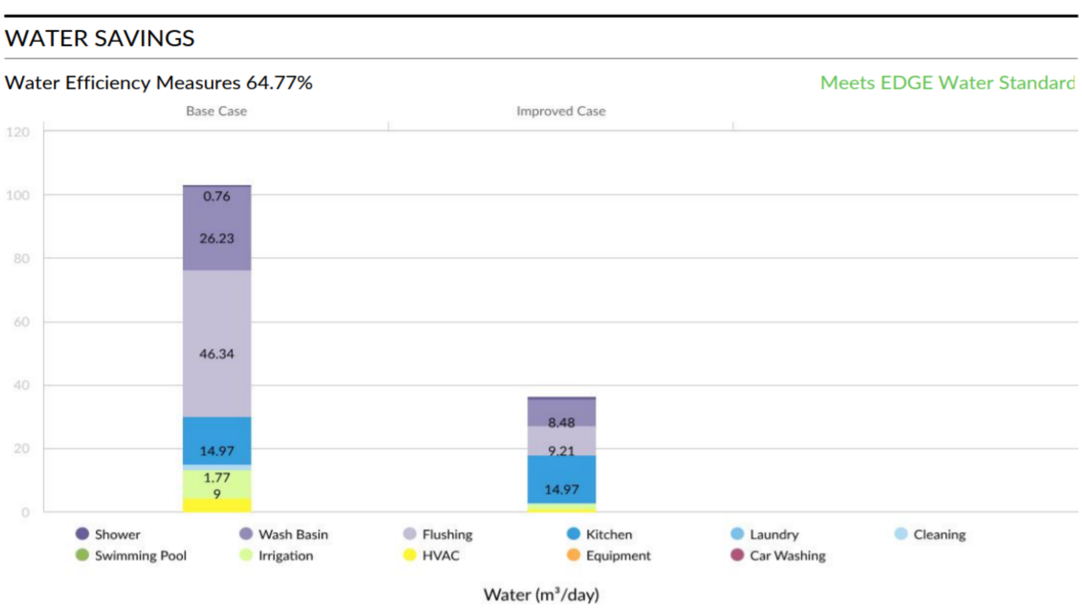


Figure 21: Water Efficiency Improvements

For the water efficiency measures, this showed an improvement of 64.77% based on only a few factors such as water-efficient faucets and smart meters. For the faucets, the 6 Liter/min base case value was used, as the actual number for the building was unknown. Thus the optimized faucets would use only 2 L/min of water. Furthermore, some other suggestions were a rainwater harvesting system integrated with the design of the building, and some type of wastewater treatment plan.

If a project manager has in-depth information regarding the building that they are planning to build or optimize, EDGE can significantly improve the many facets of efficiency. However, in the case of the LUMEB, many assumptions were made, such as that of the materials used in the building (insulation, type of flooring etc.) as this data was not available to us.

PROCESS OVERVIEW:

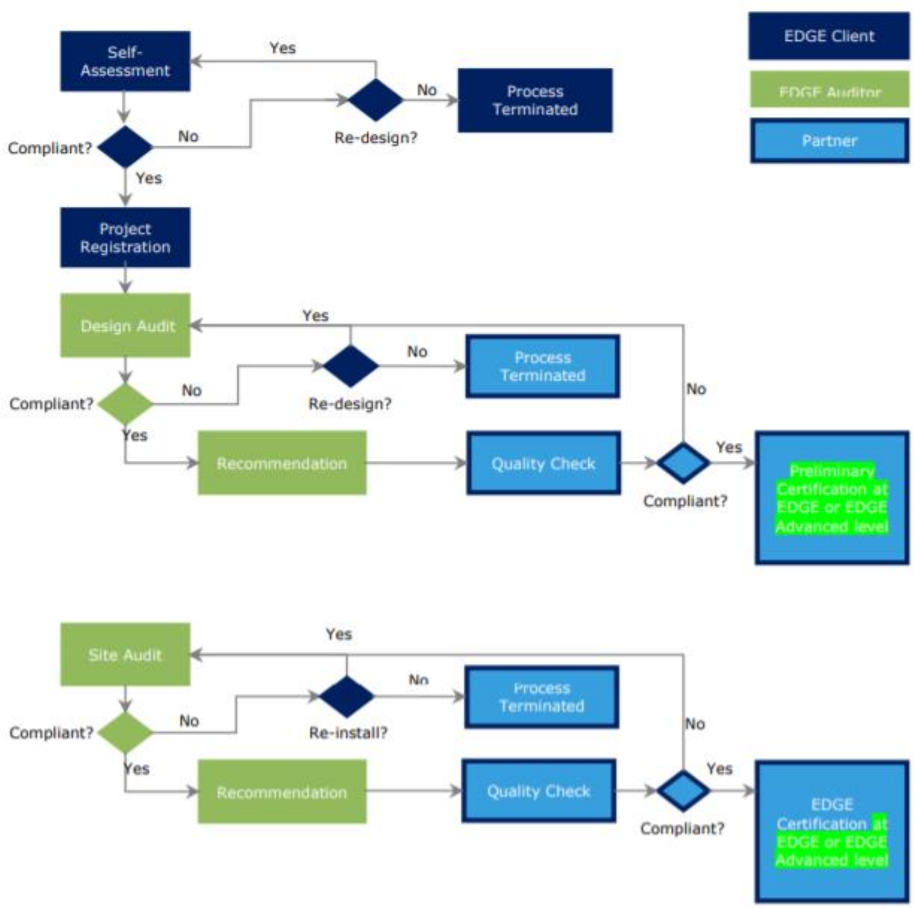


Figure 22: EDGE Protocol Flow Chart

This flow chart outlines the process of getting EDGE certified.

The first step in the process is for the project owner to save their project within the EDGE software online. This serves as an initial check to ensure that the project is within the scope of the EDGE program and can be certified in that region's market. Then, the building project will be assigned an EDGE ID Code that will be used throughout the process. It is the responsibility of the project manager to make sure that the design meets EDGE standards, and the online EDGE tool is key for this. The software will help to model a variety of different scenarios with different optimization measures. The output of the EDGE Software and the supporting documentation are known as the Self-Assessment.

Beyond this point, the client can then register their project with a relevant partner. Then, the client is responsible for paying the EDGE certification fees to the partner and appointing an EDGE auditor. The auditor will be responsible for the Design Audit portion, involving a review of the Self-Assessment and additional documentation. The auditor may make a recommendation for Preliminary Certification based on their evaluation. Subsequently, after the project has been completed, a site audit will occur, where the auditor will determine whether the completed building includes the EDGE measures set out in the initial design. Lastly, assuming everything is properly met, the auditor will make a recommendation to the partner for a final EDGE Certification.

ESTIMATED TIME FOR COMPLETION:

If the project manager has all the information required to input into the EDGE app, from beginning to end the EDGE app can generate a report with all efficiency optimizations in one hour. The further certification process takes much longer, where the Preliminary Certification will expire and no longer be valid 12 months after the project is completed or 36 months after issuance, whichever comes first. Final certification depends on how long it takes for the building to be completed, and the amount of time auditors need to conduct and approve a site audit.

In using EDGE, one can really range from a high-level understanding to an extremely in-depth look at the data. To familiarize oneself with the software does not take very long (perhaps one hour to explore each tab fully) as the interface is user-friendly with the data fields all marked clearly. However, the time frame to use the system will increase with an increase in the amount of data inputted. For example, if one spent the time to gather information about what specific materials were used in the construction of the building, this could range anywhere from a few minutes to several weeks of persistent research. Upon obtaining the data, this would give a more accurate-to-the-building output. Overall, to become familiar with the tool, run the analysis, and break down the results took about 4-5 hours over the span of a few days, not including the time it took to gather energy and square footage data.

REQUIRED DATA FIELDS:

All fields in the EDGE App have default input values, allowing users to create buildings with minimal inputs. Entering the design details of the project creates the base case building which will be used to choose energy efficiency measures to achieve savings of at least 20 percent. To build an EDGE model on the Design Page, the following data should be inputted if available:

- Building Type
- Location

- Building Utility Data
    - Annual Measured Electricity Consumption
    - Annual Measured Water Consumption
    - Annual Measured Natural Gas Consumption
    - Annual Measured Diesel Consumption
    - Annual Measured LPG Consumption
- Building Data, Area, and Load Breakdown
    - Built Up Area
    - No. of Floors Above Grade
    - No. of Floors Below Grade
    - Floor-to-floor Height
    - Roof Area
- Occupational Details
    - Occupancy (People/Unit)
- Building Costs
    - Cost of Construction
    - Estimated Sale Value
- Gross Internal Area
- Building Dimensions
    - Building Length
    - Facade Area Exposed to Outside Air
- Building HVAC System
- Fuel Usage
    - Hot Water
    - Space Heating
    - Generator
    - % of Electricity Generation Using diesel
    - Fuel Used for Cooking
    - Cost Input
- Climate Data
    - Elevation
    - Rainfall
    - CO_2 Emissions
    - Latitude
    - ASHRAE Climate Zone
    - Country Specific Climate Zone
    - Temperature
    - Relative Humidity
    - Wind Speed

Many data fields include base case numbers that can be used if certain parameters are unavailable. However, this will reduce the specificity of the results to the building itself.

USABILITY:

All fields in the EDGE App have default input values, allowing users to create buildings with minimal inputs. Users should be aware, however, that unless they replace the default settings, the EDGE App will utilize them. As a result, default values must be carefully evaluated, particularly throughout the certification process, to ensure that the assumptions accurately reflect the real structure.

Overall, EDGE has an easy-to-use interface that allows users to change and modify their data at will once the project has been saved. It is also free to use before certification is being pursued, which is a strong benefit in terms of accessibility. One can use the EDGE app even if they do not have the funds for a final certification, and EDGE can be used to pinpoint weaknesses in the building that can be improved on.

ROADBLOCKS:

Some roadblocks encountered while using EDGE are the sheer amount of specific and detailed data that is needed to obtain an accurate output. For example, building dimensions, areas of outward facing facades, and cost of construction are all pieces of information that EDGE asks for. For someone that does not have access to these (such as a student), EDGE will not provide accurate optimizations that can be implemented. Rather, EDGE can be used to understand how the above data entries can influence energy efficiency, water efficiency, etc.

For all cities included into the EDGE platform, location specific information is available. However, another disadvantage was that Champaign, IL was not included in the EDGE program, thus Chicago, IL was utilized instead. If a city is not listed as an option, a city that is close by or has comparable weather can be utilized instead. In this situation, the monthly average outdoor temperature, latitude, and average yearly rainfall statistics for the base case should be modified to match the city where the project is located under the main assumptions for the base case.

8 - DISCUSSION

A common roadblock across all tools is that current data with the correct units of measurements for all the required inputs are crucial to receive an accurate output. On the other hand, some tools have more limitations than others, such as PVWatts and IFC EDGE's lack of location-specific information for the city of Champaign, or the amount of data required for BETTER versus ENERGY STAR. Furthermore, students faced some reticence from staff and project managers when it came to data collection and accessibility to detailed building specifications. For example, WELL Certification is being pursued at the LUMEB, but it was difficult to obtain more than a high-level overview of the process due to a lack of time and cooperation from the project management. Additionally, WELL does not really have an online interface that a student can study to understand it, rather it is very geared towards a project that is already in motion.

PVWatts is unique in comparison to the other tools, in that it solely looks at one form of energy, solar. While tools like BETTER or EDGE can provide additional efficiency and sustainability recommendations, PVWatts' focus is solely on implementing renewable energy through photovoltaics. The system proposed for LUMEB did not meet the total energy consumption of the building and it would be interesting for the program to have additional sustainability recommendations to create a more holistic approach, instead of completely relying on solar energy.

In terms of user friendliness and efficiency between the four tools (not including WELL), BETTER appears to be the fastest and easiest to use. With its minimal data entry and near real-time output of energy cost savings measures and recommendations, it provides a great starting point for the user to determine more sustainable energy operations for their building and/or portfolio. However, a byproduct of this is that it is limited in what it can offer the user for actionable recommendations. For example, BETTER and EDGE are both similar in that they offer efficiency and sustainability recommendations for the building. BETTER provided one main recommendation, that of implementing Sustainable Resources for Water Heating, whereas EDGE recommended several more changes and optimizations to the space due to its much more detailed data requirements. The one recommendation that BETTER did make, however, was in line with recommendations made by EDGE to shift energy sources to more sustainable alternatives.

Therefore, of the four tools ENERGY STAR is the most effective tool. It is free to use, and while it requires very detailed sets of data to create results, it produces a more productive output that details actionable insights for the user to adopt better energy consumption practices. It is also the most widely adopted tool of these four tools across the nation.

9 - OVERALL FEEDBACK, TAKEAWAYS, AND CONCLUSIONS

A large portion of this project required time spent researching and collecting data. Additionally, a majority of the issues encountered were during the data collection phase that directly impacted the results. The process of learning about sustainable building design would be more beneficial if less time was spent on data collection so that more time could be allocated to understanding how these tools result in increased sustainability. If a large amount of data is required, a data set should be provided to allow for a more seamless process of using the tool and getting real results that can be examined to further improve the understanding of the tool. The process should be more about being able to understand and apply the results instead of finding the information.

Furthermore, if the goal is an entry-level curriculum into green design, a good starting point would be to use BETTER, PVWatts, and WELL. These tools are easier to use and provide basic understandings of the principles, which would allow for the course to be more applicable or interesting to a larger audience of students and majors. For example, WELL integrates health and wellness, so not only would it be of interest to architects and engineers, but it is also beneficial for other majors as well such as public health, or food science and nutrition. If there were a second phase, it is proposed that ENERGY STAR and EDGE would provide a more advanced understanding of these principles to students that have a more technical background.

For students without a background in building design or engineering, the BETTER tool is a great entry point to understand building makeup and efficiencies that inform energy and cost savings measures. Once familiarity with the BETTER tool is established, more complex tools such as IFC Edge and PVWatts will be more valuable to the user to understand green building improvements on a more granular level.

Additionally, as mentioned above, WELL integrates health and wellness, which are increasingly urgent considerations for building design due to the recent pandemic. The lifestyle changes that the pandemic have induced include social distancing of six feet, remote work, virtual classrooms, and masks worn in most indoor environments. Many buildings on college campuses are not conducive to this new lifestyle, and the WELL certification is a great step towards ensuring buildings accommodate these changes for everyone's well-being.

REFERENCES

ENERGY STAR Sources:

1) *Tools for tracking and benchmarking facility energy performance*. About ENERGY STAR | ENERGY STAR. Retrieved October 9, 2021, from https://www.ENERGY STAR.gov/industrial_plants/measure-track-and-benchmark/tools-tracking-and#:~:text=EPA's%20ENERGY%20STAR%20Portfolio%20Manager,it%20to%20track%20water%20consumption.
2) *Energy Star®*. Energy.gov. Retrieved October 9, 2021, from https://www.energy.gov/eere/buildings/energy-starr.
3) *Commercial energy policy fact sheet - benchmarking disclosure*. Retrieved November 9, 2021, from https://www.imt.org/wp-content/uploads/2018/02/Commercial_Energy_Policy_Fact_Sheet_-_Benchmarking__Disclosure.pdf.
4) *Overview of energy star commercial buildings program*. Retrieved November 9, 2021, from https://www.ENERGY STAR.gov/ia/partners/spp_res/neprs/ENERGY_STAR_and_Automated_Benchmarking_Quick_Facts.pdf.
5) *Colleges and universities*. ENERGY STAR Buildings and Plants | ENERGY STAR. Retrieved December 9, 2021, from https://www.ENERGY STAR.gov/buildings/resources_audience/colleges_universities.
6) *Portfolio manager*. Retrieved December 9, 2021, from https://www.ornl.gov/sites/default/files/sustain_docs/2009%20Mike%20Myers%20%20Portfolio%20Manager%20Federal%20High%20Performance%20Sustainable%20Buildings%20Checklist%20BLANK.pdf.
7) *Benchmark your building using energy star® portfolio manager®*. ENERGY STAR Buildings and Plants | ENERGY STAR. Retrieved October 9, 2021, from https://www.ENERGY STAR.gov/buildings/benchmark.
8) *Energy Star by the numbers efficiency.* Retrieved December 9, 2021, from https://www.ENERGY STAR.gov/sites/default/files/asset/document/Energy%20Star_factsheet_ByTheNumbers_C_508_2.pdf.
9) *Portfolio manager fact sheet - energy star*. Retrieved November 9, 2021, from https://www.ENERGY STAR.gov/ia/partners/reps/ci_program_sponsors/downloads/Portfolio_Manager_Fact_Sheet.pdf.

BETTER Tool Sources:

10) Li, H. *LBNL BETTER*. Better. Retrieved September 30, 2021, from https://better.lbl.gov/buildings/6888/.
11) *Building Efficiency Targeting Tool for Energy Retrofits*. Johnson Controls Retrieved September 30, 2021, from https://www.johnsoncontrols.com/insights/2020/featured-story/better-energy-analysis-tool.
12) Johnson Controls International. (2020, July 9). *Johnson Controls introduces open-source energy analysis software for targeting building efficiency retrofits*. Johnson Controls Introduces Open-Source Energy Analysis Software for Targeting Building Efficiency Retrofits. Retrieved October 2, 2021, from https://www.prnewswire.com/news-releases/johnson-controls-introduces-open-source-energy-analysis-software-for-targeting-building-efficiency-retrofits-301090982.html.
13) YouTube. *BETTER Project: Building Energy Targeting Tool for Energy Retrofits (R&D award winner)*. BEST Center. Retrieved November 15, 2021, from https://www.youtube.com/?app=desktop.
14) *A 'better' way forward for low-cost, accessible retrofits*. News Center. (2021, November 8). Retrieved November 15, 2021, from https://newscenter.lbl.gov/2021/11/08/a-better-way-forward-for-low-cost-accessible-retrofits/.

PVWatts Sources:

15) *PVWatts - NREL*. PVWatts Calculator. (n.d.). Retrieved October 30, 2021, from https://pvwatts.nrel.gov/pvwatts.php.
16) *University of Illinois Facilities and Services*. Facilities and Services University of Illinois Urbana Champaign. Retrieved October 30, 2021, from https://fs.illinois.edu/services/utilities-energy/business-operations/utility-rates.

IFC EDGE Sources:

17) *About EDGE*. EDGE Buildings. (2021, July 23). Retrieved 2021, from https://edgebuildings.com/about/about-edge/.
18) *Certify*. EDGE Buildings. (2021, July 27). Retrieved November 1, 2021, from https://edgebuildings.com/certify/.
19) *Champaign-Urbana Weather Observations.* Retrieved November 1, 2021, from https://www.isws.illinois.edu/statecli/urbana/urbana-monthly-2021.htm.
20) *Combustion of fuels - carbon dioxide emission*. Engineering ToolBox. Retrieved October 6, 2021, from https://www.engineeringtoolbox.com/co2-emission-fuels-d_1085.html.

21) *Frequently asked questions (FAQs) - U.S. energy information administration (EIA)*. Frequently Asked Questions (FAQs) - U.S. Energy Information Administration (EIA). Retrieved October 5, 2021, from https://www.eia.gov/tools/faqs/faq.php?id=74&t=11.
22) *EDGE Certification Process - Chapter 5*. Retrieved October 25, 2021, from https://edgebuildings.com/wp-content/uploads/2021/02/Ch5-Certification-Protocol-4.0.pdf.

WELL Sources:

23) *WELL v2 Overview*. V2.wellcertified.com. Retrieved November 10, 2021, from https://v2.wellcertified.com/wellv2/en/overview.
24) *WELL - Pricing Options: How it Works*. International Well Building Institute. Retrieved November 10, 2021, from https://www.wellcertified.com/certification/v2/pricing.
25) *What is the well building standard?* Air Equipment Company. (2020, April 10). Retrieved November 10, 2021, from https://www.airequipmentcompany.com/2019/03/25/what-is-the-well-building-standard/.

APPENDICES

(Separate Attached Files)

Appendix A: Contains LUMEB Floor Plans, WELL Checklist, Utilities and Energy Services FY 2021 Energy Consumption Report

Appendix B: IFC EDGE Full Data Report