Development of a Web-based Decision Tool for Selection of Distributed Energy Resources and Systems (DERS) for Moving College and Corporate Campuses Toward Net-Zero Energy

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DEVELOPMENT OF A WEB-BASED DECISION TOOL FOR SELECTION OF DISTRIBUTED ENERGY RESOURCES AND SYSTEMS (DERS) FOR MOVING COLLEGE AND CORPORATE CAMPUSES TOWARD NET-ZERO ENERGY

Abstract
Net-Zero energy buildings are currently being built, and they no longer consist of small demonstration projects but rather large commercial and institutional buildings. However, achieving a "net-zero energy building" concept for existing buildings has its challenges in an urban environment where private and/or public space around the building considered is limited, in addition to the inherent energy challenges associated with urban multi-story buildings. While the most achievable task would be energy efficiency improvements in the operation of the building electrical and mechanical systems, examples of integration of renewable heat and electrical power systems on college and corporate campuses are abundant. The integration of renewable energy systems on urban campuses presents significant logistical challenges. For instance, the available roof area may not be enough to produce a substantial amount of photovoltaic power for the buildings under consideration.

In this investigation, two students enrolled in an independent study Mechanical Engineering course at the Milwaukee School of Engineering (MSOE) developed a web-based a Distributed Energy Resources and Systems (DERS) decision guidance modeling tool that can be used by facilities directors on college or corporate campuses. Their work was augmented by an undergraduate engineering student who was employed as a research assistant during the following summer. The tool allows the following user-defined input, priorities, and constraints to generate a recommended suite of distributed energy resources that best meet the requirements of the user:

- electrical and thermal load distribution on campus
- geographical location
- user objectives (moving toward a net-zero energy campus, a net zero carbon campus, or minimization of energy costs)
- capital resources available

The model uses ambient weather data, system performance parameters, and capital costs of distributed energy resources to make recommendations on the distributed energy system configuration. The tool enables the user to identify and analyze practical technologies that can be adopted for an existing campus in moving toward a net-zero energy goal.

For calculations of solar photovoltaic (solar PV) system output, the solar irradiance and ambient temperature are used in conjunction with an estimated cell temperature correction along with rule-of-thumb derating factors (e.g. electrical losses, dirt losses, etc.). Solar thermal system output is estimated using the f-chart analysis approach which utilizes local solar irradiance data, ambient temperature, thermal load of the building, and typical performance parameters of flat plate solar thermal collectors. Combined Heat and Power (CHP) system output is estimated using design guidelines provided by the US Department of Energy's Midwest Combined Heat and Power Applications Center. The decision tool outputs the following parameters:

- Annual thermal energy output
- Annual electrical energy output
- Number of solar PV panels
- Number of solar thermal panels
- Size of the CHP system

- Internal rate of return on the total initial capital investment

Currently, the tool uses an iterative method in MATLAB to optimize the configuration of distributed energy systems as measured by the internal rate of return (IRR) realized from the initial capital investment. Future work will focus on expanding the capabilities of the tool so the user can identify the optimum configuration as measured by the amount of off-site energy purchased (thus moving toward net-zero energy), and/or by the amount of carbon emissions generated (moving toward net-zero carbon).

Introduction

This paper details the work started by two students enrolled in an 10-week independent study course in the Mechanical Engineering Department at MSOE. Their work was followed by contributions from an undergraduate research assistant who was employed over the summer. The objective of this project was to develop a distributed energy resources decision guidance tool that would be capable of making recommendations based on energy load distribution, renewable energy resource availability, user priorities, and capital constraints. The tool was to take into account solar PV, solar thermal, and combined heat and power (CHP) systems. The tool was designed to calculate the optimal size of each system for a given budget and campus location, and minimize the payback time on the investment. The tool was created using HTML, CSS, and JavaScript/jQuery web languages and runs within all major web browsers. This tool was developed within a local directory and can only be used if the root folder of the project is provided to the user. However, provided that the files can be hosted on a server, the tool can be easily configured to be viewed online. Weather data was queried from the National Renewable Energy Laboratory (NREL) using a public API [1]. The following sections go into detail on what equations were used to generate fiscal models for each source of energy.

Web-based Decision Tool

NREL API

The weather data required for the calculations within Eco-Locate were obtained using a public API [1] made available by NREL. In order to access the weather data a personalized API [1] key is required by NREL. This key is obtained by registering the campus and project to the laboratory. This is done so NREL can properly track what party is accessing their data and block users whom they believe may be using their data improperly. The following table is a summary of the data that was queried and stored from the NREL database.

Table 1: Overview of NREL Output Variables

Variable Name	Description
solrad_monthly	An array of 12 data values describing the average daily solar irradiance for one month. Units of kWh/m^2/day.
solrad_annual	A single decimal value that represents the average daily solar radiance for a year. Units of kWh/m^2/day.
tamb	An array of 12 data values of the average ambient temperature of a month. Units °C.

All insolation data is obtained with an assumed tilt angle of 20°. This is the default value NREL uses when no tilt angle is inputted by the user. For the purpose of this tool it is necessary to find the solar irradiance over a year. This is done using the following equation.

$$\mathrm{E}_{Year,Sun} = \mathrm{solrad\_annual} \cdot 365\,\frac{days}{yr} \tag{1}$$

The ambient temperature (NREL variable tamb) is also given in monthly values. The yearly average of the ambient temperature was found using the following equation.

$$T_{amb} = \frac{\sum \mathrm{tamb}}{\left(12\,\frac{\mathrm{months}}{year}\right)} \tag{2}$$

Solar PV

Solar PV was implemented into the tool by using the solar irradiance data obtained by NREL and calculating inefficiencies and rating factors associated with solar panels. The first rating factor that was calculated pertains to a solar cell's operating temperature. The cell operating temperature was calculated using the following equations:

$$T_{cell} = T_{amb} + \frac{NOCT - 20°C}{0.8} \tag{3}$$

where T_{cell} is the solar panel cell's operating temperature and NOCT is the nominal operating condition temperature for a specific solar panel brand. Each of these variables are in units of degrees Celsius. T_{cell} is needed to calculate a cell temperature rating factor expressed in the following equation.

$$f_t = 1 - 0.005\ °C^{-1} \cdot (T_{cell} - 25°C) \tag{4}$$

f_t is the temperature rating factor of a solar panel. The value of 0.005 $°C^{-1}$ is the power temperature coefficient (this varies somewhat for different panel manufacturers but 0.005 $°C^{-1}$ is a representative value). The following equation illustrates how the temperature rating factor is applied in converting the DC rating factor of a panel into AC.

$$W_{AC} = f_t \cdot \eta_{Total} \cdot W_{DC} \tag{5}$$

where η_{Total} is the combined efficiency of system. This includes AC-DC conversion losses, inefficiencies associated with dirt, as well as losses associated with wiring and other electrical connections. W_{DC} is the DC rating of a the installed solar PV array in Watts. Using weather data obtained from NREL, the total energy gathered in a year can be calculated using the following:

$$E_{year)PV} = \frac{W_{AC} \cdot \mathrm{E}_{Year,Sun}}{1000\,\frac{W}{kW}} \tag{6}$$

In this equation $\mathrm{E}_{Year,Sun}$ is represented in units of hr/yr and is done so by interpreting it as the number of hours at "peak sun" irradiance of 1 kW/m^2. The savings for a year was assumed to be equal to the energy production in a year multiplied by the unit cost of electricity. This represents the amount of money that would be required to get the same amount of energy from the grid. This is represented in Eq. (7).

$$\text{Savings}_{\text{PV}} = E_{year)PV} \cdot \text{FuelCost}_E \quad (7)$$

The FuelCost_E is the current price per kWh of electricity and must be inputted by the user. This data can typically be obtained from a user's utility bill or from an online resource.

Solar Thermal

Solar thermal is integrated into the calculator using an f-chart method of calculation. This is an experimental fit to data that is used to quantify the output of a solar thermal system. The equations used are as follows:

$$X = \frac{\left(8765\,\frac{hr}{yr}\right) \cdot F_r\text{UL} \cdot A_{ST} \cdot (100°\text{C} - T_{amb})}{\left(29.3\,\frac{kWh}{Therm}\right) \cdot L} \quad (8)$$

$$Y = \frac{F_r\tau\alpha \cdot A_{ST} \cdot \text{E}_{Year,Sun}}{\left(29.3\,\frac{kWh}{Therm}\right) \cdot \text{L}} \quad (9)$$

X and Y are factors that are used in a polynomial fit of experimental data to calculate a fraction of the thermal load that can be recovered from the sun. F_rUL and $F_r\tau\alpha$ are performance parameters of a solar thermal collector. A_{ST} is the area of one solar collector panel in m^2. T_{amb} is the average of the monthly temperatures over the entire year obtained from NREL in units of °C. In the calculation, the value of 8765 is used as a conversion from years to hours. L is the yearly thermal load in therms and must be inputted by the user. The value of 29.3 is used as a conversion factor from therms to kWh.

Using X and Y, the total thermal output can be calculated using the following equation:

$$\text{Q}_{\text{year)ST}} = (1.029Y - .0245Y^2 + .0215Y^3 - .065X + .0018X^2) \cdot L \cdot \left(29.3\,\frac{kWh}{Therm}\right) \quad (10)$$

The thermal output, $Q_{year)ST}$ is given in kWh/yr and is used to find the savings when compared to heating with natural gas. Like solar PV, the savings associated with solar thermal is equal to the amount of energy produced multiplied by the rate of natural gas, accounting for the efficiency of the water heater that would have been used to heat water if the solar thermal system were not in place. The default gas water heater efficiency of 80% is used. This is represented in Eq. (11).

$$\text{Savings}_{\text{ST}} = \frac{\text{Q}_{\text{year)ST}} \cdot \text{FuelCost}_{NG} \cdot \left(\frac{1}{29.3} \cdot \frac{Therm}{kWh}\right)}{\eta_{Water\ Heater}} \quad (11)$$

Combined Heat and Power (CHP)

A guideline for the needed system capacity of a CHP system is approximately 60% of the peak electric load at a location. This is illustrated in the following equation [2]:

$$\text{SC} = 0.60 \cdot electric\_peak \quad (12)$$

where SC is the system capacity in kW and the electric peak is the max electric load applied to a system in kW. A piecewise function had to be generated for the capital costs associated with different sized CHP systems. The plot shown in Figure 1 was generated using pricing data obtained from a CHP presentation by the Midwest CHP Application Center. The data given [2] was a range of capital costs for different system capacities. These were then taken and linearized into the graph shown.

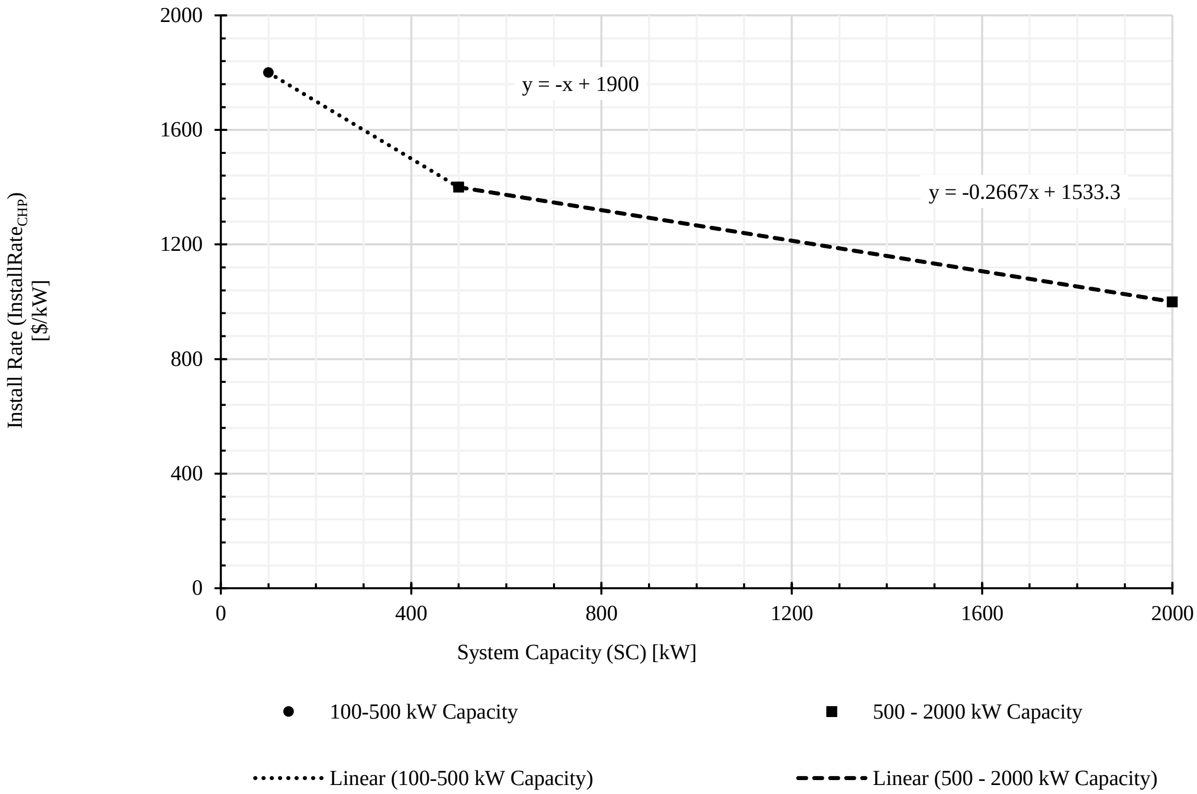


Figure 1: Assumed Install Cost for CHP Systems

The relationship between these two properties was assumed to be piecewise linear. The piecewise function associated with this plot is shown by the following equation:

$$IntallRate_{CHP} = \begin{cases} \$1800 & if\ SC < 100 \\ \left(-1\dfrac{\$}{kW}\right) \cdot SC + \$1900 & if\ 100 \geq SC > 500 \\ \left(-0.2667\dfrac{\$}{kW}\right) \cdot SC + \$1533.3 & if\ 500 \geq SC\ \geq 2000 \\ \$1000 & if\ SC > 2000 \end{cases} \tag{13}$$

where the $InstallRate_{CHP}$ is in units of $/kW and SC is the system capacity in kW. The installation cost for the system is calculated using the following equation:

$$Cost_{CHP} = \text{SC} \cdot InstallRate_{CHP} \tag{14}$$

To calculate the savings associated with CHP, the electrical and thermal output is calculated. The annual electric generation was calculated using Eq. (15)

$$\mathrm{E}_{\mathrm{year)CHP}} = \mathrm{SC} \cdot \left(8765\,\frac{hr}{yr}\right) \tag{15}$$

where $E_{year)CHP}$ is in units of kWh. The annual thermal generation was calculated by Eq. (16)

$$\mathrm{Q}_{\mathrm{year)CHP}} = E_{year)CHP} \cdot \frac{0.034\,Therms}{kWh} \tag{16}$$

That is, the annual thermal generation is the electric generation converted in units of therms. Thus, it is assumed that the amount of thermal energy generated by the CHP is equal to the amount of electrical energy generated by the system. This is generally true for reciprocating IC engine CHP systems. The efficiency associated with the two different generation systems that the CHP system is displacing is accounted for later in Eq. (20). In both cases (heat and electricity production) it is assumed that the CHP system will function constantly at system capacity. The fuel consumed by the CHP system is calculated using Eq. (17).

$$\Delta Fuel = \frac{Q_{year)CHP}}{0.29} \tag{17}$$

The amount of fuel consumed is in units of therms. The bottom factor of 0.29 represents the total efficiency of the engine gen set and is a rule of thumb value borrowed from the Midwest CHP Applications Center [2]. This value can be changed to represent the characteristics of specific equipment. The cost associated with consuming fuel is calculated by multiplying the cost of natural gas as seen below.

$$Cost_{Fuel} = \Delta Fuel \cdot \mathrm{FuelCost}_{NG} \tag{18}$$

After all prior information is calculated, both the electric and thermal revenue associated with a CHP system can be determined. The electrical revenue from CHP is calculated using Eq. (19)

$$Revenue_{E)CHP} = \mathrm{UnitCost}_{E} \cdot \mathrm{E}_{\mathrm{year)CHP}} \tag{19}$$

where $\mathrm{Revenue}_{E)CHP}$ is in dollars. The thermal savings from CHP is calculated as follows:

$$Revenue_{Q)CHP} = \frac{\mathrm{FuelCost}_{NG} \cdot \mathrm{Q}_{\mathrm{year)CHP}}}{\eta_{Water\ Heater}} \tag{20}$$

where the units are in dollars. $\eta_{waterHeater}$ is the efficiency of a gas water heater. The default value was said to be 0.80. Again, this value was borrowed from the methods illustrated by the Midwest CHP Applications Center. The total revenue associated with a CHP system is the sum of the revenue generated from the electric and thermal energy production [2]. This is represented by Eq. (21).

$$Reveune_{CHP} = Revenue_{E)CHP} + Revenue_{Q)CHP} \tag{21}$$

Finally, the yearly savings associated with a CHP system can be calculated using the following equation:

$$Savings_{CHP} = Revenue_{CHP} - Cost_{Fuel} \tag{22}$$

The cost of the CHP system is taken in to consideration later when the budget is used as a constraint for the optimization between the three systems.

Spark Spread

Spark spread is used to determine whether implementing a CHP system is economically feasible. It is defined as the average difference in energy cost ($/MMBtu) between electricity and natural gas for a facility. A $12/MMBtu or greater spark spread is recommended for economic feasibility. The following equations are used in calculating spark spread [2].

$$\overline{FuelCost_E} = \frac{Cost_{E)year}}{E_{year}} \cdot \left(\frac{293\ kWh}{MMBtu}\right) \quad (23)$$

$$\overline{FuelCost_{NG}} = \frac{Cost_{NG)year}}{Q_{year}} \cdot \left(\frac{10\ Therms}{MMBtu}\right) \quad (24)$$

$$SparkSpread = \overline{FuelCost_E} - \overline{FuelCost_{NG}} \quad (25)$$

The average fuel cost of electricity and natural gas are determined in Eq. (23) and Eq. (24). In Eq. (23) the average fuel cost for electricity ($\overline{FuelCost_E}$) in dollars is calculated by dividing the total cost for electricity in a year ($Cost_{E)year}$) by the total amount of electrical energy consumed in a year (E_{year}). A conversion factor of 293 kWh/MMBtu is used to convert kWh into British thermal units. The average fuel cost of natural gas is determined in similar fashion, however, the conversion factor that is used converts conventional US thermal units (therms) into British thermal units. The spark spread is then calculated using Eq. (25) where the difference between the fuel cost of electricity and natural gas is performed.

Output

The goal of the tool was to make recommendations to user for alternative forms of energy generation based on energy load distribution, renewable energy resource availability, user priorities, and capital constraints. Eco-Locate was designed to output the following parameters:

- Yearly Thermal Output
- Yearly Electrical Output
- Number of PV Panels
- Number of Solar Thermal Panels
- Size of CHP system
- Simple Payback Time

Payback time on investment was calculated using the following equation [3]:

$$t_{\text{SimplePayback}} = \frac{\text{Budget}}{\text{Total Yearly Savings}} \quad (26)$$

The system price was constrained by the allowed budget as inputted by the user. This is shown in the following equation:

$$\text{Price} = [\text{A} \cdot (\text{Cost}_{\text{PV}})] + [\text{B} \cdot (\text{Cost}_{\text{ST}})] + [C \cdot (Cost_{CHP})] \leq \text{Budget} \quad (27)$$

In Eq. (27), A and B are the number of solar PV and solar thermal panels, respectively. The variable C represents a value of 0 or 1 which indicates whether not a CHP system is installed. Its value is dependent on the spark spread calculation and whether not CHP is deemed cost effective. The $Cost_{PV}$ and $Cost_{ST}$ refer to the installed cost of one panel for both solar PV and solar thermal systems. The prices that were used for the basic calculation were based on installed systems on the Milwaukee School of Engineering campus. The prices and model type of the panels [4] are shown below in Table 2.

Table 2: Installed Panel Costs for the MSOE Systems

Name/Type	*Price (per panel)*
Kyocera KD205GX-LP (PV)	\$530
Alternate Energy Technologies AE-40 (Solar Thermal)	\$6000

The prices seen within Table 2 were determined using invoices from the MSOE solar PV and solar thermal systems and corroborated with prices that were found online [5, 6]. Based on the MSOE system, the cost of a single solar PV panel in 2008 was approximately \$1,000 and \$1,187 with installation. Because the price of solar PV panels has dropped significantly in last several years it was important to obtain an updated cost for the Kyocera KD205GX-LP panels [4]. When researching online retailers, it was found that the current cost of a Kyocera 205 watt panel could range anywhere from \$300 to \$350. A quote of \$339.05 was used as the primary value in estimating the current cost of the PV panels. It was assumed that installation costs would remain approximately the same at \$190 [7]. Thus, the current cost of a PV panel would approximately be equal to \$530.

Solar thermal panels were installed on the MSOE campus in 2012. The installed cost of a solar thermal panel at the time was \$6071. Because the price of solar thermal panels has not changed much since 2012 [4], a cost of \$6,000 per panel is used in the model.

The tool uses a series of iterations in order to find the optimal combination of the three systems. This method is best described as a brute-force method [8, 9] (or exhaustive search). It is a general problem solving technique that consists of analyzing all solutions to the problem with the problem constraints. Because this approach calculates a vast number of solutions, it values simplicity over speed. In fact, several seconds may be required for the final result to be displayed to the user if his/her constraints allow for a large number of iterations. Figure 2 illustrates the general logic of the tool.

```
for (0 to Max_A) // Solar PV Panels
  for (0 to Max_B) // Solar Thermal Panels
      for (0 to 1) // CHP
      Calculate ROR with A, B, & C as inputs.
      Calculate Cost with A, B, & C as inputs.
      if (NewROR < OldROR & Cost < Budget) {
        Store Values of A, B, & C.
      }
```

```
            }
        }
    }
```

Figure 2: General Optimization Logic (Not Actual Syntax)

The tool cycles through different numbers of solar PV and solar thermal panels while calculating the installation cost and payback period. If the payback period is less than the initial condition (which for the first loop is a very large number) and within the budget, then the number of each panel is stored. The implementation of a CHP system is treated as a Boolean. That is, a CHP system will either be implemented or not implemented – there would not be more than one system installed. The current optimization process does not try to limit the amount of electrical energy produced nor does it try to limit the number of panels being installed. As the tool exists today, the budget is assumed to be the main limiting factor of installation and that a user has a respective available installation area associated with that budget. Furthermore, no caps on electricity production have been introduced because it is assumed that any excess energy can be sold back to the grid via net metering.

Overview of the Tool Interface

When a user first navigates to the tool they are presented with a welcome screen (see Figure 3). On the welcome screen, a brief section of text is used to provide an overview of the tool as well as to inform the user what basic information will be needed to move forward. Once the user feels confident to continue then he/she can click the get started button to move to the next section. As one will notice, the tool has been optimized to be viewed on both a standard desktop as well as a mobile device [10].

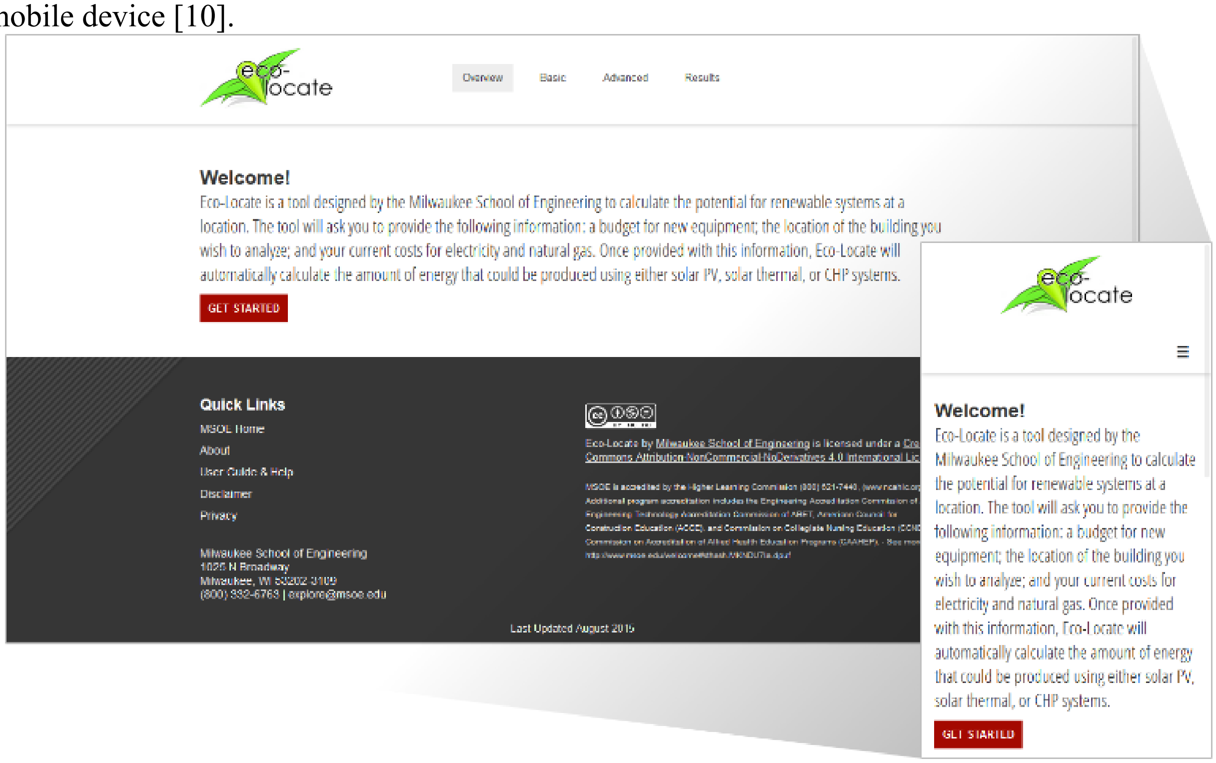


Figure 3: Welcome Screen / Homepage

The first section of the tool is labeled as “Basic Information” and is the only part that is truly dependent on the user in order for the tool to generate valid results. A screenshot of this section has been provided in the form of Figure 4. As the tool stands today there is no validation of the inputs that a user provides. That is, the JavaScript will give a prompt if the wrong variable type is given (i.e. a string is placed into field as oppose to a numeric value), however, it is not yet programmed to determine if the value placed into a field is reasonable or of the right magnitude.

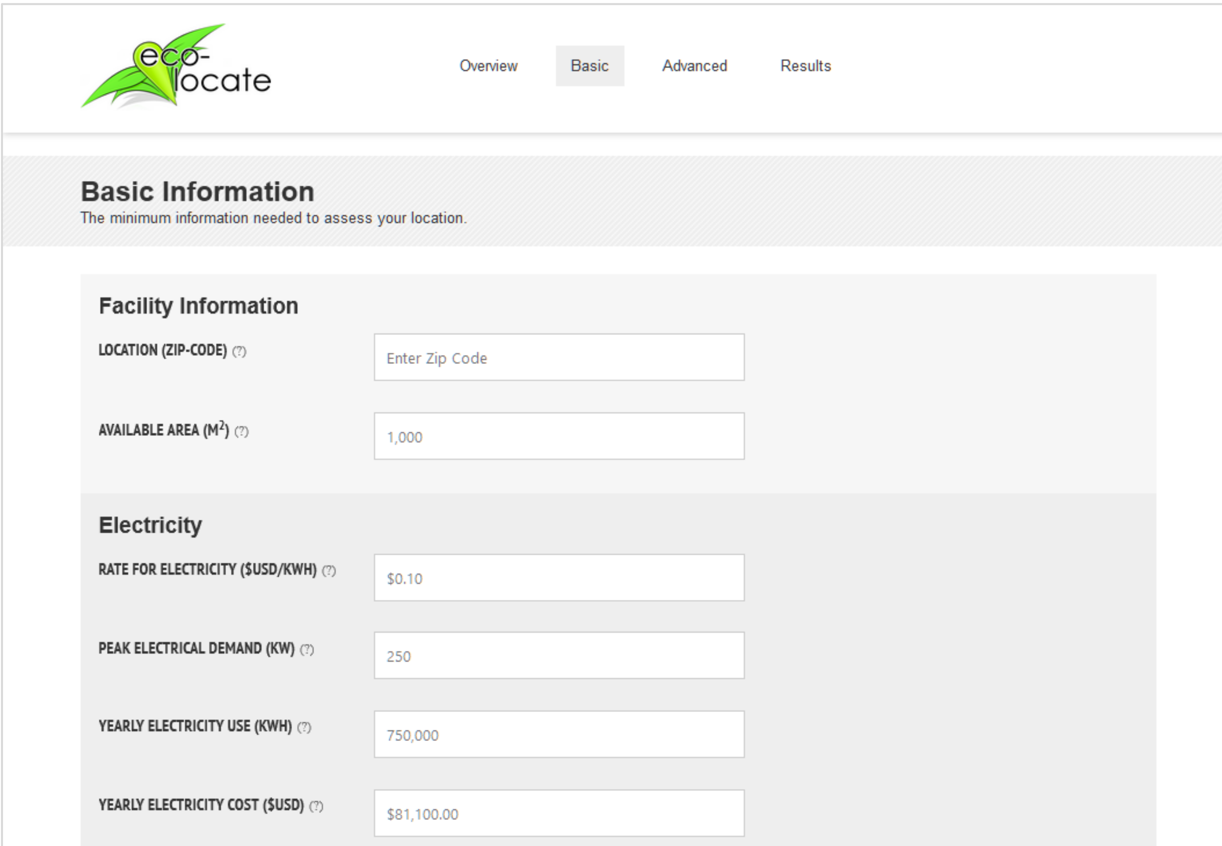


Figure 4: Screenshot of Basis Information Section

As a means of compensating for this lack of functionality, placeholders were used within each field to provide the user with an idea of what common values may look like. These placeholders are not stored within the tool and should only be used as a default if the information needed to calculate results is not readily available. The most important field within this section is the project budget as it will have the greatest impact on the final results.

As stated previously, the solar irradiance information for a given location was retrieved using the NREL API [1]. When a user places their respective zip code within the location field, a request is sent to the NREL database to retrieve the average solar irradiance for each month. This data is stored locally within the browser and is only lost if the user refreshes the page or overwrites the information by using a different zip code. The following figure illustrates the generated bar graph that is displayed to a user after he/she retrieves the solar irradiance information. The data shown within this figure is for Milwaukee, WI (53202). The third party plugin that was used to generate the graph is limited in its ability to label both the horizontal and vertical axis. The horizontal axis can be clearly seen to be divided into months whereas the vertical axis has been left blank as it could not be programmed within the plugin. The units corresponding to the vertical axis are kWh/m^2/month. A work around this limitation involved creating labels that would be hidden until that data was obtained.

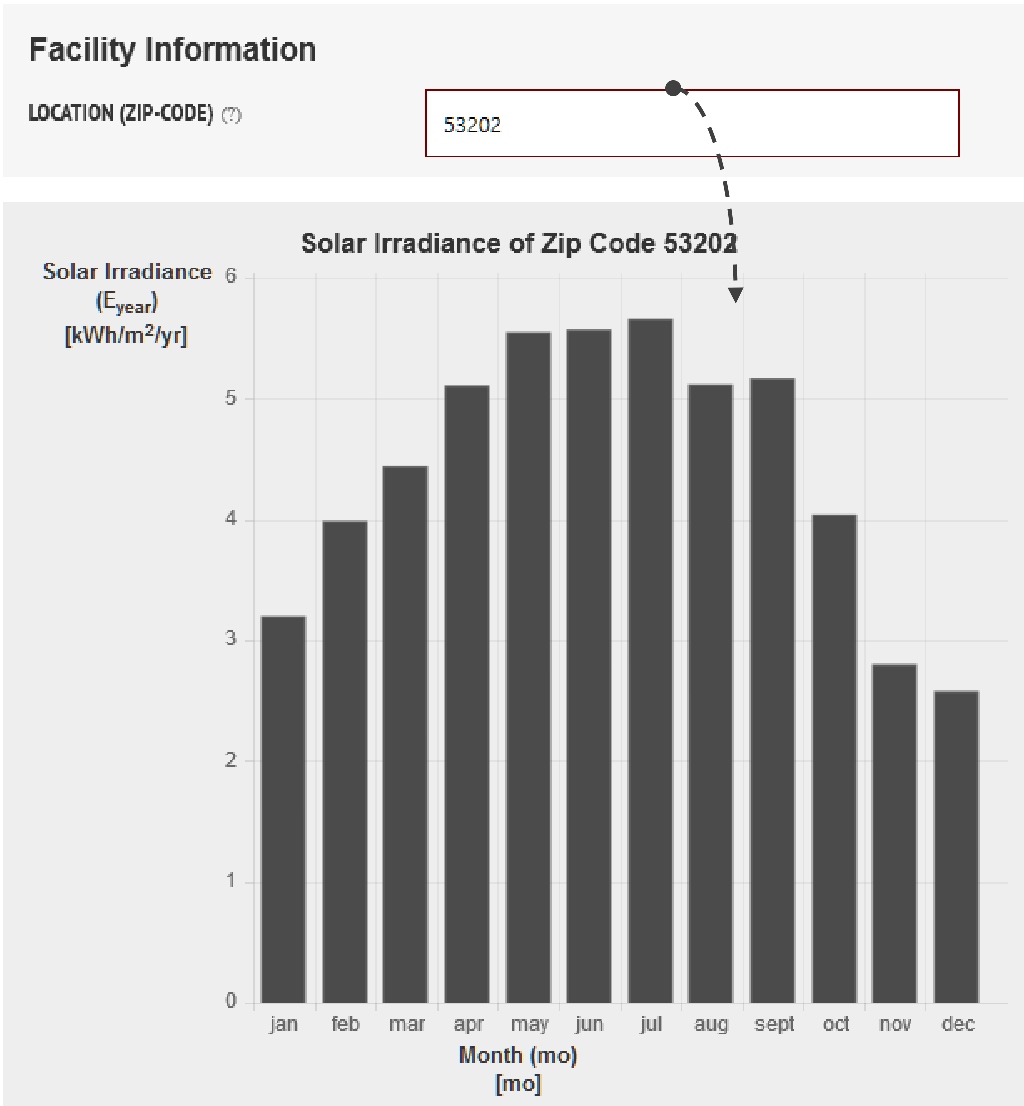


Figure 5: Generate Solar Irradiance Chart

As one can see, the solar irradiance for Milwaukee produces somewhat of a bell shape curve. This is expected as the amount of sun light is higher during the summer months as opposed to the winter. This graph, however, does not necessarily mean that most energy is produced during the summer. As discussed in the Solar PV section of this document, the amount of energy produced is dependent on the operating temperature of the solar cell (i.e. high cell temperatures correlates to reduced efficiency).

Once a user fills in all of the required information, he/she has the option to review the section referred to as “Advanced Information”. The advanced information section lists all of the defaults that were used within the internal calculations of the tool. These values were derived using commercial information based on solar PV and solar thermal panels. Figure 6 is a screenshot of the advanced section of the tool and some of the values that are listed within it.

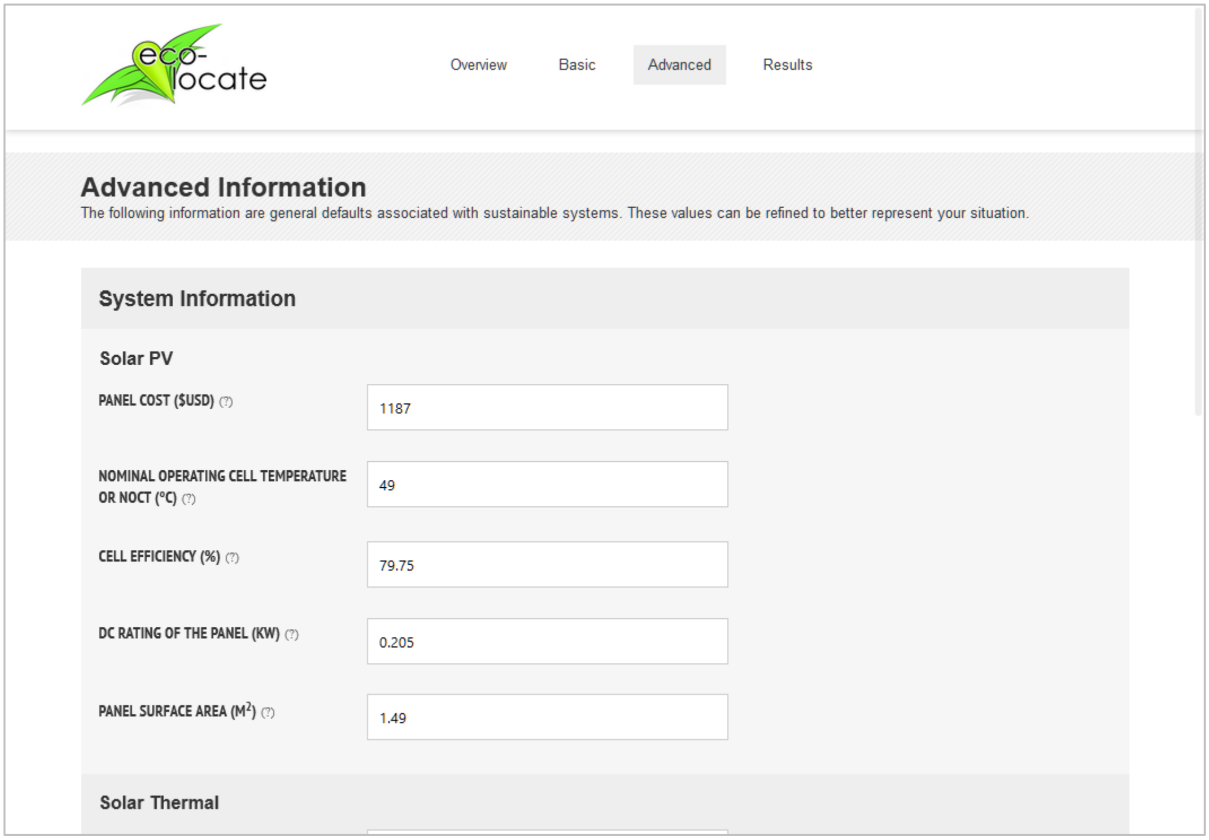


Figure 6: Screenshot of Advanced Information Section

A tool-tip (or help dialogue) was created for this section of the tool because much of the information listed was believed to be uncommon knowledge.[1] That is, an average consumer is not informed about the characteristics of panels and other renewable systems. In fact, consumers would only be interested in fine tuning the model if they had specific manufacturers in mind. Figure 7 is an illustration of the help feature that was implemented within the tool. In this figure the help window corresponding to the peak electrical demand has been shown. When a user clicks the question mark near the property name a modal window is brought to the top of the screen with further information about the property. This information may be a more detailed definition of the property, or in this case, details on where the value for this property may be found.

[1] The tool-tip functionality was created using the combination of a custom JavaScript function (known as "tool_tip()") and a JavaScript library known as jQuery.

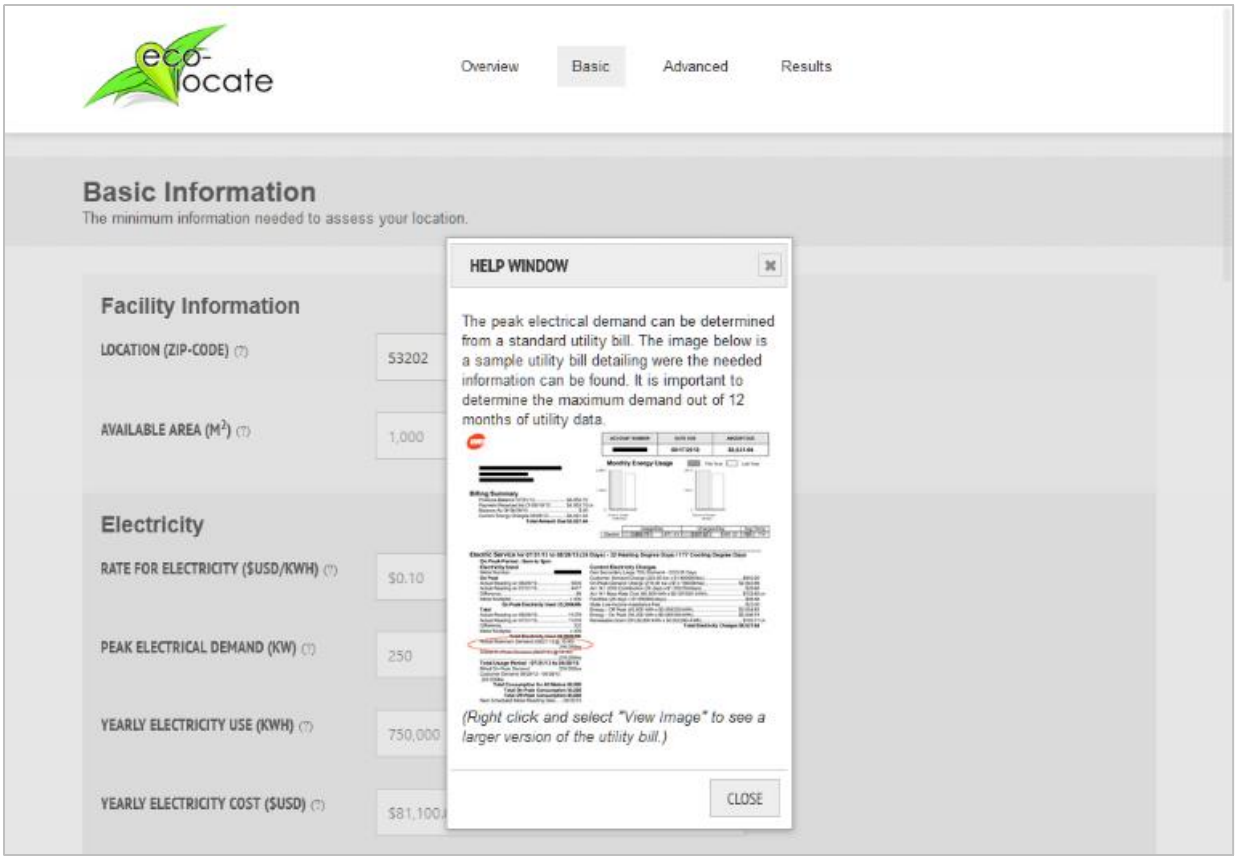
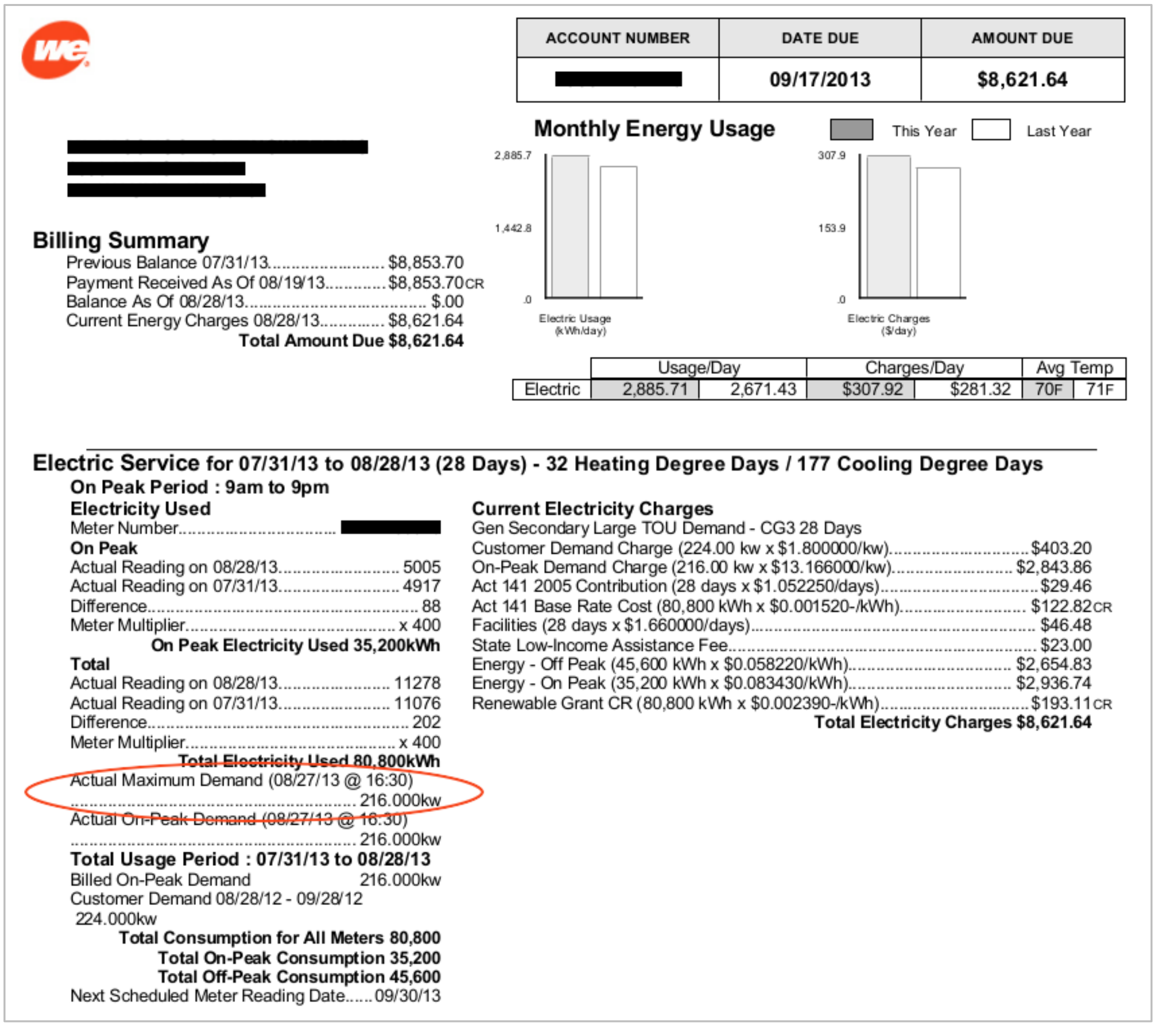


Figure 7: Example of Help Dialogue



ACCOUNT NUMBER	DATE DUE	AMOUNT DUE
[redacted]	09/17/2013	$8,621.64

[redacted]

Monthly Energy Usage This Year Last Year

	Usage/Day		Charges/Day		Avg Temp	
Electric	2,885.71	2,671.43	$307.92	$281.32	70F	71F

Billing Summary

Previous Balance 07/31/13........................ $8,853.70
Payment Received As Of 08/19/13............ $8,853.70CR
Balance As Of 08/28/13....................................... $.00
Current Energy Charges 08/28/13............. $8,621.64
Total Amount Due $8,621.64

Electric Service for 07/31/13 to 08/28/13 (28 Days) - 32 Heating Degree Days / 177 Cooling Degree Days

On Peak Period : 9am to 9pm

Electricity Used
Meter Number................................. [redacted]
On Peak
Actual Reading on 08/28/13.......................... 5005
Actual Reading on 07/31/13.......................... 4917
Difference.. 88
Meter Multiplier... x 400
On Peak Electricity Used 35,200kWh
Total
Actual Reading on 08/28/13....................... 11278
Actual Reading on 07/31/13....................... 11076
Difference.. 202
Meter Multiplier... x 400
Total Electricity Used 80,800kWh
Actual Maximum Demand (08/27/13 @ 16:30)
.... 216.000kw
Actual On-Peak Demand (08/27/13 @ 16:30)
.... 216.000kw
Total Usage Period : 07/31/13 to 08/28/13
Billed On-Peak Demand 216.000kw
Customer Demand 08/28/12 - 09/28/12
224.000kw
Total Consumption for All Meters 80,800
Total On-Peak Consumption 35,200
Total Off-Peak Consumption 45,600
Next Scheduled Meter Reading Date...... 09/30/13

Current Electricity Charges
Gen Secondary Large TOU Demand - CG3 28 Days
Customer Demand Charge (224.00 kw x $1.800000/kw)............................ $403.20
On-Peak Demand Charge (216.00 kw x $13.166000/kw)......................... $2,843.86
Act 141 2005 Contribution (28 days x $1.052250/days)................................ $29.46
Act 141 Base Rate Cost (80,800 kWh x $0.001520-/kWh).......................... $122.82CR
Facilities (28 days x $1.660000/days).. $46.48
State Low-Income Assistance Fee.. $23.00
Energy - Off Peak (45,600 kWh x $0.058220/kWh)................................. $2,654.83
Energy - On Peak (35,200 kWh x $0.083430/kWh).................................. $2,936.74
Renewable Grant CR (80,800 kWh x $0.002390-/kWh)............................. $193.11CR
Total Electricity Charges $8,621.64

Figure 8: Detailed View of Tool-Tip Sample Utility Bill

Once a user has filled all the necessary fields, he/she can scroll to the bottom of the page and click calculate. The user will then be transferred to the output section where the generated results will be displayed. As of now the results are displayed as text and do not include graphics representing the underlying economics. Figure 9 details a screenshot of a sample output.

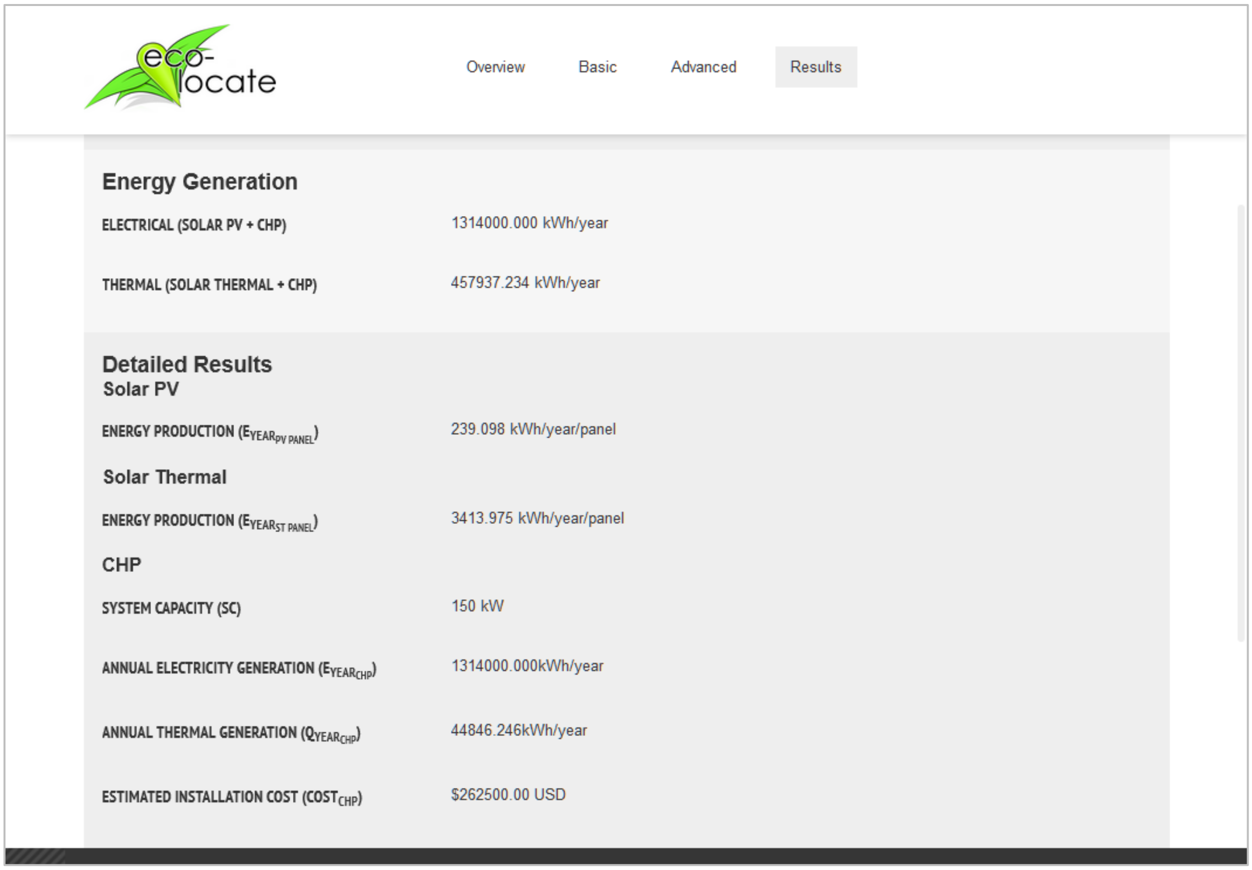


Figure 9: Screenshot of Sample Output

Future Plans

Further development of the tool may be performed to increase the accuracy of the generated results. Additional geometric constraints such as cell size and available area would provide saturation limits on the number of solar PV and solar thermal panels that could be implemented at the given location. In addition to this, average operating and maintenance costs would be added to the budget and rate of return calculations, thus providing more accurate results. Furthermore, calculations for inflation and the time value of money could be taken into consideration.

Additional changes that should be made are to the supplementing documents associated with the tool. The about page for the tool is scarce and only includes the authors of the tool as well a single acknowledgement. Although tool-tips have been implemented, it would be beneficial to create a user guide / help section for the tool. Due to time constraints this could not be implemented during this project timeline. In this section a user could refer to more detailed documentation and perhaps be presented with examples of where they can get utility information and specifications.

None of the information placed within the tool can be recorded due to the nature of how it was programmed. JavaScript is a client side language and therefore it is impossible to grab any of the generated results from a user (nor is it possible to grab any of the data they input). Nonetheless, a privacy section of the tool must also be completed in the future. The section would simply state that no information can be stored or is stored by MSOE. This is a common practice to do for web sites that require information from its visitors.

An evolution of this tool (as in several months in development) would be to host it on a web server and implement other technologies such as sessions and exporting results in a PDF format. In addition, variable optimization schemes could be added. That is, a user can decide whether he or she would want to determine the greatest CO_2 reduction instead of minimizing the payback period. These capabilities would most likely have to be assigned to a software engineer, however, as the needed knowledge to perform such tasks are out of the scope of the typical mechanical engineer.

Conclusion
Eco-Locate is a functioning tool developed by MSOE during an independent study course followed by an undergraduate research assistantship. Both solar PV and solar thermal analysis are consistent with hand calculations and online resources such as the NREL simulation tools PVWatts and System Advisory Model (SAM). Further refinement is necessary to improve the optimization results. Because of the low cost of solar PV panels and because excess energy assumed to be sold back to the grid, the tool will often suggest utilizing the maximum amount of panels that the budget will accommodate.

Acknowledgements
This work was funded in part by the MidWest Energy Research Consortium (MWERC).

Nomenclature

A	Number of solar PV panels
API	Application Program Interface
A_{ST}	Area of a solar thermal collector
B	Number of solar thermal panels
Budget	User's budget
C	Boolean if CHP is implemented
$Cost_{CHP}$	Cost of a CHP system
$Cost_{Fuel}$	Cost for fuel per year for CHP
$Cost_{PV}$	Cost of one solar PV panel
$Cost_{ST}$	Cost of one solar thermal panel
CSS	Cascading Style Sheet
electric_peak	Peak electrical load input by user
$E_{Year)CHP}$	Yearly electrical energy from CHP
$E_{Year)PVmodule}$	Electrical energy of one PV panel in 1yr
$E_{year,Sun}$	Total insolation energy available in one year
FrUL	Efficiency characteristic (ST) W/m^2
Frτα	Efficiency characteristic (ST)
f_t	Temperature derating factor
$FuelCost_{NG}$	Current cost per therm of natural gas
$\overline{FuelCost}_{NG}$	Year average cost per therm of nat. gas
$FuelCost_E$	Current cost per kWh of electricity
$\overline{FuelCost}_E$	Year average cost per kWh of electricity

HTML	Hypertext Markup Language
$InstallRate_{CHP}$	Install rate for a CHP system
IRR	Internal Rate of Return
L	Thermal Load input by user
MSOE	Milwaukee School of Engineering
NOCT	Nominal Operating Cell Temperature
NREL	National Renewable Energy Laboratory
$Q_{Year)CHP}$	Yearly thermal energy generation from CHP
$Q_{Year)ST}$	Yearly thermal energy generation from ST
$Revenue_{CHP}$	Revenue from all sources(CHP)
$Revenue_{E)CHP}$	Revenue from electrical energy (CHP)
$Revenue_{Q)CHP}$	Revenue from thermal energy (CHP)
ROI	Return on Investment
$Savings_{CHP}$	Savings per year from CHP
$Savings_{PV}$	Savings of one PV panel per year
$Savings_{ST}$	Savings from ST per year
SC	System Capacity of CHP
Solrad_annual	NREL yearly insolation array data
Solrad_monthly	NREL monthly insolation array data
SparkSpread	The amount of spark spread in $/MMBtu for a given location.
tamb	NREL monthly ambient temperature data
T_{amb}	Average yearly ambient temp
T_{cell}	Solar panel cell operation temp
$t_{SimplePayback}$	Simple payback time in years
W_{AC}	AC power of one solar panel
W_{DC}	DC rated power of one solar panel
ΔFuel	Fuel consumed in one year (CHP)
η_{Total}	Combined system efficiency
$\eta_{WaterHeater}$	Hot water heater efficiency

Subscripts

amb	Ambient
AC	Alternating Current
DC	Direct Current
cell	Solar Cell
E	Electric
T	Thermal
CHP	Combined Heat & Power
NG	Natural Gas
PV	Photovoltaic
ST	Solar Thermal

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Appendix

Code 1: Eco-Locate Main Logic (JavaScript – energy_calc.js)

```
$(document).ready(function () {
    var g_pvwatts_data = undefined;

    /*
         * outputs the message to the user in the given htmlId if the
         * parameter outNum exists and has isNaN(outNum) === false
         */
    function output_calculation(htmlId, msg, outNum) {
        if (typeof outNum === 'number' && !isNaN(outNum)) {
            $(htmlId).html(msg + ': ' + outNum)
                        .removeClass('bg-danger').addClass('bg-info');
        }
        else {
            $(htmlId).html('<span>Incorrect input</span>')
                        .removeClass('bg-info').addClass('bg-danger');
        }
    }

    /*
         * output that input is incorrect to the specified HTMLID
         */
    function bad_input(htmlId) {
        $(htmlId).html('<span>ERROR: Incorrect Input</span>')
                .removeClass('bg-info').addClass('bg-danger');
    }

    // Gathering Inputs - January 2015 by Evan Sendra
    // gets all the form inputs of the form specified by FORM_ID and returns them in a dictionary based on the
id of the input
    function get_all_form_inputs(form_id, parse_as, except) {
        // default parameters if not provided
        parse_as = typeof parse_as === 'undefined' ? parseFloat : parse_as;
        except = typeof except === 'undefined' ? [] : except;

        var ret_dict = {};
        var selection_string = 'form#' + form_id + ' :input';
        $(selection_string).each(function () {
            var input = $(this);
            var isExempt = $.inArray(input.attr('id'), except) !== -1;
            if (input.attr('id') != undefined && !isExempt) {
                var parsed = parse_as(input.val());
                if (parsed === NaN) {
                    throw "not a number";
                }
                ret_dict[input.attr('id')] = parsed;
            }
            else if (isExempt || input.attr('type') === 'submit') {
                // allow unsanitized, but don't put into hash
            }
            else {
                throw "input undefined";
            }
        });
        return ret_dict;
    }

    /*
         * called when the solar_pv form is submitted
         */
    $('#solar_pv_form').on('submit', function (event) {
        event.preventDefault();
        solar_pv_calculation();
    });
```

```
/*
     * called when the solar thermal form is submitted
     */
$('#solar_thermal_form').on('submit', function (event) {
    event.preventDefault();
    solar_thermal_calculation();
});



/* SWITCHING TABS */
function switch_tab(clicked_tab_id, clicked_content_id) {
    var active_tab_id = '#' + $('.nav-active').attr('id');
    var active_content_id = '#' + $('.content-active').attr('id');

    // switch active tab style
    $(active_tab_id).removeClass('nav-active');
    $(clicked_tab_id).addClass('nav-active');

    $(active_content_id).removeClass('content-active');
    $(clicked_content_id).addClass('content-active');

    // return false;
}

$('#nav_overview a').click(function (e) {
    switch_tab('#nav_overview', '#overview-sec');
});

$('#nav_basic a').click(function (e) {
    switch_tab('#nav_basic', '#basic');
});

$('#nav_advanced a').click(function (e) {
    switch_tab('#nav_advanced', '#advanced');
});

$('#nav_output a').click(function (e) {
    switch_tab('#nav_output', '#output');
});

$("#get_started").click(function (e) {
    switch_tab('#nav_basic', '#basic');
});

/**
     * calculation of user output
     */
$('.calculate').click(function (e) {
    e.preventDefault();
    var has_err = false;
    try {
        if (g_pvwatts_data === undefined)
            throw "No NREL Weather Data";

        // gather and sanitize inputs
        basic_input = get_all_form_inputs('basic_form', parseFloat);
        advanced_input = get_all_form_inputs('advanced_form', parseFloat);

        var arr = g_pvwatts_data.tamb;
        var avg = arr.reduce(function (a, b) {
            return a + b;
        }) / parseFloat(arr.length);


        // ---------------------------------------------------------------------------------------------
        // NREL DATA CALC ------------------------------------------------------------------------------
        // ---------------------------------------------------------------------------------------------
        console.group("NREL DATA CALC");
```

```
            // Solar Irradiance
            var eyear_sun = g_pvwatts_data.solrad_annual * 365;
            console.log(" - Yearly Solar Irradiance (Eyear_sun??) = " + eyear_sun + " [kWh/m^2/yr] \n");

            console.groupEnd();


            // -----------------------------------------------------------------------------------------
            // SOLAR PV --------------------------------------------------------------------------------
            // -----------------------------------------------------------------------------------------
            console.group("SOLAR PV");

            // Cell Temperature
            var T_cell = avg + (advanced_input['NOCT'] - 20) / 0.8;
            console.log(" - Cell Temperature (T_cell) = " + T_cell + " [C]");

            // Temperature De-rating Factor
            var f_t = 1 - .005 * (T_cell - 25);
            console.log(" - Temperature De-rating Factor (f_t) = " + f_t);

            // AC Rating Factor
            var AC_rate = f_t * (advanced_input['cell_eff'] / 100) * advanced_input['dc_rate'];
            console.log(" - AC Rating Factor (AC_rate) = " + AC_rate + " [kW]")

            // Electricity Generation per Panel
            var E_year_PV_panel = (AC_rate * eyear_sun);
            console.log(" - Electricity Generation per Solar PV Panel (E_year_PV_panel) " + E_year_PV_panel + "
[kWh/panel/year]");

            // Savings PV (per Panel)
            var Savings_PV_panel = E_year_PV_panel * (basic_input['e_cost']);
            console.log(" - Savings per Solar PV Panel (Savings_PV_panel) = " + Savings_PV_panel + "
[$USD/panel/year] \n");

            console.groupEnd();


            // -----------------------------------------------------------------------------------------
            // SOLAR THERMAL ---------------------------------------------------------------------------
            // -----------------------------------------------------------------------------------------
            console.group("SOLAR THERMAL");

            // f-Chart Locations
            var X = (8765 * advanced_input['frul'] * advanced_input['area_therm'] * (100 - avg)) /
(basic_input['therm_load'] * 29.3);
            var Y = (advanced_input['frta'] * advanced_input['area_therm'] * eyear_sun) /
(basic_input['therm_load'] * 29.3);
            console.log("f-chart Data Point Locations");
            console.log("X = " + String(X.toFixed(3)) + " Y = " + String(Y.toFixed(3)) + "\n");

            // f-Chart Result
            var f = (1.029 * Y) - (0.065 * X) - (0.245 * Y * Y) + (0.0018 * X * X) + (0.0215 * Y * Y * Y);
            console.log("f = " + f);

            // Thermal Generation per Panel
            Q_year_ST_panel = f * (basic_input['therm_load'] * 29.3);
            // Q_year_ST_panel = Q_year_ST_panel / 29.3; // Converting to therms.
            console.log(" - Thermal Generation per Solar Thermal Panel (Q_year_ST_panel) = " +
String(Q_year_ST_panel) + " [kWh/panel/year]");

            // Savings ST (per Panel)
            Savings_ST_panel = (Q_year_ST_panel) * (basic_input['nat_gas_cost']);
            console.log(" - Savings per Solar Thermal Panel (Savings_ST_panel) = " + Savings_ST_panel + "
[$USD/panel/year] \n")

            console.groupEnd();
```

```
            // ---------------------------------------------------------------------------------------------
            // SPARK SPREAD ---------------------------------------------------------------------------------
            // ---------------------------------------------------------------------------------------------
            console.group("SPARK SPREAD");

            // Gathering Needed Data
            var E_year = basic_input['E_year'];                                         // Yearly Energy Used (kWh)
            var Q_year = basic_input['therm_load'];                                     // Yearly Gas Used (therms)
            var Cost_E_year = basic_input['Cost_E_year'];                               // Yearly Energy Cost ($USD)
            var Cost_Q_year = basic_input['Cost_Q_year'];                               // Yearly Gas Cost ($USD)

            // Electricity Fuel Cost (Fuel Rate)
            var fuel_cost_e = (Cost_E_year / E_year) * 293 /* kWh/MMBTU */;
            console.log(" - Avg. Electricity Fuel Cost/Rate (FuelCost_E) = " + fuel_cost_e + " [$USD/MMBTU]");

            // Natural Gas Fuel Cost (Fuel Rate)
            var fuel_cost_ng = (Cost_Q_year / Q_year) * 10 /*therm/MMBTU */;
            console.log(" - Avg. Natural Gas Fuel Cost/Rate (FuelCost_NG) = " + fuel_cost_ng + " [$USD/MMBTU]");

            // Spark Spread Calculation
            var spark_spread = fuel_cost_e - fuel_cost_ng;
            console.log(" - Spark Spread (SparkSpread) = " + spark_spread + " [$USD/MMBTU]");

            // Is CHP feasible?
            if (spark_spread >= 12) {
                var Install_CHP = true;
                console.log(" - DECISION: CHP is financially feasible. CHP will be implemented unless the budget
does not allow for it.")
            } else {
                var Install_CHP = false;
                var Cost_CHP = 0;
                console.log(" - DECISION: CHP should not be implemented. The spark spread is under the
recommended 12 $USD/MMBtu. ")
            }

            console.groupEnd();


            // ---------------------------------------------------------------------------------------------
            // CHP ------------------------------------------------------------------------------------------
            // ---------------------------------------------------------------------------------------------
            console.group("CHP");

            // If CHP isn't feasible by spark spread, skip calculations.
            if (Install_CHP == true) {

                // System Capacity (kW)
                var SC = .6 * basic_input['peak_electric']; //kW
                console.log(" - System Capacity (SC) = " + String(SC) + " [kW]");

                // Calculating Install Rate ($USD/kW^2)
                var InstallRate_CHP = 0;
                if (SC < 100) {
                    IntallRate_CHP = 1800;
                } else if (SC >= 100 && SC < 500) {
                    IntallRate_CHP = -1 * SC + 1900;
                } else if (SC >= 500 && SC <= 2000) {
                    IntallRate_CHP = -.2667 * SC + 1533.3;
                } else {
                    IntallRate_CHP = 1000;
                }

                // CHP Install Cost
                var Cost_CHP = SC * IntallRate_CHP; // $USD
                console.log(" - CHP System Install Cost (Cost_CHP) = " + String(Cost_CHP) + " [$USD]");

                // Continue w/ calculations if the cost of CHP is less than the budget (i.e. Cost_CHP < budget).
                if (Cost_CHP <= basic_input['budget']) {
```

```
                    // Estimated Annual Electric Generation (CHP)
                    var annual_electric = SC * 8760; // kWh
                    console.log(" - Annual Electric Generation (E_year_CHP) = " + String(annual_electric) + "
[kWh/year]");

                    // Estimated Annual Thermal Generation (CHP)
                    var annual_therm = annual_electric * 0.0341295634; // therm
                    console.log(" - Annual Thermal Generation (Q_year_CHP) = " + String(annual_therm) + "
[therms/year]");

                    // Estimated Fuel Consumption (CHP)
                    var fuel_consumed = annual_therm * (1 / .32) * (1 / .905); //therm
                    console.log(" - Fuel Consumed (dFuel) = " + String(fuel_consumed) + " [therms]");

                    // Electric Revenue
                    var e_revenue = basic_input['e_cost'] * annual_electric; // $USD
                    console.log(" - Electric Revenue = " + String(e_revenue) + " [$USD/year]");

                    // Thermal Revenue
                    var therm_revenue = 1.25 * basic_input['nat_gas_cost'] * annual_therm; // $USD
                    console.log(" - Thermal Revenue = " + String(therm_revenue) + " [$USD/year]");

                    // Revenue from CHP
                    var revenue_chp = e_revenue + therm_revenue; // $USD
                    console.log(" - Total Revenue of CHP = " + String(revenue_chp) + " [$USD/year]");

                    // Fuel Expenses
                    var fuel_expense = fuel_consumed * basic_input['nat_gas_cost']; // $USD
                    console.log(" - Fuel Expenses = " + String(fuel_expense) + " [$USD/year]");

                    // Savings from CHP
                    var Savings_CHP = revenue_chp - fuel_expense; // $USD
                    console.log(" - Savings from CHP = " + String(Savings_CHP) + " [$USD/year]");

                    // Edit Outputs if Results Don't Make Sense
                    if (Savings_CHP < 0) {
                        Savings_CHP = 0;
                        Cost_CHP = 0;
                        SC = 0;
                    }

                } else {
                    var Install_CHP = false;
                    var Cost_CHP = 0;
                    var Savings_CHP = 0;
                    var annual_electric = 0;
                    var annual_therm = 0;
                    SC = 0;
                    console.log(" - The installation cost for a CHP system is larger than the provided budget. A
CHP system cannot be installed. \n");
                }
            }

            console.groupEnd();


            // -----------------------------------------------------------------------------------------
            // BRUTE FORCE OPTIMIZATION -------------------------------------------------------------------
            // -----------------------------------------------------------------------------------------
            console.group("BRUTE FORCE OPTIMIZATION");
            console.group("MAXIMUM NUMBER OF PANELS THAT CAN BE INSTALLED");

            // Panel Area Constraints
            var A_available = basic_input['A_available'];
            var A_PV_panel = advanced_input['area_pv'];
            var A_ST_panel = advanced_input['area_therm'];

            // Panel Cost Constraints
            var Budget = basic_input['budget'];
```

```
            var Cost_PV_panel = advanced_input['panel_cost_pv'];
            var Cost_ST_panel = advanced_input['panel_cost_st'];

            // Max Panels by Area
            console.group("BY AREA")
            var max_n_PV_area = Math.floor(A_available / A_PV_panel); console.log(" - Maximum Number of Solar PV
Panels by Area (max_n_PV_area) = " + max_n_PV_area + " [panels]");
            var max_n_ST_area = Math.floor(A_available / A_ST_panel); console.log(" - Maximum Number of Solar
Thermal Panels by Area (max_n_ST_area) = " + max_n_ST_area + " [panels]");
            console.groupEnd();

            // Max Panels by Budget/Cost
            console.group("BY BUDGET")
            var max_n_PV_cost = Math.floor((Budget - Cost_CHP) / Cost_PV_panel); console.log(" - Maximum Number
of Solar PV Panels by Cost (max_n_PV_cost) = " + max_n_PV_cost + " [panels]");
            var max_n_ST_cost = Math.floor((Budget - Cost_CHP) / Cost_ST_panel); console.log(" - Maximum Number
of Solar Thermal Panels by Cost (max_n_ST_cost) = " + max_n_ST_cost + " [panels]");
            console.groupEnd();

            // Max Panels is Min of Area & Budget
            console.group("TOTAL");
            var max_n_PV = Math.min.apply(Math, [max_n_PV_area, max_n_PV_cost]);
            console.log(" - Maximum Number of Solar PV Panels (max_n_PV)= " + max_n_PV + " [panels]");
            var max_n_ST = Math.min.apply(Math, [max_n_ST_area, max_n_ST_cost]);
            console.log(" - Maximum Number of Solar Thermal (max_n_ST) = " + max_n_ST + " [panels]");
            console.groupEnd();
            console.groupEnd();

            // Optimization Approach
            console.group("BEST COMBINATION OF SYSTEMS");

            // Initializing Variables
            var n_PV = 0; var n_ST = 0;  // Both begin at 0. That is, assume no solar PV or solar thermal panels
are installed.
            var PayBackPeriod = 9999999999999999999999999; // Large payback period. Units: years.

            // Creating Rate of Return Function
            function ROR(money_spent, deflation_percentage_of_money) {

            }

            // Optimization Loop (Brute Force Method)
            for (var tmp_n_PV = 0; tmp_n_PV <= max_n_PV; tmp_n_PV++) {
                for (var tmp_n_ST = 0; tmp_n_ST <= max_n_ST; tmp_n_ST++) {
                    var tmp_Cost_Total = (tmp_n_PV * Cost_PV_panel) + (tmp_n_ST * Cost_ST_panel) + Cost_CHP; //
$USD
                    var tmp_Savings_Total = (tmp_n_PV * Savings_PV_panel) + (tmp_n_ST * Savings_ST_panel) +
Savings_CHP;  // $USD/year
                    var tmp_PayBackPeriod = tmp_Cost_Total / tmp_Savings_Total;
                    var tmp_A_used = (tmp_n_PV * A_PV_panel) + (tmp_n_ST * A_ST_panel);

                    // Storing Values
                    if (tmp_PayBackPeriod < PayBackPeriod && tmp_Cost_Total <= Budget && tmp_A_used <=
A_available) {
                        PayBackPeriod = tmp_PayBackPeriod;
                        n_PV = tmp_n_PV;
                        n_ST = tmp_n_ST;
                    }

                }
            }

            console.log(" - Estimated Payback Period = " + PayBackPeriod + " [years]");
            if (Install_CHP == true) {
                console.log(" - A CHP system with a " + SC + " [kW] system capacity.")
            } else {
                console.log(" - A CHP system should not be installed.")
            }
            console.log(" - Number of Solar PV Panels (n_PV) = " + n_PV + " [panels]");
```

```
            console.log(" - Number of Solar Thermal Panels (n_ST) = " + n_ST + " [panels]");
            console.groupEnd();
            console.groupEnd();


            // ----------------------------------------------------------------------------------------------
            // CALCULATING AMOUNT OF ENERGY PRODUCED -------------------------------------------------------
            // ----------------------------------------------------------------------------------------------
            console.group("TOTAL ENERGY PRODUCED");

            // ELECTRICAL ENERGY
            console.group("ELECTRICAL ENERGY");

            var E_year_PV = n_PV * E_year_PV_panel;
            console.log(" - Solar PV = " + E_year_PV + " [kWh]");

            var E_year_CHP = annual_electric;
            console.log(" - CHP = " + E_year_CHP + " [kWh]");

            var E_year_total = E_year_PV + E_year_CHP;
            console.log(" - TOTAL = " + E_year_total + " [kWh]");

            // Produced vs. Demand
            var E_year_diff = E_year_total - E_year;
            var E_percentage = E_year_total / E_year;
            E_percentage = E_percentage * 100;

            if (E_year_diff >= 0) {
                // E_year_diff is positive = Producing More Energy than Typ. Needed
                // Getting Percentage
                console.log(" - You can produce all of your yearly demand for electricity. You can produce " +
E_percentage + "% of your typical demand.");
            } else {
                // E_year_diff is zero or negative. Producing Less Energy than Typ. Needed.
                console.log(" - You cannot produce enough electrical energy to meet your yearly demand. You can
only produce " + E_percentage + "% of your typical demand.");
            }

            // How Many PV Panels would I need to just meet my electrical demand?
            var min_n_PV_needed = E_year / E_year_PV_panel;
            console.log("The Number of Panels you would need to just meet your Electrical Demand (w/out CHP) = "
+ min_n_PV_needed + " [panels]");

            min_n_PV_needed = (E_year - annual_electric) / E_year_PV_panel;
            console.log("The Number of Panels you would need to just meet your Electrical Demand (w/ CHP) = " +
min_n_PV_needed + " [panels]");

            console.groupEnd();

            // THERMAL ENERGY
            console.group("THERMAL ENERGY");

            var Q_year_ST = n_ST * Q_year_ST_panel;
            console.log(" - Solar Thermal =  " + Q_year_ST + " [kWh]");

            var Q_year_CHP = annual_therm;
            console.log(" - CHP = " + Q_year_CHP + " [kWh]");

            var Q_year_total = Q_year_ST + Q_year_CHP;
            console.log(" - TOTAL = " + Q_year_total + " [kWh]");

            // Produced vs. Demand
            var Q_year_diff = Q_year_total - Q_year;
            var Q_percentage = Q_year_total / Q_year;
            Q_percentage = Q_percentage * 100;

            if (Q_year_diff >= 0) {
                // E_year_diff is positive = Producing More Energy than Typ. Needed
                // Getting Percentage
```

```
                console.log(" - You can produce all of your yearly demand for heat. You can produce " +
Q_percentage + "% of your typical demand.");
            } else {
                // E_year_diff is zero or negative. Producing Less Energy than Typ. Needed.
                console.log(" - You cannot produce enough thermal energy to meet your yearly demand. You can
only produce " + Q_percentage + "% of your typical demand.");
            }

            console.groupEnd();

            console.groupEnd();

            // -----------------------------------------------------------------------------------------
            // OUTPUT TO USER'S -----------------------------------------------------------------------
            // -----------------------------------------------------------------------------------------
            // ENERGY PRODUCTION
            document.getElementById("E_year_total").innerHTML = "<p>" + String(E_year_total.toFixed(3)) + "
kWh/year </p>";
            document.getElementById("Q_year_total").innerHTML = "<p>" + String(Q_year_total.toFixed(3)) + "
kWh/year </p>";

            // OPTIMIZATION SECTION
            document.getElementById("PayBackPeriod").innerHTML = "<p>" + String(PayBackPeriod.toFixed(3)) + "
years </p>";
            document.getElementById("n_PV").innerHTML = "<p>" + String(n_PV) + " panels </p>";
            document.getElementById("n_ST").innerHTML = "<p>" + String(n_ST) + " panels </p>";

            // DETAILED SECTION - SOLAR PV
            document.getElementById("E_year_PV_panel").innerHTML = "<p>" + String(E_year_PV_panel.toFixed(3)) +
" kWh/year/panel </p>";

            // DETAILED SECTION - SOLAR THERMAL
            document.getElementById("Q_year_ST_panel").innerHTML = "<p>" + String(Q_year_ST_panel.toFixed(3)) +
" kWh/year/panel </p>";

            // DETAILED SECTION - CHP
            if (Install_CHP == true) {
                document.getElementById("SC").innerHTML = "<p>" + String(Math.floor(SC)) + " kW </p>";
                document.getElementById("E_year_CHP").innerHTML = "<p>" + String(E_year_CHP.toFixed(3)) +
"kWh/year </p>";
                document.getElementById("Q_year_CHP").innerHTML = "<p>" + String(Q_year_CHP.toFixed(3)) +
"kWh/year </p>";
                document.getElementById("Cost_CHP").innerHTML = "<p>$" + String(Cost_CHP.toFixed(2)) + " USD
</p>";
            } else {
                document.getElementById("CHP-output").innerHTML = "<div class='pad-top-btm'><p><b> A CHP system
cannot be installed. </b></p></div>"
            }



            console.groupEnd();
        }


        catch (err) {
            has_err = true;
            console.log(err);
        }
        finally {
            if (has_err) {
                bad_input('#output_content');
            }

            // switch tabs to results
            switch_tab('#nav_output', '#output');
        }
    });
```

```
    function reportErr(msg) {
        $('#zip_code').val('');
        alert(msg);
    }

    /*
     * creates a chart of solar irradiance based on months / years using the PV watts
     * API after the user has typed in a zipcode
     */
    $('#zip_code').focusout(function () {

        var zip = $(this).val();

        if (zip.length == 5) {
            if (parseInt(zip) == 'NaN') {
                reportErr("zip code must be 5 letters and all numeric");
            }
            else {
                // get sol_irr from the website

$.getJSON('https://developer.nrel.gov/api/pvwatts/v4.json?api_key=5NFOJoJcOEtt1l9XkYkcyLNLZKQ3gvDHS08zXadG&syste
m_size=1&timeframe=hourly&address=' + zip,
                  function (data) {

                      if (data.errors == 0) {
                          g_pvwatts_data = data['outputs'];

                          // round solar irradiance data to 3 decimals
                          var solrad = [];
                          for (var i = 0; i < data.outputs.solrad_monthly.length; ++i)
                              solrad[i] = Math.round(data.outputs.solrad_monthly[i] * 100) / 100;

                          chartData = prepareData(solrad);

                          // make the chart
                          ctx = document.getElementById("chart").getContext("2d");

                      }
                      else {
                          reportErr(data.errors[0]);
                      }
                  })
                      .fail(function () {
                          reportErr("couldn't get data for zip code:" + zip);
                      })
                      .success(function () {
                          $('#chart_title').html('Solar Irradiance of Zip Code ' + zip);
                          window.myBar = new Chart(ctx).Bar(chartData, {
                              responsive: true
                          });
                          $('#chart').show();
                      });
            }
        }
    });

    /*
    * returns data object for the barchart
    * sol_irr - an array of the average solar irradiance by month (12 elems)
    */
    function prepareData(sol_irr) {
        if (sol_irr === undefined)
            sol_irr = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12];

        var retChartData = {
            labels: ["jan", "feb", "mar", "apr", "may", "jun", "jul", "aug", "sept", "oct", "nov", "dec"],
            datasets: [
            {
                fillColor: "rgba(75,75,75,1)",
```

```
                strokeColor: "rgba(75,75,75,0.8)",
                highlightFill: "rgba(167,0,0,0.75)",
                highlightStroke: "rgba(167,0,0,1)",
                data: sol_irr
            }
            ]
        }

        return retChartData;
    }


});
```

Code 2: Tool-tip Logic and Content (JavaScript – tool_tip.js)

```
// TOOL-TIP LIBRARY FOR ECO-LOCOATE
/*
Created by: Wesley A. Zloza
Created: January 30, 2015
Last Modified: August 24, 2015
*/

// CHANGE LOG
/*

JANUARY 30, 2015 by Wesley A. Zloza
 - Wrote the "tool-tip()" function that calls the variables listed below. The variable names
should be the same as the id for their respective input. That is, the zip code input with id
"zip_code" should have a tool-tip variable name "zip_code". This is done for consistency.
 - Added tool-tips for the following: zip_code, NOCT, cell_eff, watts_dc_rate, area_pv,
area_therm, frul, frta.

AUGUST 14, 2015 by Wesley A. Zloza
 - Fixed spelling mistakes found in previous version.
 - Added tool-tips for new inputs placed within the tool. These tool-tips are as follows:
available_area, E_year, Cost_E_year.

AUGUST 18, 2015 by Wesley A. Zloza
 - Added tool-tips for new inputs placed within the tool. These tool-tips are as follows:
Q_year and Cost_Q_year.
 - Improvements made to additional tool-tips.

AUGUST 24, 2015 by Wesley A. Zloza
 - Added a better tool-tips for solar thermal properties frul and frta. Included specification
sheet that highlights were those properties can be found.

*/

// DEFINING VARIABLES (I.E. TOOL-TIP INFORMATION)
var input_id;
var tool_tip_content = {
    // Facility Information
    zip_code: 'Input the zip code for the location that you would like be analyzed. Once the 5
digit zip code is placed within the field the solar irradiance data for that location will be
displayed below in the form of a bar graph.',
    A_available: 'The amount of area (in sq. meters) that could be used to install solar PV and
solar thermal panels. An approximation can be determined using the following online tool: <a
href="http://www.daftlogic.com/projects-google-maps-area-calculator-tool.htm"
target="_blank">Daft Logic Area Calculator</a>. The amount of space required for a CHP system
is assumed to be available and is dependent on both the calculated <a
href="https://en.wikipedia.org/wiki/Spark_spread" target="_blank">spark spread</a> and
budget.',

    // Solar PV & Electricity Tool-Tips
    e_cost: 'An approximation for the rate of electricity can be determined using the utility
bill associated with the analyzed location. The image below is a sample utility bill detailing
were the needed information can be found. <img src="img/electric_bill_fuel_cost.png"
style="width: 100%; height: auto;"/> <i>(Right click and select "View Image" to see a larger
version of the utility bill.)</i>',
    peak_electric: 'The peak electrical demand can be determined from a standard utility bill.
The image below is a sample utility bill detailing were the needed information can be found. It
is important to determine the maximum demand out of 12 months of utility data. <img
src="img/electric_bill_peak_electric_demand.png" style="width: 100%; height: auto;" />
<i>(Right click and select "View Image" to see a larger version of the utility bill.)</i>',
    E_year: 'The total amount of electricity (in kWh) consumed by the facility being analyzed.
This data can be determined by taking the summation of electricity used in a month as found on
a standard utility bill. This is expressed in the sample utility bill seen below. <img
src="img/electric_bill_total_electric_used_year.png" style="width: 100%; height: auto;" />
<i>(Right click and select "View Image" to see a larger version of the utility bill.)</i>',
    Cost_E_year: 'The total amount of money ($USD) spent on electricity in a year. This can be
determined by taking the summation of the electricity cost used in a month as found on a
```

```
standard utility bill. This is expressed in the sample utility bill seen below. <img
src="img/electric_bill_total_electric_cost_year.png" style="width: 100%; height: auto;" />
<i>(Right click and select "View Image" to see a larger version of the utility bill.)</i>',
    NOCT: "Nominal Operating Condition Temperature: This value is specific to the type of solar
panel that is being implemented and should be provided by the supplier. A common location for
this value can be found within the solar panel specifications or data sheet.",
    cell_eff: "Cell Efficiency: This refers to how well a panel can convert the solar energy
into electrical energy. The efficiency listed here also includes the AC to DC conversion loss.
This should be given by the supplier of the solar panel.",
    watts_dc_rate: "The DC rated wattage of the implemented solar panel. This is found within
the manufacturer specifications.",
    area_pv: "The surface area of a single solar panel. This information is specific to the
type of panel being implemented and should be found within the supplier specifications.",

    // Solar Thermal & Heat Use Tool-Tips
    nat_gas_cost: 'An approximation for the rate of natural gas can be determined using a
standard utility bill. The image below is a sample utility bill detailing were the needed
information can be found. <img src="img/gas_bill_fuel_cost.png" style="width: 100%; height:
auto;"/> <i>(Right click and select "View Image" to see a larger version of the utility
bill.)</i>',
    therm_load: 'The total amount of natural gas (in therms) consumed by the facility being
analyzed. This data can be determined by taking the summation of gas used in a month as found
on a standard utility bill. This is expressed in the sample utility bill seen below. <img
src="img/gas_bill_total_gas_used_year.png" style="width: 100%; height: auto;" /> <i>(Right
click and select "View Image" to see a larger version of the utility bill.)</i>',
    /* Q_year: 'The total amount of natural gas (in therm) consumed by the facility being
analyzed. This data can determined by taking the summation of gas used in a month as found on a
standard utility bill. This is expressed in the sample utility bill seen below. <img
src="img/gas_bill_total_gas_used_year.png" style="width: 100%; height: auto;" /> <i>(Right
click and select "View Image" to see a larger version of the utility bill.)</i>', */
    Cost_Q_year: 'The total amount of money ($USD) spent on natural gas in a year. This can be
determined by taking the summation of the gas cost used in a month as found on a standard
utility bill. This is expressed in the sample utility bill seen below. <img
src="img/gas_bill_total_gas_cost_year.png" style="width: 100%; height: auto;" /> <i>(Right
click and select "View Image" to see a larger version of the utility bill.)</i>',
    area_therm: "This is the surface area of one solar thermal collector. This information is
specific to the type of panel being implemented and should be found within the supplier
specifications.",
    frul: 'F<sub>r</sub>UL is a specification of a solar thermal panel and can be found within
the manufacturer spec. sheet. <img src="img/solar_thermal_spec.png" style="width: 100%; height:
auto;" /> <i>(Right click and select "View Image" to see a larger version of the utility
bill.)</i>',
    frta: 'F<sub>r</sub>&tau;&alpha; is a specified characteristic of a solar thermal panel.
<img src="img/solar_thermal_spec.png" style="width: 100%; height: auto;" /> <i>(Right click and
select "View Image" to see a larger version of the utility bill.)</i>',

    // Combined Heat and Power Tool-Tips
    // no tool-tips needed just yet.

    // Fiscal Analysis
    budget: 'The amount of money ($USD) granted for an energy project. That is, the amount of
money that can be used to install solar PV, solar thermal, and CHP systems.'
}

// THE LOGIC
function tool_tip(input_id) {

    document.getElementById("dialog-message").innerHTML = tool_tip_content[input_id];

        $("#dialog-message").dialog({
            modal: true,
            draggable: false,
            closeOnEscape: true,
            hide: {effect: "fadeOut", duration: 500},
            show: {effect: "fadeIn", duration: 500},
            position: {my: "top+200", at: "top", of: window},
            buttons: {
                Close: function () {
                    $(this).dialog("close");
```

```
                }
            }
    });
}
```

Code 3: Homepage (HTML – index.html)

```
<html>
<head>
    <!-- PAGE INFORMATION -->
    <title>Eco-Locate</title>
    <meta charset="UTF-8" />
    <meta name="description" content="Evalulate your location for new sustainable resources" />
    <meta name="keywords" content="MSOE, sustainable, calculator" />
    <meta name="author" content="Wesley A. Zloza" />
    <meta name="viewport" content="width=device-width,initial-scale=1">

    <!-- LINKING SITE ICON -->
    <link rel="icon" href="img/fav_icon.png" type="image/png" />

    <!-- LINKING STYLE SHEETS -->
    <link rel="stylesheet" type="text/css" href="css/responsive-nav.css" />
    <link rel="stylesheet" type="text/css"
href="https://ajax.googleapis.com/ajax/libs/jqueryui/1.11.2/themes/smoothness/jquery-ui.css" />
    <link rel="stylesheet" type="text/css" href="css/style.css" />

    <!-- LINKING FONTS -->
    <link href='http://fonts.googleapis.com/css?family=PT+Sans+Narrow:400,700' rel='stylesheet'
type='text/css'>
    <link href='http://fonts.googleapis.com/css?family=Open+Sans+Condensed:300'
rel='stylesheet' type='text/css'>

    <!-- LINKING JAVASCRIPT-->
    <script src="http://ajax.googleapis.com/ajax/libs/jquery/2.1.1/jquery.min.js"></script>
    <script src="https://ajax.googleapis.com/ajax/libs/jqueryui/1.11.2/jquery-
ui.min.js"></script>
    <script type="text/javascript" src="js/responsive-nav.js"></script>
    <script type="text/javascript" src="js/Chart.js"></script>
    <script type="text/javascript" src="js/energy_calc.js"></script>
    <script type="text/javascript" src="js/tool_tip.js"></script>
</head>


<body>
    <!-- NAVIGATION -->
    <div id="nav" class="col col-12">
        <div class="contain">

            <!-- MSOE LOGO -->
            <div class="col col-4 pad">
                <a href="index.html"><img id="nav_logo" src="img/project_logo_alt_v2.png"
style="height: 75px; cursor: pointer" /></a>
            </div>

            <!-- NAV FOR DIFFERENT ANALYSIS -->
            <div class="col col-8">
                <div id="tab_nav" class="nav-collapse">
                    <ul>
                        <li id="nav_overview" class="nav-active"><a
href="javascript:void(0)">Overview</a></li>
                        <li id="nav_basic"><a href="javascript:void(0)">Basic</a></li>
                        <li id="nav_advanced"><a href="javascript:void(0)">Advanced</a></li>
                        <li id="nav_output"><a href="javascript:void(0)">Results</a></li>
                    </ul>
                </div>
            </div>

            <!-- RESPONSIVE NAV PARAMETERS -->
            <!-- POSSIBLE HARD CODE INTO RESPONSIVE NAV.JS TO CLEAN HTML -->
            <script>
                var navigation = responsiveNav(".nav-collapse", {
                    animate: true,                    // Boolean: Use CSS3 transitions, true or
false
```

```
                    transition: 284,                  // Integer: Speed of the transition, in
milliseconds
                    label: "Menu",                    // String: Label for the navigation
toggle
                    insert: "before",                 // String: Insert the toggle before or
after the navigation
                    customToggle: "",                 // Selector: Specify the ID of a custom
toggle
                    closeOnNavClick: true,           // Boolean: Close the navigation when one
of the links are clicked
                    openPos: "relative",              // String: Position of the opened nav,
relative or static
                    navClass: "nav-collapse",         // String: Default CSS class. If changed,
you need to edit the CSS too!
                    navActiveClass: "js-nav-active",  // String: Class that is added to <html>
element when nav is active
                    jsClass: "js",                    // String: 'JS enabled' class which is
added to <html> element
                    init: function () { },            // Function: Init callback
                    open: function () { },            // Function: Open callback
                    close: function () { }            // Function: Close callback
                });
            </script>
        </div>
    </div>

    <!-- TOOL TIP BASIC ARCHITECTURE (NOT SEEN UNLESS CALLED) -->
    <div id="dialog-message" class="tool-tip-hidden" title="Help Window"></div>


    <!-- FORM INPUTS AND DIFF. SECTIONS -->
    <!-- SECTION #0 - ABOUT/OVERVIEW OF THE TOOL -->
    <section id="overview-sec" class="row content-active">
        <div id="overview" class="contain">
            <h2>Welcome!</h2>
            <p style="font-size: 1.4em; font-family: 'Open Sans Condensed', sans-serif; line-
height: 30px;">Eco-Locate is a tool designed by the Milwaukee School of Engineering to
calculate the potential for renewable systems at a location. The tool will ask you to provide
the following information: a budget for new equipment; the location of the building you wish to
analyze; and your current costs for electricity and natural gas. Once provided with this
information, Eco-Locate will automatically calculate the amount of energy that could be
produced using either solar PV, solar thermal, or CHP systems. </p><br />
            <a id="get_started" class="btn btn-primary">Get Started</a>
        </div>
    </section>

    <!-- SECTION #1 - BASIC CALC INFORMATION -->
    <section id="basic" class="row">

        <!-- HEADER BAR -->
        <div class="header col col-12 bg-pattern-1">
            <div class="contain">
                <div class="col col-12 pad">
                    <h2>Basic Information</h2>
                    <p>The minimum information needed to assess your location.</p>
                </div>
            </div>
        </div>

        <div class="contain pad">
            <form id="basic_form">

                <!--
********************************************************************************** -->
                <!-- FACILITY INFORMATION
************************************************************* -->
                <!--
********************************************************************************** -->
                <div class="col col-12 bg-color-4 pad">
```

```
                    <h3>Facility Information</h3>
                    <!-- ZIP CODE (I.E. LOCATION) -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Location (Zip-Code)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('zip_code')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="zip_code" type="text"
placeholder="Enter Zip Code"></div>
                    </div>

                    <!-- AVAILABLE AREA -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Available Area (m<sup>2</sup>)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('A_available')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="A_available" type="text"
placeholder="1,000"></div>
                    </div>
                </div>

                <!--
********************************************************************************** -->
                <!-- ELECRICITY SECTION
*************************************************************** -->
                <!--
********************************************************************************** -->
                <div class="col col-12 bg-color-5 pad">
                    <h3>Electricity</h3>
                    <!-- RATE OF ELECTRICITY -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Rate for Electricity ($USD/kWh)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('e_cost')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="e_cost" type="text"
placeholder="$0.10"></div>
                    </div>

                    <!-- PEAK ELECTRICAL DEMAND -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Peak Electrical Demand (kW)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('peak_electric')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="peak_electric" type="text"
placeholder="250"></div>
                    </div>

                    <!-- TOTAL ELECTRICITY USED IN A YEAR -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Yearly Electricity Use (kWh)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('E_year')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="E_year" type="text"
placeholder="750,000"></div>
                    </div>

                    <!-- TOTAL ELECTRICITY COST IN A YEAR -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Yearly Electricity Cost ($USD)</label>
```

```
                            <span class="tool-tip-icon" onclick="tool_tip('Cost_E_year')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="Cost_E_year" type="text"
placeholder="$81,100.00"></div>
                    </div>
                </div>

                <!--
********************************************************************************* -->
                <!-- HEATING INFORMATION
************************************************************** -->
                <!--
********************************************************************************* -->
                <div class="col col-12 bg-color-4 pad">
                    <h3>Heating</h3>
                    <!-- NATURAL GAS RATE INPUT -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Rate for Natural Gas ($USD/therm)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('nat_gas_cost')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="nat_gas_cost" type="text"
placeholder="$0.60"></div>
                    </div>

                    <!-- BASE THERMAl LOAD -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Yearly Natural Gas Use (therm)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('therm_load')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="therm_load" type="text"
placeholder="93,000"></div>
                    </div>

                    <!-- TOTAL NATURAL GAS USED IN A YEAR -->
                    <!--
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Yearly Natural Gas Use (therm)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('Q_year')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="Q_year" type="text"
placeholder=""></div>
                    </div>
                    -->
                    <!-- TOTAL NATURAL GAS COST IN A YEAR -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Yearly Natural Gas Cost ($USD)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('Cost_Q_year')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="Cost_Q_year" type="text"
placeholder="$80,200.00"></div>
                    </div>
                </div>

                <!--
********************************************************************************* -->
                <!-- FINANCIAL INFORMATION
************************************************************ -->
                <!--
********************************************************************************* -->
                <div class="col col-12 bg-color-5 pad">
```

```
                    <h3>Financial Information</h3>
                    <!-- PROJECT BUDGET -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Budget ($USD)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('budget')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="budget" type="text"
placeholder="$1,000,000.00"></div>
                    </div>
                </div>


                <div class="col col-3"></div>
                <div class="col col-9">
                    <input class="calculate btn btn-primary" type="submit" value="calculate">
                </div>
            </form>

            <!--
********************************************************************************** -->
            <!-- SOLAR IRRADIENCE CHART
*********************************************************** -->
            <!--
********************************************************************************** -->
            <!-- Containing Element -->
            <div class="col col-8 bg-color-5 pad" style="margin: 1em 0em 2em 0em;">

                <!-- Chart Title -->
                <div class="row">
                    <p id="chart_title" class="title"></p>
                </div>

                <div class="row">
                    <!-- Y Label -->
                    <div style="display: block; float: left; width: 20%;">
                        <p class="y-label">Solar Irradiance (E<sub>year</sub>)<br
/>[kWh/m<sup>2</sup>/yr]</p>
                    </div>

                    <!-- Chart Field (i.e. Canvas) -->
                    <div style="display: block; float: left; width: 80%;">
                        <canvas id="chart" class="chart" height="300"></canvas>
                    </div>

                    <!-- X Label -->
                    <div class="col col-12">
                        <p class="x-label">
                            Month (mo)<br />
                            [mo]
                        </p>
                    </div>

                </div>
            </div>

        </div>
    </section>

    <!-- SECTION #2 - ADVANCED SECTION -->
    <section id="advanced" class="row">

        <!-- HEADER BAR -->
        <div class="header col col-12 bg-pattern-1">
            <div class="contain">
                <div class="col col-12 pad">
                    <h2>Advanced Information</h2>
```

```
                    <p>The following information are general defaults associated with
sustainable systems. These values can be refined to better represent your situation.</p>
                </div>
            </div>
        </div>

        <!-- CONTAINING ELEMENT -->
        <div class="contain pad">
            <div class="col col-12 bg-color-5 pad">
                <div class="row">
                    <h3>System Information</h3>
                </div>
            </div>
            <form id="advanced_form">

                <!--
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~-->
                <!-- SOLAR PV SUB-SECTION -->
                <div class="col col-12 bg-color-4 pad">
                    <div class="row">
                        <h4>Solar PV</h4>
                    </div>
                    <!-- Cost -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Panel Cost ($USD)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('panel_cost_pv')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="panel_cost_pv" type="text"
value="1187" required="required"></div>
                    </div>
                    <!-- NOCT -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Nominal Operating Cell Temperature or NOCT (&deg;C)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('NOCT')"> (?)</span>
                        </div>
                        <div class="col col-9"><input id="NOCT" type="text" value="49"
required="required"></div>
                    </div>
                    <!-- CELL EFF. -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Cell Efficiency (%)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('cell_eff')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="cell_eff" type="text" value="79.75"
required="required"></div>
                    </div>
                    <!-- DC RATING FOR A PANEL -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>DC Rating of the Panel (kW)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('dc_rate')">
(?)</span>
                        </div>
                        <div class="col col-9"><input id="dc_rate" type="text" value="0.205"
required="required"></div>
                    </div>
                    <!-- SURFACE AREA OF A PANEL -->
                    <div class="row">
                        <div class="col col-3 pad-top-btm">
                            <label>Panel Surface Area (m<sup>2</sup>)</label>
                            <span class="tool-tip-icon" onclick="tool_tip('area_pv')">
(?)</span>
                        </div>
```

```
                         <div class="col col-9"><input id="area_pv" type="text" value="1.49"
required="required"></div>
                     </div>
                 </div>

                 <!--
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~-->
                 <!-- SOLAR THERMAL SUB-SECTION -->
                 <div class="col col-12 bg-color-5 pad">
                     <div class="row">
                         <h4>Solar Thermal</h4>
                     </div>
                     <!-- Cost -->
                     <div class="row">
                         <div class="col col-3 pad-top-btm">
                             <label>Panel Cost ($USD)</label>
                             <span class="tool-tip-icon" onclick="tool_tip('panel_cost_st')">
(?)</span>
                         </div>
                         <div class="col col-9"><input id="panel_cost_st" type="text"
value="6071" required="required"></div>
                     </div>
                     <!-- FrUL -->
                     <div class="row">
                         <div class="col col-3 pad-top-btm">
                             <label>FrUL (kW/m<sup>2</sup>&middot;C)</label>
                             <span class="tool-tip-icon" onclick="tool_tip('frul')"> (?)</span>
                         </div>
                         <div class="col col-9"><input id="frul" type="text" value="0.0049099"
required="required"></div>
                     </div>
                     <!-- FrTauAlpha -->
                     <div class="row">
                         <div class="col col-3 pad-top-btm">
                             <label>Fr&tau;&alpha; (undf.)</label>
                             <span class="tool-tip-icon" onclick="tool_tip('frta')"> (?)</span>
                         </div>
                         <div class="col col-9"><input id="frta" type="text" value="0.706"
required="required"></div>
                     </div>
                     <!-- SURFACE AREA OF A PANEL -->
                     <div class="row">
                         <div class="col col-3 pad-top-btm">
                             <label>Panel Surface Area (m<sup>2</sup>)</label>
                             <span class="tool-tip-icon" onclick="tool_tip('area_therm')">
(?)</span>
                         </div>
                         <div class="col col-9"><input id="area_therm" type="text" value="3.716"
required="required"></div>
                     </div>
                 </div>

                 <!--
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~-->
                 <!-- COMBINED HEAT AND POWER (CHP) -->
                 <!-- <div class="row">
                     <h4>Combined Heat &amp; Power (CHP)</h4>
                 </div>
                 <p><i>There are no parameters yet available for this system.</i></p> -->
                 <!--
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~-->
                 <!-- SUBMIT BUTTON -->
                 <div class="col col-3"></div>
                 <div class="col col-9">
                     <input class="calculate btn btn-primary" type="submit" value="calculate">
                 </div>
             </form>

         </div>
```

```html
    </section>

    <!-- SECTION #3 - OUTPUT SECTION -->
    <section id="output" class="row">

        <!-- HEADER BAR -->
        <div class="header col col-12 bg-pattern-1">
            <div class="contain">
                <div class="col col-12 pad">
                    <h2>Generated Results</h2>
                    <p></p>
                </div>
            </div>
        </div>

        <!-- DETAILED RESULTS -->
        <div class="contain pad" id="output-content">

            <!-- OPTIMIZATION RESULTS -->
            <div class="row bg-color-5 pad">
                <h3>Optimization Results</h3>

                <!-- Pay Back Period -->
                <div class="row">
                    <div class="col col-4 pad-top-btm">
                        <label>Simple Payback Period:</label>
                    </div>
                    <div class="col col-8 pad-top-btm" id="PayBackPeriod"></div>
                </div>

                <!-- Number of Solar PV Panels -->
                <div class="row">
                    <div class="col col-4 pad-top-btm">
                        <label>Number of Solar PV Panels (n<sub>PV</sub>)</label>
                    </div>
                    <div class="col col-8 pad-top-btm" id="n_PV"></div>
                </div>

                <!-- Number of Solar Thermal Panels -->
                <div class="row">
                    <div class="col col-4 pad-top-btm">
                        <label>Number of Solar Thermal Panels (n<sub>ST</sub>)</label>
                    </div>
                    <div class="col col-8 pad-top-btm" id="n_ST"></div>
                </div>

            </div>

            <!-- ENERGY GENERATION -->
            <div class="row bg-color-4 pad">
                <h3>Energy Generation</h3>

                <!-- Electrical Energy Generation -->
                <div class="row">
                    <div class="col col-4 pad-top-btm">
                        <label>Electrical (Solar PV + CHP)</label>
                    </div>
                    <div class="col col-8 pad-top-btm" id="E_year_total"></div>
                </div>

                <!-- Thermal Energy Generation -->
                <div class="row">
                    <div class="col col-4 pad-top-btm">
                        <label>Thermal (Solar Thermal + CHP)</label>
                    </div>
                    <div class="col col-8 pad-top-btm" id="Q_year_total"></div>
                </div>
            </div>
```

```
            <!-- DETAILED RESULTS -->
            <div class="row bg-color-5 pad">
                <h3>Detailed Results</h3>

                <!-- Solar PV -->
                <h4>Solar PV</h4>
                <div class="row">
                    <div class="col col-4 pad-top-btm">
                        <label>Energy Production (E<sub>year<sub>PV Panel</sub></sub>)</label>
                    </div>
                    <div class="col col-8 pad-top-btm" id="E_year_PV_panel"></div>
                </div>

                <!-- Solar Thermal -->
                <h4>Solar Thermal</h4>
                <div class="row">
                    <div class="col col-4 pad-top-btm">
                        <label>Energy Production (E<sub>year<sub>ST Panel</sub></sub>)</label>
                    </div>
                    <div class="col col-8 pad-top-btm" id="Q_year_ST_panel"></div>
                </div>


                <!-- CHP -->
                <h4>CHP</h4>
                <!-- System Capacity -->
                <div id="CHP-output" class="row">
                    <div class="row">
                        <div class="col col-4 pad-top-btm">
                            <label>System Capacity (SC)</label>
                        </div>
                        <div class="col col-8 pad-top-btm" id="SC"></div>
                    </div>

                    <!-- Annual Electricity Generation -->
                    <div class="row">
                        <div class="col col-4 pad-top-btm">
                            <label>Annual Electricity Generation
(E<sub>year<sub>CHP</sub></sub>)</label>
                        </div>
                        <div class="col col-8 pad-top-btm" id="E_year_CHP"></div>
                    </div>

                    <!-- Annual Thermal Generation -->
                    <div class="row">
                        <div class="col col-4 pad-top-btm">
                            <label>Annual Thermal Generation
(Q<sub>year<sub>CHP</sub></sub>)</label>
                        </div>
                        <div class="col col-8 pad-top-btm" id="Q_year_CHP"></div>
                    </div>

                    <!-- Installation Cost-->
                    <div class="row">
                        <div class="col col-4 pad-top-btm">
                            <label>Estimated Installation Cost (Cost<sub>CHP</sub>)</label>
                        </div>
                        <div class="col col-8 pad-top-btm" id="Cost_CHP"></div>
                    </div>
                </div>

            </div>


        </div>
    </section>

    <!-- FOOTER -->
```

```html
    <footer id="footer" class="col col-12">
        <div class="contain">
            <div id="footer_container" class="col col-12">

                <!-- QUICK LINKS -->
                <div class="col col-6 pad">
                    <h3>Quick Links</h3>
                    <ul id="footer_nav">
                        <li><a href="http://www.msoe.edu">MSOE Home</a></li>
                        <li><a href="about.html">About</a></li>
                        <li><a href="help.html">User Guide &amp; Help</a></li>
                        <li><a href="legal.html">Disclaimer</a></li>
                        <li><a href="privacy.html">Privacy</a></li>
                    </ul><br />

                    <!-- SCHOOL ADDRESS -->
                    <address class="text-small">
                        Milwaukee School of Engineering<br />
                        1025 N Broadway<br />
                        Milwaukee, WI 53202-3109<br />
                        (800) 332-6763 | explore@msoe.edu
                    </address>
                </div>

                <!-- OTHER FOOTER INFO -->
                <div class="col col-6 pad">
                    <p><a rel="license" href="http://creativecommons.org/licenses/by-nc-
nd/4.0/"><img alt="Creative Commons License" style="border-width:0; margin: 10px 0px 10px 0px;"
src="img/cc_lic_badge.png" /></a><br /><span xmlns:dct="http://purl.org/dc/terms/"
href="http://purl.org/dc/dcmitype/InteractiveResource" property="dct:title" rel="dct:type">Eco-
Locate</span> by <a xmlns:cc="http://creativecommons.org/ns#" href="http://www.msoe.edu"
property="cc:attributionName" rel="cc:attributionURL">Milwaukee School of Engineering</a> is
licensed under a <a rel="license" href="http://creativecommons.org/licenses/by-nc-
nd/4.0/">Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International
License</a>.</p><br />

                    <p style="font-size: 0.6em;"> MSOE is accredited by the Higher Learning
Commission (800) 621-7440, (www.ncahlc.org). Additional program accreditation includes the
Engineering Accreditation Commission of ABET, Engineering Technology Accreditation Commission
of ABET, American Council for Construction Education (ACCE), and Commission on Collegiate
Nursing Education (CCNE) and Commission on Accreditation of Allied Health Education Programs
(CAAHEP). - See more at: http://www.msoe.edu/welcome#sthash.MKNDU7Ia.dpuf </p>
                </div>

                <!-- DATE UPDATED -->
                <div class="col col-12 text-center pad" style="font-size: 10px;">
                    <p>Last Updated August 2015</p>
                </div>

            </div>
        </div>
    </footer>

</body>
</html>
```

Code 4: Tool Stylesheet (CSS - style.css)

```
* {
        box-sizing: border-box;
        margin: 0;
        padding: 0;
}

html{
}

body {
        overflow-x: hidden;
}

.fixed {
  position: fixed;
  width: 100%;
  top: 0;
  left: 0;
}

/* FONTS */
a,p,li,address {
        font-family: "Arial";
  font-size: 13px;
        color: #333;
  line-height: 17px;
}

a {
        color: #A40900;
}

address {
    font-style: normal;
}

h1,h2,h3,h4,h5,h6 {
    font-family: 'Arial', sans-serif;
    font-weight: bold;
    color: #333;
}

/* -------------- */
/* Chart Labeling */
/* -------------- */
.title {
    display: block;
    text-align: center;
    font-weight: bold;
    font-size: 1em;
}

.x-label {
    text-align: center;
    font-weight: bold;
}

.y-label {
    display: block;
    text-align: center;
    font-weight: bold;
    position: relative;
    bottom: 0;
    writing-mode: tb-rl;
    /*
    writing-mode: vertical-lr;
```

```css
    -webkit-transform: rotate(-90deg);
    -moz-transform: rotate(-90deg);
    -ms-transform: rotate(-90deg);
    -o-transform: rotate(-90deg);
    transform: rotate(-90deg);
    -webkit-transform-origin: 50% 50%;
    -moz-transform-origin: 50% 50%;
    -ms-transform-origin: 50% 50%;
    -o-transform-origin: 50% 50%;
    transform-origin: 50% 50%;
    */
}

label {
        font-family: 'PT Sans Narrow', sans-serif;
  font-weight: bold;
        text-transform: uppercase;
        font-size: 0.90em;
        color: #333;
    margin: 1em 0em 1em 0em;
}

.text-center { text-align: center;  }
.text-left   { text-align: left;    }
.text-right  { text-align: right;   }
.text-fill   { text-align: justify; }
.text-small  { font-size: 0.9em;    }



/* ---------- */
/* TOOL TIPS */
/* --------- */

.tool-tip-icon {
    font-size: 0.7em;
    cursor: pointer;
    color: #666;
}

.tool-tip-icon:hover {
    color: #A40900;
}

.tool-tip-hidden {
    display: none;
}

.ui-dialog{
  box-shadow: 0px 1px 5px rgba(0,0,0,0.3) !important;
  border-radius: 0px !important;

}

.ui-dialog-titlebar {
  background: #eee !important;
  border-radius: 0px !important;
  border: 1px solid #ccc;
  font-family: 'PT Sans Narrow', sans-serif !important;
  font-size: 0.9em !important;
  text-transform: uppercase !important;
  color: #333 !important;
}

.ui-dialog-content {
  padding: 20px 10px 20px 10px !important;
  font-family: "Arial" !important;
  font-size: 13px !important;
  color: #333 !important;
```

```
  line-height: 17px !important;
}

.ui-dialog-buttonpane {
  border-top: 1px solid #ccc !important;
}

.ui-dialog-buttonpane, .ui-dialog-buttonset {
  margin: 0 !important;
  padding: 0 !important;
}

.ui-button {
  background: #eee !important;
  font-family: 'PT Sans Narrow', sans-serif !important;
  font-size: 0.8em !important;
  text-transform: uppercase !important;
  color: #333 !important;
  border: 1px solid #ccc !important;
  border-radius: 0px !important;
  transition: linear 0.25s !important;
}

/* END OF TOOL TIPS */


.chart {
    max-width: 600px;
    min-width: 320px;
}


/* LISTS */
ol,ul {
        margin-left: 30px;
}

li {
        margin: 10px 0px 10px 0px;
}

/* CUSTOM SYTLING ELEMENTS */
.paper {
        margin-top: 30px !important;
        margin-bottom: 50px !important;
        padding: 75px !important;
        border: 1px solid #ccc;
        box-shadow: 0px 4px 5px rgba(0,0,0,0.5);
}

/* ---------------------------------------------
  NAVIGATION STYLES
  (+ responsive-nav.css file is loaded in the <head>)
--------------------------------------------- */
#nav {
    height: 110px;
    position: fixed;
    /*overflow: hidden; */
    z-index: 102;
    top: 0;
    background: #fff;
    box-shadow: 0px 1px 5px rgba(0,0,0,0.2);
}

.nav-active * {
    background: #eee;
    color: #333;
}
```

```
.nav-collapse::before {
    box-shadow: inset 0px -3px 3px black;
}

.nav-collapse,
.nav-collapse * {
  -moz-box-sizing: border-box;
  -webkit-box-sizing: border-box;
  box-sizing: border-box;
  width: 100%;
}

.nav-collapse ul {
    margin: 0;
    padding: 0;
    display: block;
    list-style: none;
    float: right;
    width: 100%;
}

.nav-collapse ul li {
    width: auto;
    margin-top: 35px;
}

.nav-collapse ul li a {
    margin: 0px 10px 0px 10px;
    padding: 0.7em 1em;
    width: auto;
    display: inline-block;
    float: left;
    color: #333;
    cursor: pointer;
    text-decoration: none;
}

.nav-collapse a:hover {
    background: url("../img/pattern-1.png");
    background-repeat: repeat;
}

@media screen and (max-width: 760px){
    .nav-collapse {
        margin: 0;
        border-top: 1px solid #ccc;
        border-bottom: 1px solid #bbb;
    }

    .nav collapse ul {
        padding: 0px;
    }

    .nav-collapse ul li {
        margin: 0;
        padding: 0;
        width: 100%;
    }

    .nav-collapse ul li a {
        margin: 0;
        padding: 1em;
        width: 100%;
        height: auto;
        overflow: hidden;
        border-bottom: 1px solid #ccc;
        background: #efefef;
        color: #333;
    }
```

```
}

@media screen and (min-width: 761px) {
  .nav-collapse ul ul a {
    display: none;
  }
}

@-webkit-viewport { width: device-width; }
@-moz-viewport { width: device-width; }
@-ms-viewport { width: device-width; }
@-o-viewport { width: device-width; }
@viewport { width: device-width; }



/* ------------------------------------------
  NAV TOGGLE STYLES
--------------------------------------------- */

@font-face {
  font-family: "responsivenav";
  src:url("../icons/responsivenav.eot");
  src:url("../icons/responsivenav.eot?#iefix") format("embedded-opentype"),
    url("../icons/responsivenav.ttf") format("truetype"),
    url("../icons/responsivenav.woff") format("woff"),
    url("../icons/responsivenav.svg#responsivenav") format("svg");
  font-weight: normal;
  font-style: normal;
}

.nav-toggle {
  position: fixed;
  -webkit-font-smoothing: antialiased;
  -moz-osx-font-smoothing: grayscale;
  -webkit-touch-callout: none;
  -webkit-user-select: none;
  -moz-user-select: none;
  -ms-user-select: none;
  user-select: none;
  text-decoration: none;
  text-indent: -999px;
  position: relative;
  overflow: hidden;
  width: 70px;
  height: 55px;
  float: right;
}

.nav-toggle:before {
  color: #333; /* Edit this to change the icon color */
  font-family: "responsivenav", sans-serif;
  font-style: normal;
  font-weight: normal;
  font-variant: normal;
  font-size: 28px;
  text-transform: none;
  position: absolute;
  content: "≡";
  text-indent: 0;
  text-align: center;
  line-height: 55px;
  speak: none;
  width: 100%;
  top: 0;
  left: 0;
}

.nav-toggle.active::before {
```

```
  font-size: 24px;
  content:"x";
}

#footer_nav * {
        list-style: none;
        font-size: 0.95em;
        color: white !important;
        text-decoration: none;
}

#footer_nav { margin-left: 0px;}
#footer_nav a { transition: linear 0.25s; }
#footer_nav a:hover { text-decoration: underline; }

/* BACKGROUNDS */
.bg-color-1 { background: #000000; }                                      /* WHITE
                */
.bg-color-2 { background: #A40900; }                                      /* RED
                */
.bg-color-3 { background: #333333; }
.bg-color-4 { background: #f6f6f6; }
.bg-color-5 { background: #eeeeee; }

.bg-color-3 *{
        color: #fff !important;
}

.bg-pattern-1 {
        background: url("../img/pattern-1.png");
        background-repeat: repeat;
}

/* FORMS */
.btn {
        margin: 1em 0em 1em 0em;
        padding: 0.75em;
        border: none;
        text-transform: uppercase;
        font-weight: 600;
        cursor: pointer;
}

.btn-primary {
        background: #A40900;
        color: white;
}

.btn-primary:hover{
        background: #760000;
}

input {
        margin: 1em;
        padding: 0.75em;
        border: 1px solid #ccc;
        width: 320px;

}

input:focus {
        border: 1px solid #760000;
}

select {
        margin: 1em;
        border: 1px solid #ccc;
        width: 320px;
        padding: 0.75em;
```

```
}

select option {
        padding: 0.75em;
}

.header{
    margin: 130px 0em 1.5em 0em !important;
}

#progress_bar_outline {
        width: 100%;
        height: 15px;
        margin: 10px 0px 0px 0px;
        background: #efefef;
}

#progress_bar_inside {
        height: 100%;
        background: #A40900;
}

/* LAYOUT/ARCHITECTURE */
.contain {
        margin: 0 auto;
        padding: 0;
        max-width: 960px;
}

.col {
        margin: 0;
        padding: 0;
        float: left;
        overflow: hidden;
}

.row {
    margin: 0;
    padding: 0;
    float: left;
    overflow: hidden;
    width: 100%;
}

.col-12 {width: 100%;}
.col-11 {width: 91.66666666666667%;}
.col-10 {width: 83.33333333333333%;}
.col-9  {width: 75.00000000000000%;}
.col-8  {width: 66.66666666666667%;}
.col-7  {width: 58.33333333333333%;}
.col-6  {width: 50.00000000000000%;}
.col-5  {width: 41.66666666666667%;}
.col-4  {width: 33.33333333333333%;}
.col-3  {width: 25.00000000000000%;}
.col-2  {width: 16.66666666666667%;}
.col-1  {width: 8.333333333333333%;}

.pad {
    padding: 1em;
}

.pad-top-btm {
    padding: 1em 0em 1em 0em;
}

/* FOOTER */
#footer {
        background: url("../img/footer-bg-1.png"), url("../img/footer-bg-2.png"), #363636;
        background-repeat: no-repeat, no-repeat;
```

```css
        background-position: top left, bottom right;
}

#footer_container {
  padding: 2em 0em 0em 0em;
        background: #363636;
        position: relative;
        z-index: 1;
}

#footer_container * {
        color: #fff;
}


#overview {
    margin: 130px auto 20px auto;
    padding: 2em 1em 2em 1em !important;
}

/* RESPONSIVE LAYOUT */
@-webkit-viewport { width: device-width; }
@-moz-viewport { width: device-width; }
@-ms-viewport { width: device-width; }
@-o-viewport { width: device-width; }
@viewport { width: device-width; }

@media (min-width:761px) {

}

@media (max-width:760px) {
    #overview {
        margin-top: 1em;
        padding-top: 1em !important;
    }

        .header {
                margin: 1em 0em 1em 0em !important;
        }

        #nav {
                height: auto;
                position: relative;
        }

    #nav_logo{
        display: block;
        margin: 0 auto;
    }

    .paper {
        margin: 1em;
        padding: 1.5em !important;

    }

    .col-12,
    .col-11,
    .col-10,
    .col-9,
    .col-8,
    .col-7,
    .col-6,
    .col-5,
    .col-4,
    .col-3,
    .col-2,
    .col-1
```

```
        { min-width: 100%; }


    .col {
        display: block;
    }

    input {
        width: 100%;
        margin: 0.5em 0em 0.5em 0em;
    }

    .tabs {
        margin: 0;
    }

    .tabs li {
            width:100%;
            margin: 0 auto;
        }

        .tabs a {
                text-align: center;
                padding: 10px 0;
        }
}

/* only display active section */
section, section.col {
        display: none;
}

section.content-active {
        display: inline-block;
}

.output
{
    margin: 20px 0px 20px 0px;
    transition-property: display;
}

.bg-info
{
    border: 1px solid #00bcc8;
    border-radius: 5px;
        background: #d9edf7;
}

.bg-info * {
    color: #00bcc8 !important;
}

.bg-danger
{
    border: 1px solid #A40900;
    border-radius: 5px;
        background: #f2dede;
}

.center
{
  margin: 0 auto;
  text-align: center;
}
```