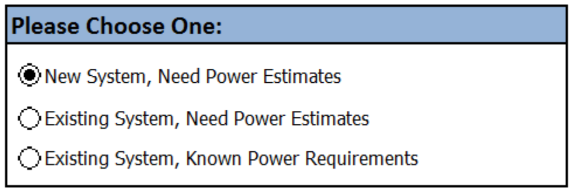
This software can help a user determine if combined heat and power (CHP) is a suitable source of energy for their aquaponics system. The software uses different scenarios for users who have no existing system, or users that have an existing system in place. Additionally, for those who have a system in place the software has a different scenario for those who know the thermal requirements for the system and for those who don't. The users that do not have an existing system the software can also help determine what size of a water pump and aeration pump should be used as well as how much power would be required to artificially light a greenhouse based upon geographical location and required amount of grow time per day.

Summary:

1) Open the Excel file "Test_Structure (Macro-Enabled)"
2) Select the correct scenario
3) Enter in all known parameters
4) Save the file
5) Close the Excel file
6) Open and run "Aquaponics_Energy_Tool.exe"
7) Select the Excel file "Test_Structure (Macro-Enabled)" if prompted to "Find File to Import"
8) Review outputs to determine if combined heat and power is a feasible option as the energy supply system

Open the Excel File "Test Structure (Macro-Enabled)"

Choosing the right scenario:



1: "***New System, Need Power Estimates"***
The first scenario is where no aquaponic system is in place but the user is in the process of building a system. The user is looking to learn more about the thermal and electricity demands of a potential aquaponic system and if combined heat and power (CHP) could be beneficial for that system. On the initial page the user should select "*New system, Need Power Estimates."*

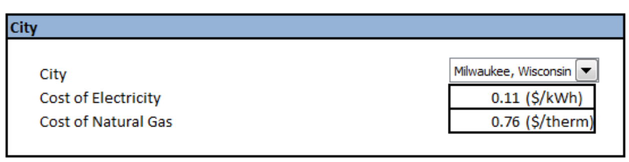
2: ***"Existing System, Need Power Estimates"***
The second scenario is an existing aquaponic system, but none of the thermal or electrical demands are known. The user is looking to find the estimated loads of the existing system and if CHP could be a feasible option for the operation in place. On the initial page the user should select "*Existing System, Need Power Requirements*."

3: ***"Existing System, Known Power Requirements"***
The third scenario is where there is an existing system and the thermal loads of the system are known. The user will input the known loads and the software will determine if CHP could be feasible for the existing system. On the initial page the user should select "*Existing System, Known Power Requirements*."

Entering the known inputs:

Depending upon the scenario selected the user will be asked to enter different inputs to help determine if CHP is a feasible for supplying thermal load to the aquaponic system.

For all three scenarios the following inputs will be asked:



City: For this input the user will select the city in which the aquaponic system is going to be built or where it exists. This helps determine the differing electrical loads determined for possible artificial lighting.

Cost of Electricity/Cost of Natural Gas: For these inputs the user will set the price of both the electricity and natural gas. The prices can be found from the local utility. These help determine the payback period for a possible CHP system.

Environmental	
Average local CO2 emission for electricity generation	610 (g/kWh)
Average national CO2 emission for electricity generation	550 (g/kWh)

Average Local/National CO_2 Emissions for Electricity Generation: For these inputs the user inputs the local and national CO_2 emissions for electricity generation. These help determine the annual amount of CO_2 avoided. The values shown are the current national emissions profiles for the United States and for Milwaukee, WI.

CHP	
Total Purchase and Installation Cost (excluding incentives)	33000 dollars
Total Savings from Incentives	1500 dollars
Total Annual Maintenance Cost	100 dollars
Max Thermal Output Per Unit	12 kW
Max Electrical Output Per Unit	4.7 kW
Generator Efficiency	0.25 out of 1
Heater Efficiency (enter 2 for electric heater)	0.75 out of 1
Number of units	1

Total Purchase and Installation Cost: For this input the total purchase price of the CHP unit(s) is used. Be sure to use the TOTAL price of all units and not the INDIVIDUAL price of a single unit. However, if the user is only interested in one unit, there is no issue. Be sure to exclude any incentives or annual maintenance costs from the total purchase cost, as they are entered separately. The values shown are for the Marathon ecopower CHP system.

Total Savings from Incentives: For this input use any savings acquired from incentives. Any incentive will help lower the payback period for the CHP system(s).

Total Annual Maintenance Cost: For this input include any costs that may be needed to help keep the CHP system(s) in running condition. Costs could come from oil changes, new parts, etc.

Max Thermal Output Per Unit: For this input use the max thermal output per CHP system. If different sized systems are of interest average the thermal output. The max thermal output should be included in a CHP system's specification sheet.

Max Electrical Output per Unit: For this input use the max electrical output per CHP system. If different sized systems are of interest average the electrical output. The electrical output should be included in a CHP system's specification sheet.

Generator Efficiency: For this input use the efficiency of the electrical generator in the CHP system.

Heater Efficiency: For this input, enter the efficiency of the natural gas heater that the CHP system would be replacing or supplementing. Enter a value of 2 if using an electric heater to prompt the software to use the proper analysis type.

Number of Units: For this input use the total number of CHP units being considered.

Tank	
Number of Tanks	1 Tank
Width of Each Tank	4 ft
Length of Each Tank	60 ft
Height of Each Tank	4 ft
Fish Stocking Density	0.5 lb/gal

Tank	
Number of Tanks	1 Tank
Width of Each Tank	4 ft
Length of Each Tank	96 ft
Height of Each Tank	4 ft
Flow rate to grow bed	110 gpm

Number of Tanks: For this input use the number of tanks being considered in the aquaponic system to be coupled with the CHP system.

Width of Each Tank: For this input use the width of each tank in the aquaponic system. If the widths of the tanks are different, average the widths of all the tanks being used.

Length of Each Tank: For this input use the length of each tank in the aquaponic system. If the lengths of the tanks are different, average the length of all tanks being used.

Height of Each Tank: For this input use the height of each tank in the aquaponic system. If the heights of the tanks are different, average the height of all the tanks being used.

Fish Stocking Density: For this input use the stocking density of the fish being used. This is applicable in only scenario 1 where there is no aquaponic system in existence.

Flow Rate to Grow Bed: For this input use the flow rate of the water circulating between the fish tank and grow bed. This is only applicable in scenarios where an aquaponic system is already in existence.

<u>The following input is used only in scenario 1 and 2.</u>

Tank and Weather Information

Input the expected green house conditions and tank water temperature.

	Indoor Ambient Temperature	Water Temperature	Relative Humidity
January	60 F	71.5 F	45 %
February	60 F	71.5 F	45 %
March	60 F	71.5 F	45 %
April	60 F	71.5 F	45 %
May	65 F	71.5 F	45 %
June	70 F	71.5 F	45 %
July	80 F	71.5 F	45 %
August	80 F	71.5 F	45 %
September	75 F	71.5 F	45 %
October	60 F	71.5 F	45 %
November	60 F	71.5 F	45 %
December	60 F	71.5 F	45 %
Estimated temperature Drop over Grow Bed	0.5 F		

Tank and Weather Information: For these inputs the monthly greenhouse indoor temperature, relative humidity, and the fish tank water temperature are used. Additionally, the estimated temperature drop over the grow bed is used. This helps determine the amount of thermal load existing in the aquaponic system.

<u>The following inputs are used only in scenario 1 "New System, Need Power Estimates."</u>

Plumbing Information	
Number of elbows	2
Number of tees	0
Pipe diameter	3 in
Height difference between grow bed and tank	8 ft
Aeration Blower efficiency	0.64 out of 1
Water Pump Efficiency	0.45 out of 1

Number of Elbows: For this input the number of elbows used in the piping starting from the pump and ending in the grow bed are used.

Number of Tees: For this input the number of tees used in the piping starting from the pump and ending in the grow bed are used.

Pipe Diameter: For this input the diameter of the pipe in the piping from the fish tank to the grow bed is used.

Height Difference between Grow Bed and Tank: For this input the height difference between the pump and the grow bed is used.

Aeration Blower Efficiency: For this input the efficiency of the aeration blower is used. If the efficiency of the blower is 64% use 0.64.

Water Pump Efficiency: For this input the efficiency of the water pump is used. If the efficiency of the water pump is 45% use 0.45.

Artificial Lighting	
Grow Area per kW	50 ft^2/kW
Desired Grow Time per Day	18 hr/day

Grow Area per kW: For this input the lighting coverage of the artificial lighting is used. The grow area per kW can be found from the lighting specifications.

Desired Grow Time per Day: For this input the desired amount of time that the plants will be under actual or simulated sunlight is used.

<u>The following inputs are used only in scenario 3, “Existing System, Known Power Estimates.”</u>

Thermal Load	
If known, the thermal load is entered for each month.	
January	12 kW
February	12 kW
March	12 kW
April	6 kW
May	3 kW
June	0 kW
July	0 kW
August	3 kW
September	6 kW
October	12 kW
November	12 kW
December	12 kW

Thermal Load: Since the thermal loads are known in this scenario, the monthly required thermal loads for the aquaponic system are used.

<u>After the known inputs are entered:</u>

1) Save the Excel file

It is necessary that the user now saves the document in order to update all the parameters. All that is necessary is to press the “Save” key. Be sure not to” Save As”, but to simply save over the existing file without changing the file name.

2) Exit the Excel program

Once the file has been saved, close the Excel program completely. The excel program will be re-opened by the following software.

3) Open and run Aquaponics_Energy_Tool.exe

Double click on the executable file after the Excel file is closed.

4) Select the Excel file “Test_Structure (Macro-Enabled)”

The program may ask the user to “Find File to Import”. Select the Excel file saved earlier titled “Test_Structure (Macro-Enabled).” The program will continue to run and will re-open the Excel file when the analysis is complete.

5) Scroll through and review outputs

Once the Excel file has been re-opened be sure to scroll through to see the desired outputs. The initial inputs will be available for viewing as well in case the user forgot what was entered. The type of outputs can be seen and described in the following section.

Reviewing the outputs:

The following parameters are found in the outputs for all three scenarios.

CHP System Output Totals	
Annual Electric:	38676.7 kWh
Annual Thermal:	98749.02 kWh
Annual Benefit:	3557 $
Simple Payback:	8.9 Years
Annual CO2 avoided nationally:	16724 kg
Annual CO2 avoided locally:	19044 kg

Annual Electric: This output shows the total annual amount of electricity generated by the CHP system(s).

Annual Thermal: This output shows the total annual amount of thermal energy supplied to the fish tanks by the CHP system(s).

Annual Benefit: This output shows the amount of dollars saved each year by using a CHP system in combination with the aquaponic system.

Simple Payback: This output shows the simple payback period of the CHP system(s), or the time period in which the CHP system(s) will pay itself off.

Annual CO_2 Avoided Nationally: This output shows the annual amount of CO_2 avoided in comparison to the national statistic.

Annual CO_2 Avoided Locally: This output shows the annual amount of CO_2 avoided in comparison to the local statistic.

The following parameters are found in the outputs for only scenario 1 and 2.

Thermal Load Estimates and CHP Capabilities

	Provided	Required	Units
January	3.0	3.0	kW
February	3.0	3.0	kW
March	3.0	3.0	kW
April	3.0	3.0	kW
May	2.8	2.8	kW
June	2.7	2.7	kW
July	2.4	2.4	kW
August	2.4	2.4	kW
September	2.5	2.5	kW
October	3.0	3.0	kW
November	3.0	3.0	kW
December	3.0	3.0	kW

Thermal Load Estimates and CHP Capabilities: This output shows the amount of monthly thermal load required by the aquaponics system and the monthly thermal load provided by the CHP system(s). The provided load will only be as high as the required load.

-The following parameters are found in the outputs for only scenario 1.

Grow Bed Sizing Estimates	
Grow Bed Area:	1968 ft^2
Grow Bed Depth:	1.0 ft
Flow Rate:	85 GPM

Grow Bed Area: This output shows the recommended amount of surface area for the grow bed.

Grow Bed Depth: This output shows the recommended amount of grow bed depth in combination with the grow bed surface area.

Flow Rate: This output shows the recommended flow rate of the water through the piping that connects the grow bed to the fish tanks.

Pumping and Aeration Estimates	
Pumping:	0.414 Hp
Aeration:	0.945 Hp

Pumping: This output shows the recommended power for a water pump to be used in the piping. It will not return a standard value for a pump.

Aeration: This output shows the recommended power for an aeration blower to be used in the fish tank. It will not return a standard value for a blower.

Monthly Artificial Lighting Load Estimates		
January	16456	kWh
February	13858	kWh
March	14685	kWh
April	11338	kWh
May	11102	kWh
June	9252	kWh
July	9330	kWh
August	10905	kWh
September	12795	kWh
October	14960	kWh
November	16810	kWh
December	17834	kWh

Monthly Artificial Lighting Load Estimates: This output shows the amount of supplemental lighting will be required if you choose to use artificial lighting based upon the geographical location and the selected hours of grow time.