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>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>solrad_monthly</td>
<td>An array of 12 data values describing the average daily solar irradiance for one month. Units of kWh/m²/day.</td>
</tr>
<tr>
<td>solrad_annual</td>
<td>A single decimal value that represents the average daily solar radiance for a year. Units of kWh/m²/day.</td>
</tr>
<tr>
<td>tamb</td>
<td>An array of 12 data values of the average ambient temperature of a month. Units °C.</td>
</tr>
</tbody>
</table>
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.

$$E_{Year,Sun} = \text{solrad}_{\text{annual}} \cdot 365 \frac{days}{yr} \quad (1)$$

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.

$$T_{amb} = \frac{\sum \text{tamb}}{(12 \text{ months/year})}$$ \quad (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:

$$T_{cell} = T_{amb} + \frac{\text{NOCT} - 20^\circ C}{0.8} \quad (3)$$

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.

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

$f_t$ is the temperature rating factor of a solar panel. The value of 0.005 $^\circ C^{-1}$ is the power temperature coefficient (this varies somewhat for different panel manufacturers but 0.005 $^\circ C^{-1}$ 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.

$$W_{AC} = f_t \cdot \eta_{\text{Total}} \cdot W_{DC} \quad (5)$$

where $\eta_{\text{Total}}$ 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:

$$E_{(\text{Year})PV} = \frac{W_{AC} \cdot E_{Year,Sun}}{1000 \frac{W}{kW}} \quad (6)$$

In this equation $E_{\text{Year,Sun}}$ 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/m². 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).
The FuelCostE 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:

\[ X = \frac{\left(8765 \ \text{hr/yr}\right) \cdot F_r \cdot UL \cdot A_{ST} \cdot (100^\circ C - T_{amb})}{29.3 \ \text{kWh/Term} \cdot L} \]  

\[ Y = \frac{F_r \cdot \tau\alpha \cdot A_{ST} \cdot E_{Year, Sun}}{29.3 \ \text{kWh/Term} \cdot L} \]  

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. \( F_r \cdot UL \) and \( F_r \cdot \tau\alpha \) 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:

\[ Q_{Year, ST} = (1.029Y - 0.0245Y^2 + 0.215Y^3 - 0.065X + 0.0018X^2) \cdot L \]  

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).

\[ \text{Savings}_{ST} = \frac{Q_{Year, ST} \cdot \text{FuelCost}_{NG} \cdot \left(1 - \frac{\text{Therm}}{\text{kWh}}\right)}{\eta_{Wate r \text{ Heater}}} \]  

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]:

\[ SC = 0.60 \cdot electric\_peak \]
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.

\[
InstallRate_{CHP} = \begin{cases} 
1800 & \text{if } SC < 100 \\
-1 \cdot \frac{\$}{kW} \cdot SC + 1900 & \text{if } 100 \geq SC > 500 \\
-0.2667 \cdot \frac{\$}{kW} \cdot SC + 1533.3 & \text{if } 500 \geq SC \geq 2000 \\
1000 & \text{if } SC > 2000
\end{cases}
\]  

(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:

\[
Cost_{CHP} = SC \cdot InstallRate_{CHP}
\]  

(14)

**Figure 1: Assumed Install Cost for CHP Systems**
To calculate the savings associated with CHP, the electrical and thermal output is calculated. The annual electric generation was calculated using Eq. (15)

\[ E_{\text{year}}^{\text{CHP}} = SC \cdot \left(8765 \, \frac{\text{hr}}{\text{yr}}\right) \]  

(15)

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

\[ Q_{\text{year}}^{\text{CHP}} = \frac{E_{\text{year}}^{\text{CHP}} \cdot 0.034 \, \text{Therms}}{kWh} \]  

(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).

\[ \Delta \text{Fuel} = \frac{Q_{\text{year}}^{\text{CHP}}}{0.29} \]  

(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.

\[ \text{Cost}_{\text{Fuel}} = \Delta \text{Fuel} \cdot \text{FuelCost}_{\text{NG}} \]  

(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)

\[ \text{Revenue}_{E}^{\text{CHP}} = \text{UnitCost}_{E} \cdot E_{\text{year}}^{\text{CHP}} \]  

(19)

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

\[ \text{Revenue}_{Q}^{\text{CHP}} = \frac{\text{FuelCost}_{\text{NG}} \cdot Q_{\text{year}}^{\text{CHP}}}{\eta_{\text{Water Heater}}} \]  

(20)

where the units are in dollars. \( \eta_{\text{Water Heater}} \) 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).

\[ \text{Revenue}_{\text{CHP}} = \text{Revenue}_{E}^{\text{CHP}} + \text{Revenue}_{Q}^{\text{CHP}} \]  

(21)

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

\[ \text{Savings}_{\text{CHP}} = \text{Revenue}_{\text{CHP}} - \text{Cost}_{\text{Fuel}} \]  

(22)
The cost of the CHP system is taken into 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].

\[
\text{SparkSpread} = \overline{FuelCost_E} - \overline{FuelCost_{NG}} 
\]

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 (\(\text{Cost}_{E,\text{year}}\)) by the total amount of electrical energy consumed in a year (\(E_{\text{year}}\)). 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 users 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]:

\[
t_{\text{SimplePayback}} = \frac{\text{Budget}}{\text{Total Yearly Savings}} 
\]

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

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

<table>
<thead>
<tr>
<th>Name/Type</th>
<th>Price (per panel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyocera KD205GX-LP (PV)</td>
<td>$530</td>
</tr>
<tr>
<td>Alternate Energy Technologies AE-40 (Solar Thermal)</td>
<td>$6000</td>
</tr>
</tbody>
</table>

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.

```plaintext
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.
      }
```
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 2: General Optimization Logic (Not Actual Syntax)

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](image)

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 workaround this limitation involved creating labels that would be hidden until that data was obtained.

\[ \text{Figure 5: Generate Solar Irradiance Chart} \]

As one can see, the solar irradiance for Milwaukee produces somewhat of a bell shape curve. This is expected as the amount of sunlight 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. 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
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.
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\textsubscript{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**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Number of solar PV panels</td>
</tr>
<tr>
<td>API</td>
<td>Application Program Interface</td>
</tr>
<tr>
<td>(A_{ST})</td>
<td>Area of a solar thermal collector</td>
</tr>
<tr>
<td>B</td>
<td>Number of solar thermal panels</td>
</tr>
<tr>
<td>Budget</td>
<td>User’s budget</td>
</tr>
<tr>
<td>C</td>
<td>Boolean if CHP is implemented</td>
</tr>
<tr>
<td>(\text{Cost}_{\text{CHP}})</td>
<td>Cost of a CHP system</td>
</tr>
<tr>
<td>(\text{Cost}_{\text{Fuel}})</td>
<td>Cost for fuel per year for CHP</td>
</tr>
<tr>
<td>(\text{Cost}_{\text{PV}})</td>
<td>Cost of one solar PV panel</td>
</tr>
<tr>
<td>(\text{Cost}_{\text{ST}})</td>
<td>Cost of one solar thermal panel</td>
</tr>
<tr>
<td>CSS</td>
<td>Cascading Style Sheet</td>
</tr>
<tr>
<td>electric_peak</td>
<td>Peak electrical load input by user</td>
</tr>
<tr>
<td>(E_{\text{Year}}\text{(CHP)})</td>
<td>Yearly electrical energy from CHP</td>
</tr>
<tr>
<td>(E_{\text{Year}}\text{(PV module)})</td>
<td>Electrical energy of one PV panel in 1 yr</td>
</tr>
<tr>
<td>(E_{\text{Year, Sun}})</td>
<td>Total insolation energy available in one year</td>
</tr>
<tr>
<td>FrUL</td>
<td>Efficiency characteristic (ST) W/m\textsuperscript{2}</td>
</tr>
<tr>
<td>(f_{\tau})</td>
<td>Efficiency characteristic (ST)</td>
</tr>
<tr>
<td>(f_{i})</td>
<td>Temperature derating factor</td>
</tr>
<tr>
<td>(\text{FuelCost}_{\text{NG}})</td>
<td>Current cost per therm of natural gas</td>
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<tr>
<td>(\text{FuelCost}_{\text{NG}})</td>
<td>Year average cost per therm of nat. gas</td>
</tr>
<tr>
<td>(\text{FuelCost}_{E})</td>
<td>Current cost per kWh of electricity</td>
</tr>
<tr>
<td>(\text{FuelCost}_{E})</td>
<td>Year average cost per kWh of electricity</td>
</tr>
</tbody>
</table>
HTML
Hypertext Markup Language
InstallRateCHP
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_{T}^{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.
t_{amb}
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
\Delta F_{uel}
Fuel consumed in one year (CHP)
\eta_{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
References


Appendix

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

```javascript
$(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 */

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;
}

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

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

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

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

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

/***
 * calculation of user output
 */

$('button').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((a, b) => a + b) / parseFloat(arr.length);

        // NREL DATA CALC ---------------------------------------------------------------
        // NREL DATA CALC
        console.group("NREL DATA CALC");
    } catch (err) {
        has_err = true;
    }

    if (has_err) {
        alert("An error occurred: " + err);
    }
});
// 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 - 0.005 * (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();
```javascript
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_spreaad = fuel_cost_e - fuel_cost_ng;
console.log("- Spark Spread (SparkSpread) = "+ spark_spreaad + " [$USD/MMBTU]");

// Is CHP feasible?
if (spark_spreaad >= 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) {
    InstallRate_CHP = 1800;
  } else if (SC >= 100 && SC < 500) {
    InstallRate_CHP = -1 * SC + 1900;
  } else if (SC >= 500 && SC <= 2000) {
    InstallRate_CHP = -.2667 * SC + 1533.3;
  } else {
    InstallRate_CHP = 1000;
  }

  // CHP Install Cost
  var Cost_CHP = SC * InstallRate_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']) {
    
  }
}
console.groupEnd();
```
// 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
// ----------------------------------------

// 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();

// 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]" );

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 thermal. 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.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'>" + " A CHP system cannot be installed. </div>" + "</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=5NFOJo3cOEtiiI9XkYkcyLNLZQ3gvDHSh8zXadG&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;
}

});
// TOOL-TIP LIBRARY FOR ECO-LOCATE
/*
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, frra.

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
- 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 frra. Included specification
sheet that 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 to analyze. 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;"/>
(Right click and select "View Image" to see a larger version of the utility bill.)

    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;"/>
(Right click and select "View Image" to see a larger version of the utility bill.)

    E_year: 'The total amount of electricity (in kWh) consumed by the facility being analyzed.
This data can be determined by adding 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;" />
(Right click and select "View Image" to see a larger version of the utility bill.)

    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;" />

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;" />

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;" />

Q_year: "The total amount of natural gas (in therm) 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;" />

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;" />

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;" />

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;" />

// 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");
            }
        }
    });
<html>
<head>
<!-- PAGE INFORMATION -->
<title>Eco-Locate</title>
<meta charset="UTF-8" />
<meta name="description" content="Evaluate 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" />
<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/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">
        <ul id="tab_nav" class="nav-collapse">
            <li id="nav_overview" class="nav-active"><a href="javascript:void(0)" id="nav_overview">Overview</a></li>
            <li id="nav_basic"><a href="javascript:void(0)" id="nav_basic">Basic</a></li>
            <li id="nav_advanced"><a href="javascript:void(0)" id="nav_advanced">Advanced</a></li>
            <li id="nav_output"><a href="javascript:void(0)" id="nav_output">Results</a></li>
        </ul>
    </div>
    </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

</script>
Welcome!

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.
<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>

<!-- ELECRICITY SECTION -->
<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>
  </div>
</div>
**HEATING INFORMATION**

---

**NATURAL GAS RATE INPUT**

**Rate for Natural Gas ($USD/therm)**

**Yearly Natural Gas Use (therm)**

---

**TOTAL NATURAL GAS USED IN A YEAR**

---

**TOTAL NATURAL GAS COST IN A YEAR**

---

**FINANCIAL INFORMATION**
<h3>Financial Information</h3>

<!-- PROJECT BUDGET -->
<div class="row">
  <div class="col col-3 pad-top-btm">
    <label>Budget ($USD)</label>
    <input id="budget" type="text" placeholder="$1,000,000.00"></div>
</div>

<form>
  <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;">
  <p id="chart_title" class="title"></p>
</div>

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

<!----- Y Label ----->
<div style="display: block; float: left; width: 20%;">
  <p class="y-label">Solar Irradiance (E_{year}\text{kWh/m}^{2}/yr)\end{equation}</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)\end{equation}</p>
</div>

</div>

</section>

<!----- SECTION #2 - ADVANCED SECTION ------>
<section id="advanced" class="row">
  <div class="header col col-12 bg-pattern-1">
    <div class="contain">
      <div class="col col-12 pad">
        <h2>Advanced Information</h2>
      </div>
    </div>
  </div>
</section>
The following information are general defaults associated with sustainable systems. These values can be refined to better represent your situation. 

Solar PV

- Panel Surface Area (m²)
- DC Rating for a Panel (kW)
- Nominal Operating Cell Temperature or NOCT (°C)
- Cell Efficiency (%)
- Panel Cost ($USD)

These values are required and can be refined to better represent your situation.
There are no parameters yet available for this system.
<!-- 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>
    </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>
  <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>

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

Solar PV

Solar Thermal

CHP

System Capacity

Annual Electricity Generation

Annual Thermal Generation

Installation Cost
* { 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-rl;
    */
@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: 8.33333333333333%;}

.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;
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;
padding-top: 1em !important;
  }

  #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;
}