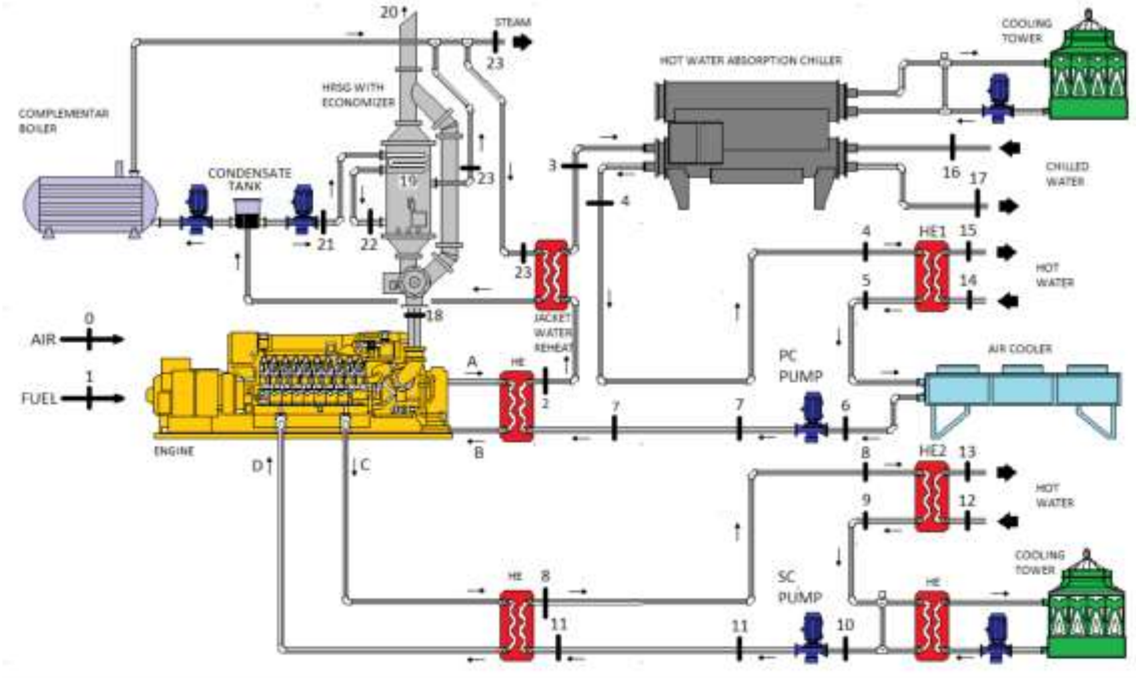
Sisterm
Thermal Systems

COGMCI

INTERNAL COMBUSTION ENGINE COGENERATION / TRIGENERATION SOFTWARE



VERSION 1.1a – JULY 2020

Campinas – São Paulo - Brasil

COGMCI is a software developed by Sisterm Thermal Systems – Campinas – SP - Brazil
www.sisterm.com.br sisterm@sisterm.com.br Phone: +55 (19) 3579-1505

COGMCI Software – Engine Cogeneration / Trigeneration

Start Guide

Content

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HELP RESOURCES

The purpose of this manual is to introduce the user to the capabilities of the COGMCI Software.

Training can be arranged as a “live webinar” or a “site training”.

Send us an e-mail to make part of our “user group list”: cogmci@sisterm.com.br

Topic Help: explained at this manual.

E-mail Based Help: cogmci@sisterm.com.br

Additional help: please check all the documents on the documents directory

C:/COGCMIVer1/Documents

COGMCI System Solutions contact information:

Phone: +55 (19) 3579-1505

Author: Dr. Denilson Boschiero do Espirito Santo

Sisterm Thermal System – principal

Campinas - São Paulo - Brazil

INTRODUCTION

What is COGMCI Software?

COGMCI Software is a dynamic evaluator software, that assists designers and suppliers of internal combustion engine cogeneration / trigeneration system to develop high efficiency solutions.

COGMCI System Solutions (*knowledge of energy systems and their design required*).

Although this software includes default values entered at each data input field, a fundamental knowledge of energy systems and specially in engine COGENERATION / TRIGENERATION systems is required for the proper application of the software.

COGMCI Software Project Files

Several energy profiles can be crated and saved at a single file – cmidat file.

A file that summarizes all your project inputs can be saved – cmi file.

COGMCI Software files may be saved for reference, shared for review and stored in a library for use on future projects.

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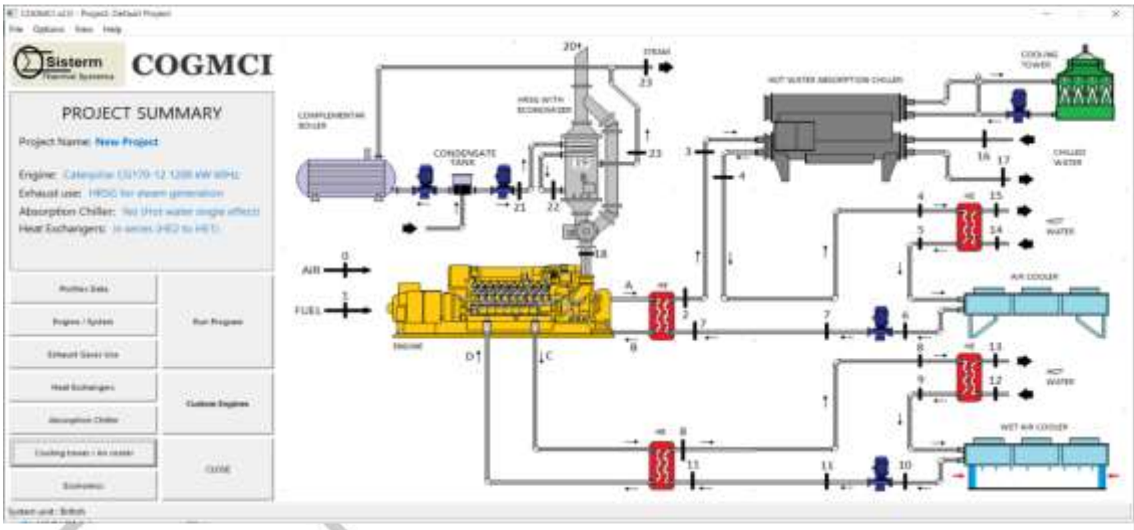
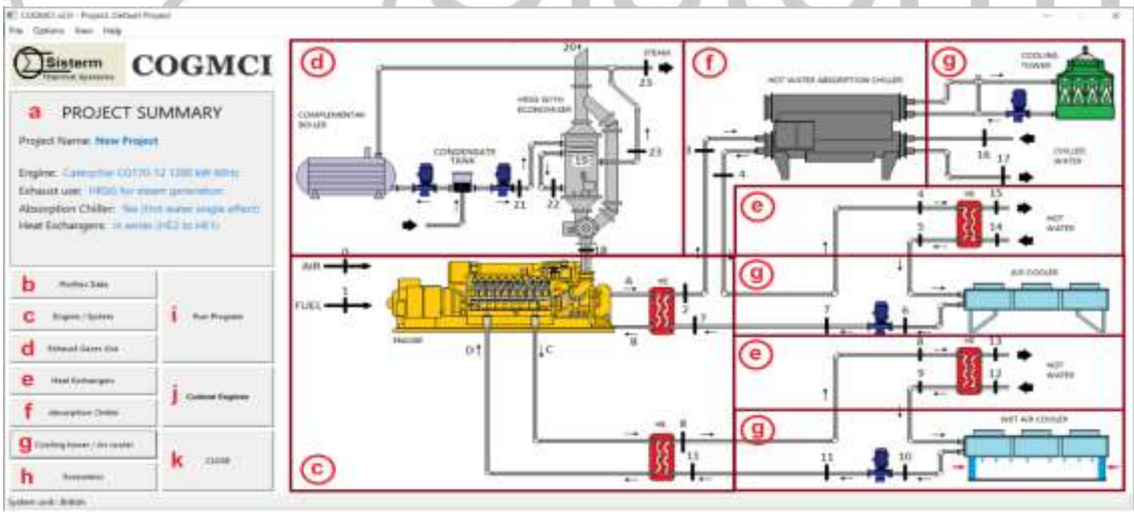
COGMCI MAIN SCREEN



The MAIN screen shows an overall arrangement of the COGMCI operation window. On the screen right side a visual setup of the current system and on the left the input data buttons of each part of the cogeneration system. The screen is divided as follow:



a) PROJECT SUMMARY

It's a summary of the system in use (being designed).It shows the selected engine, the exhaust gas use, if there is an absorption chiller and heat exchangers.

PROJECT SUMMARY

Project Name: **New Project**

Engine: Generic Aspirated engine 1

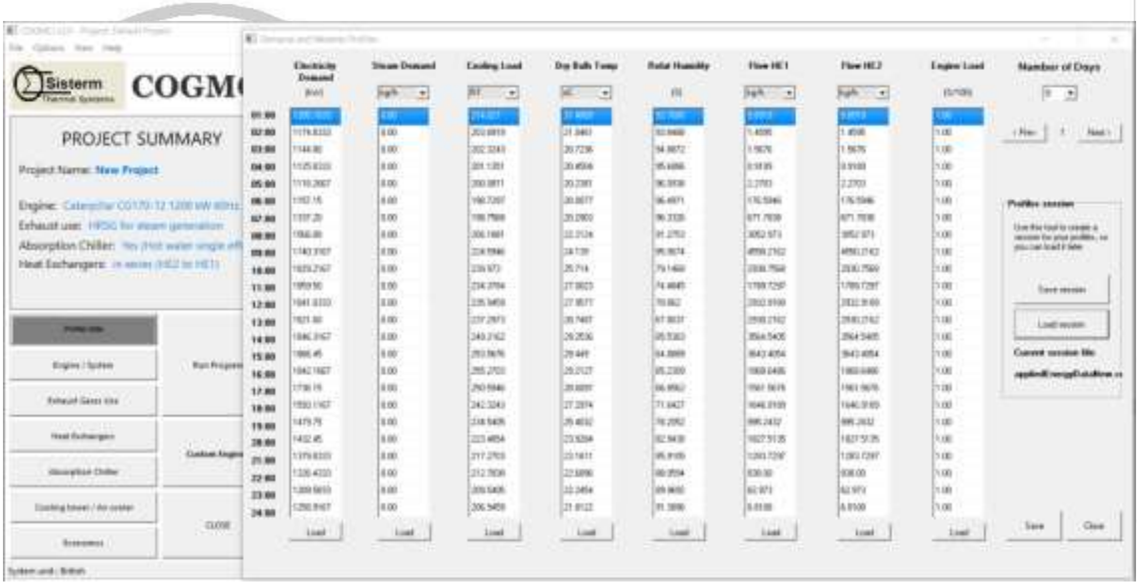
Exhaust use: HRSG for steam generation

Absorption Chiller: Yes (Hot water single effect)

Heat Exchangers: in series (HE2 to HE1)

b) PROFILES DATA

The PROFILE DATA BUTTON open the PROFILE DATA UPLOAD SCREEN, it is used to upload the energy demands of the cogeneration system.



The PROFILE DATA SCREEN is used to enter or upload the necessary energy profiles and weather profiles data that will be used for the simulation. The following profiles should be defined:

ENERGY PROFILES:

- **Electricity Demand:** Site electricity demand profile.
- **Steam Demand:** Site steam demand profile.
- **Cooling Load:** Site air conditioning cooling load.
- **Heat Exchanger 1 Flow (HE1):** First hot water demand (medium temperature).
- **Heat Exchanger 2 Flow (HE2):** Second hot water demand (low temperature).

CLIMATIC PROFILE:

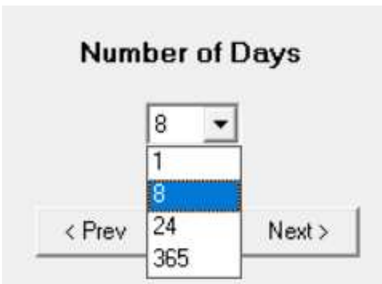
- **Dry Bulb Temperature:** site dry bulb temperature profile.
- **Relative Humidity:** site relative humidity profile.

OPERATIONAL PROFILE

- **Engine load profile:** defines the engine load, enable the user to defines a reduced engine load for some simulating hours.

The above profiles can be saved at a project directory folder (data base – *.cmidat file), and be uploaded to the software again reducing the data input time.

1. Setup the simulation number of days:



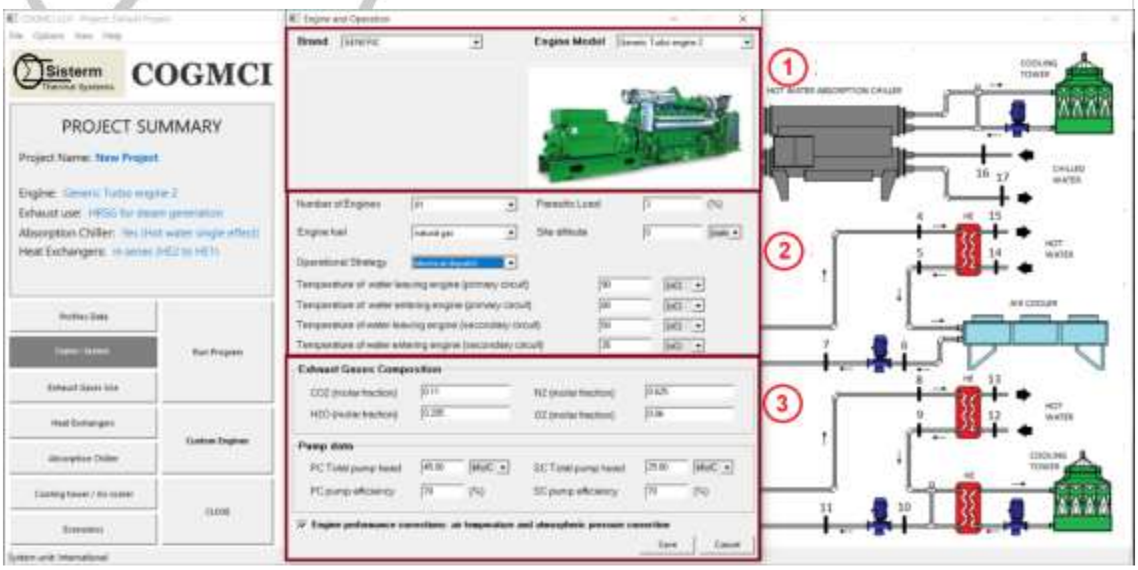
1: Single day profile.
8: Two profiles for each weather season (average weekdays and weekends).
24: Two profiles for each month of the year (average weekdays and weekends)
365: One profile for every day of the year.

2. Load Single Profile data:
   Allows uploading a single type of data profile, data files must but saved and edited in an Excel format file that is provided with the COGMCI software.
   The data file input needs to be compatible with the simulation number of days.
   All energy demand and climatic profiles should be uploaded to run a simulation analysis.
   Energy demand and climatic profiles are not necessary in the design analysis.

3. Save Session and Load Session Buttons:
   Enable saving the energy and weather profiles previously uploaded to the system creating a *.cmidat save file of all 8 profiles. The *.cmidat files allow a fast upload of the data and use it for other simulations / studies.

4. Save and Close Button
   Saves the data profiles on the program and exit PROFILE DATA window to MAIN WINDOW

c) ENGINE / SYSTEM



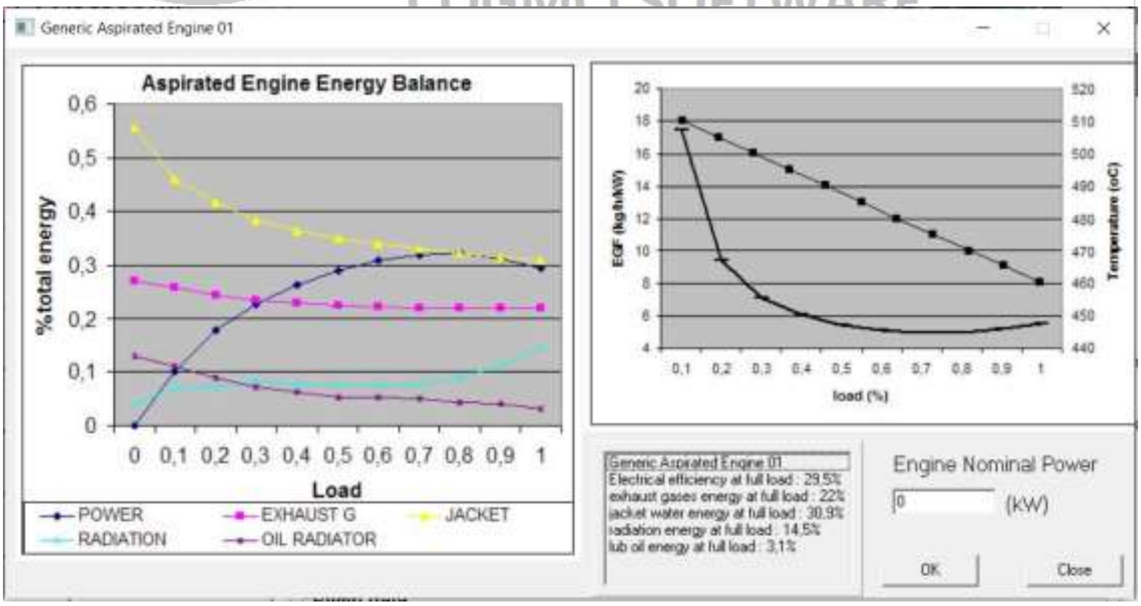
BRAND and MODEL selection:

Select the **brand** and **model** of the engine with the dropdown list.

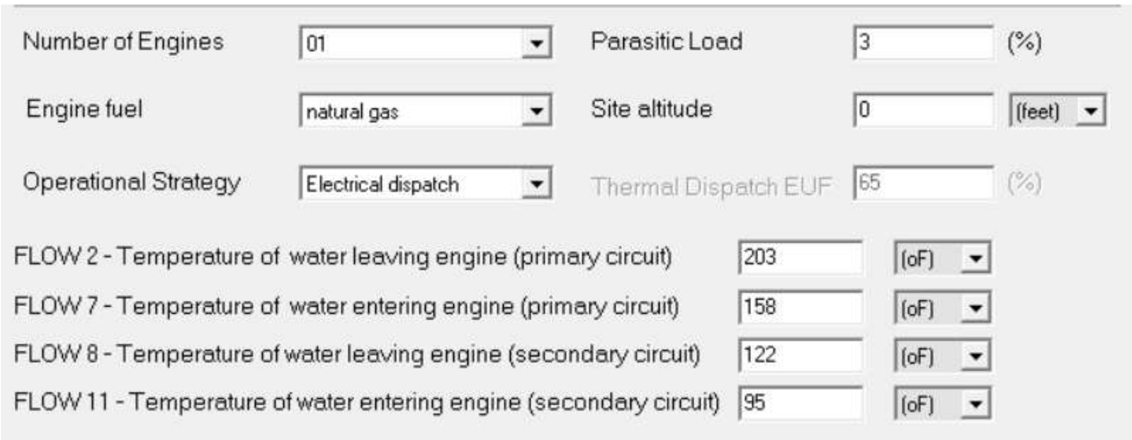
A limited number of commercial engines are available.

When selecting the GENERIC Engine Models, a new window with the engine energy balance and exhaust gas temperature and flow is open. The engine nominal power should be defined by the user. Three different generic engines are available.

COGMCI also allows the user to build their own engines performance curves. These engines are called "Custom Engines". The user can talk with their engine supplier, ask for the engine performance data (full load and part load), built the engine performance curves (polynomial regression), feed the software COGMCI and simulate the system utilizing real engine performance curves. Natural gas, diesel or biofuels chemical composition can affect the engine performance. Check the "custom engine section" for more information.



2. SYSTEM and ENGINE definitions.



Number of engines: define the number of engines that makes part of the cogeneration system. Two or three engine systems are simulated as two/three individual cogeneration / trigeneration system operating in parallel mode and supplying the utilities to the building / process.
In multiple engine system, the engines can be turned on and off if the system operates at electric dispatch and the hourly electricity demand is lower than the engines power.

Parasitic load: indicates the percentage of the engine power output that is used at the cogeneration / trigeneration auxiliary systems (motors, pumps, fan, cooling tower, etc).

Engine fuel: choose the fuel that is used by the engine.
Three options are available: i) natural gas, (ii) diesel or (iii) biogas.

Site altitude: define the site altitude where the cogeneration / trigeneration system is being planned to be constructed. This data can be used to correct the engine power output.

Operational strategy: define the operational strategy of the cogeneration system. Two possibilities are available:

- Electrical dispatch: at this mode the engine will follow the electricity demand profile. Electricity is transferred to the grid if the minimum engine load is achieved and surplus electricity is bought from the grid if the demand is higher than the engine power.
- Full Load: the engine operates at full load all the time, exchanging electricity with the grid accordingly with the hourly demand and power production.
- Thermal dispatch: the engine will operate at electrical dispatch while your defined minimal EUF is achieved. If the calculated EUF is lower then the defined, the engine will reduce the load trying to reach the defined EUF.
  RELEASED AT DECEMBER 2019.

Thermal dispatch EUF: define the minimal EUF for the thermal dispatch operation mode.

Temperature of water leaving the engine (primary circuit): define the temperature of water leaving the engine jacket. (Flow 2).

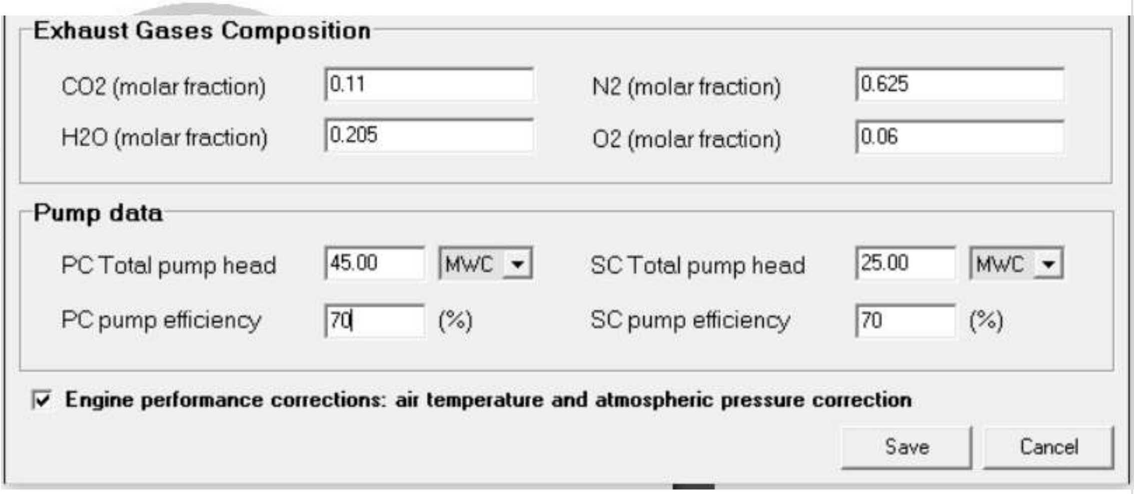
This data is normally defined by the engine manufacturer.

Temperature of water entering the engine (primary circuit): define the temperature of water entering the engine jacket. (Flow 7)
This data is normally defined by the engine manufacturer.

Temperature of water leaving the engine (secondary circuit): define the water temperature leaving the oil radiator and/or intercooler(s). (Flow 8)
This data is normally defined by the engine manufacturer.

Temperature of water entering the engine (secondary circuit): define the water temperature entering the oil radiator and/or intercooler(s). (Flow 11)
This data is normally defined by the engine manufacturer.

3. Exhaust Gas Composition and Pump Configuration:

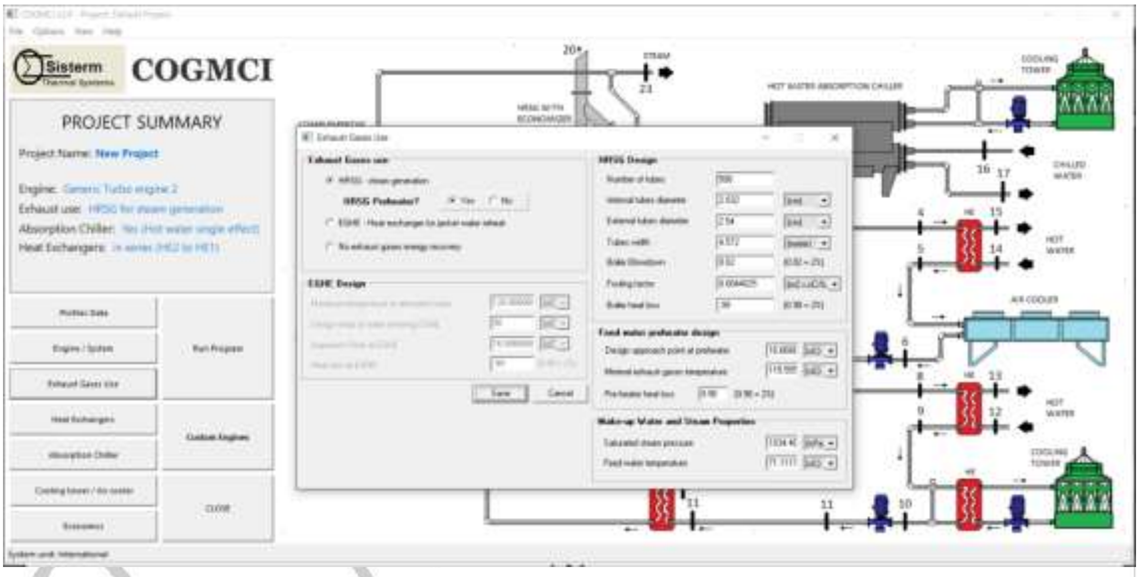


Exhaust gas composition: define the exhaust gas composition, considering a mixture of ideal gases composed of: N2, O2, CO2 and H20 – molar fraction.

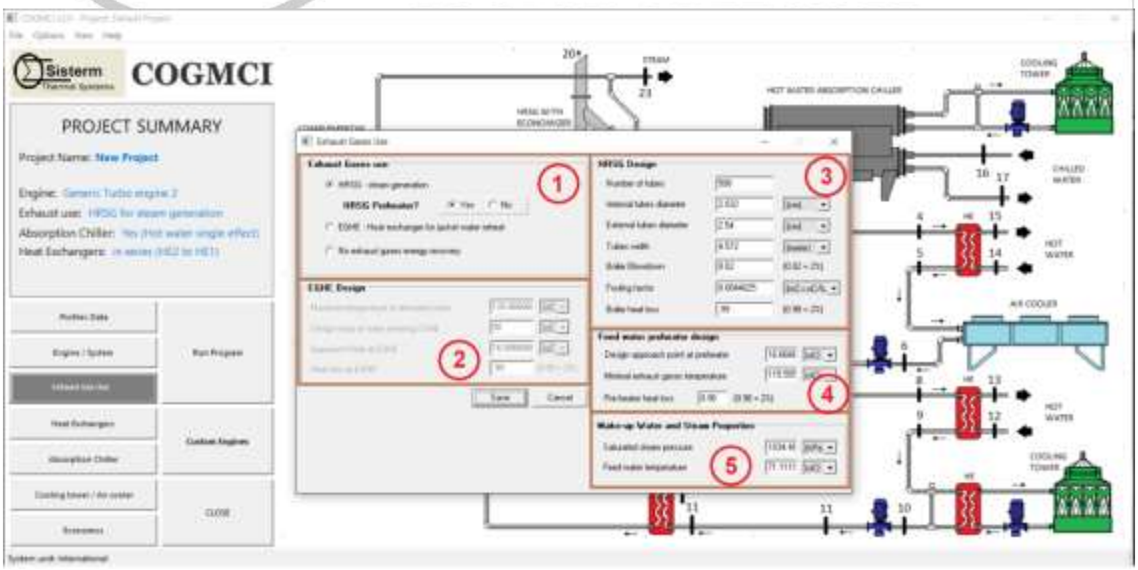
Pump Configuration: define engine primary and secondary circuits the pumps pressure drop and total efficiency (mechanical x electrical).

- PC total pump head: Defines primary circuit pump pressure.
- PC pump efficiency: Defines primary circuit pump efficiency.
- SC Total Pump head: Defines secondary circuit pump pressure
- SC pump efficiency: Defines secondary circuit pump efficiency.
- Engine performance corrections: mark this field is you want COGMCI software to correct the engine performance due to site high ambient dry bulb temperature and altitude.

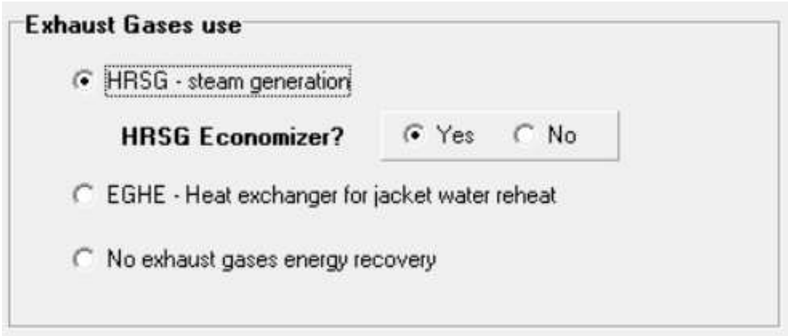
d) EXHAUST GASES USE



Select the use and configuration for the exhaust gas use, the screen is divided in 5 parts as follow:



1. EXHAUST GASES USE



HRSG for steam generator: the engine exhaust gases energy is used to produce saturated steam at a heat recovery steam generator (HRSG).

HRSG Economizer: define if the HRSG feed water economizer should or should not be used.

Heat exchanger for jacket water reheat: the engine exhaust gases energy is recovered at the exhaust gas heat exchanger (EGHE) to reheat the engine primary circuit water.

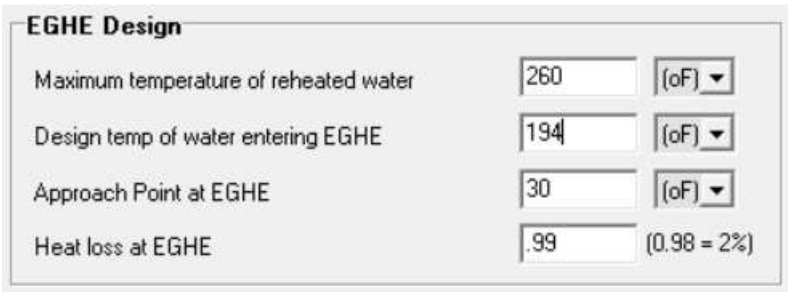
No exhaust gases recovery of energy: at this option no engine exhaust gas energy recovery is assumed. It means the engine exhaust gas is discharged directly to the atmosphere.

- Use this option if EXHAUST GAS AND HOT WATER ABSORPIOTN CHILLER is to be selected in the ABSORPTION CHILLER screen.

2. EXHAUST GAS HEAT EXCHANGER DESIGN (EGHE DESIGN)

(Only available if heat exchangers for jacket water reheat was selected).

The EGHE design and simulation is performed using UA equations, it means that the complete design is not developed. The COGMCI software will design an EGHE based on your defined design data and an EGHE simulation model is used when the engine operates at part load.



Maximum temperature of reheated water: define the maximum temperature of the water leaving the exhaust gas heat exchanger (EGHE).

Although the water temperature leaving the EGHE (flow 3) is calculated by the software by means of thermodynamic properties of primary circuit temperatures (ENGINE / SYSTEM screen) and the engine exhaust gas mass flow and temperature, this value limits the maximum hot water temperature leaving the EGHE.

Design temperature of water entering EGHE: define the temperature of water entering EGHE. Normally it is the same temperature of water leaving the engine at the primary circuit (flow 2).

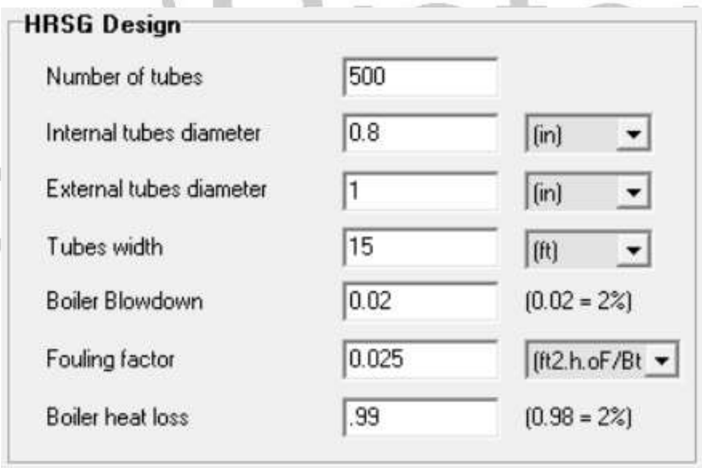
Approach Point at EGHE: define the approach point at the exhaust gases heat exchanger (EGHE). The approach point is the difference between the water temperature entering the EGHE (flow 2) and the exhaust gas leaving the EGHE (flow 20).

Heat loss at EGHE: define the EGHE energy loss (heat transfer to the surroundings).

3. HRSG DESIGN – Heat recovery steam generator.

The HRSG design and simulation is performed using UA equations and design parameters (detailed design), it means that the complete design is developed. The COGMCI software user needs to define physical characteristics of the HRSG. The defined design data and the simulation model is used when the engine operates at part load.

A single pass (exhaust gases) is designed / simulated.



Number of tubes: define the number of tubes of the HRSG. The exhaust gas mass flow is divided by the number of tubes.

Internal tubes diameter: define the internal diameter of the tubes utilized in the HRSG construction.

External tubes diameter: define the external diameter of the tubes utilized in the HRSG construction.

Tubes width: define the width of the tubes utilized in the HRSG construction.

Boiler blowdown: define the expected HRSG blowdown.

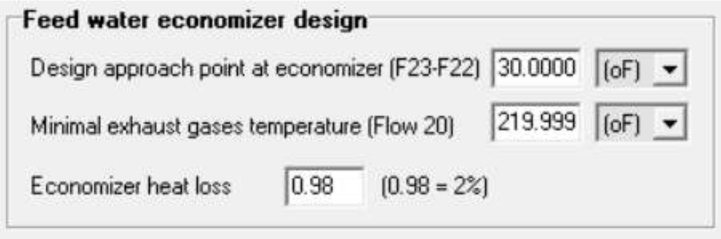
Fouling Factor: define the fouling factor at the gas side at the HRSG. Fouling factor only influences the flue gas pressure drop in the HRSG.

HRSG heat loss: inform the HRSG heat loss to the surroundings (HRSG external surface).

4. HRSG FEED WATER ECONOMIZER DESIGN

(Only when HRSG Steam generator is selected)

The HRSG economizer design and simulation is performed using UA equations, it means that the complete design is not developed. The COGMCI software will design a HRSG economizer based on your defined design data and the simulation model is used when the engine operates at part load or an exhaust gas by-pass is performed.



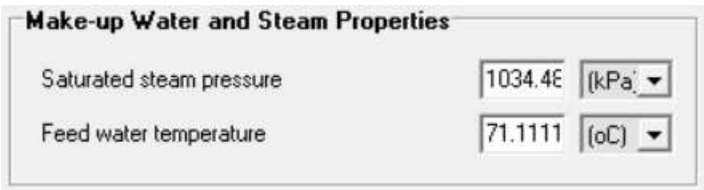
Design approach point at economizer: define the approach point at the HRSG Economizer. The economizer approach point is the temperature difference between the saturated steam (flow 23) and the water leaving the economizer (flow 22).

Minimal exhaust gases temperature: define the minimal admissible temperature for the exhaust gases leaving the economizer.

Economizer heat loss: define the heat loss at the economizer body.

5. MAKE UP WATER AND STEAM PROPERTIES

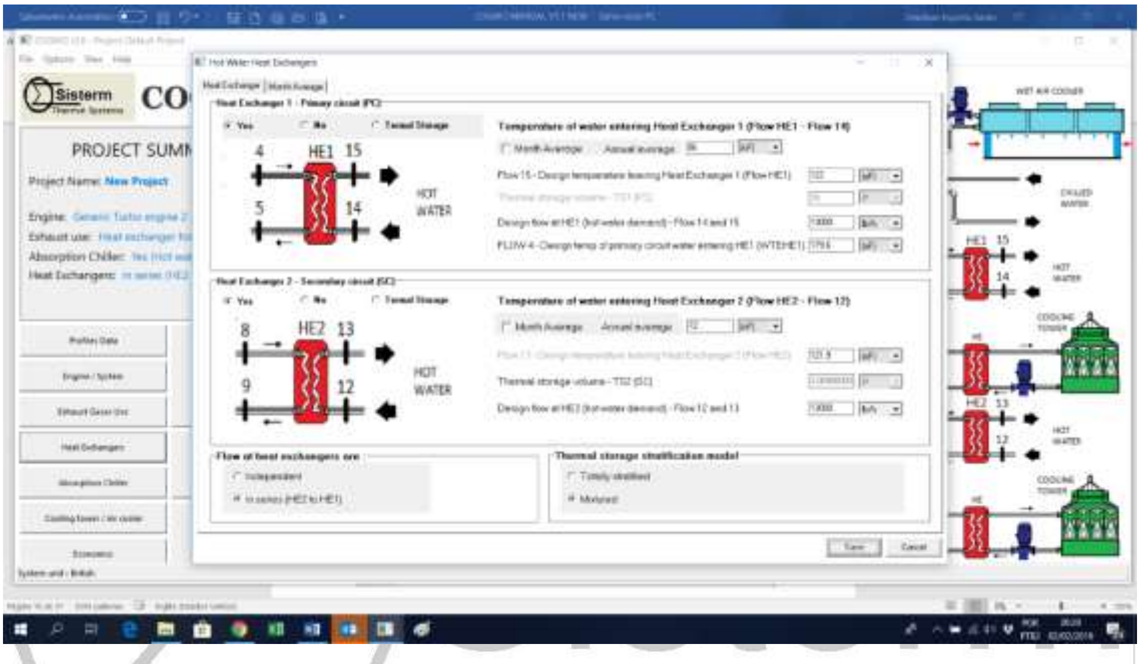
(Only when HRSG Steam generator is selected)



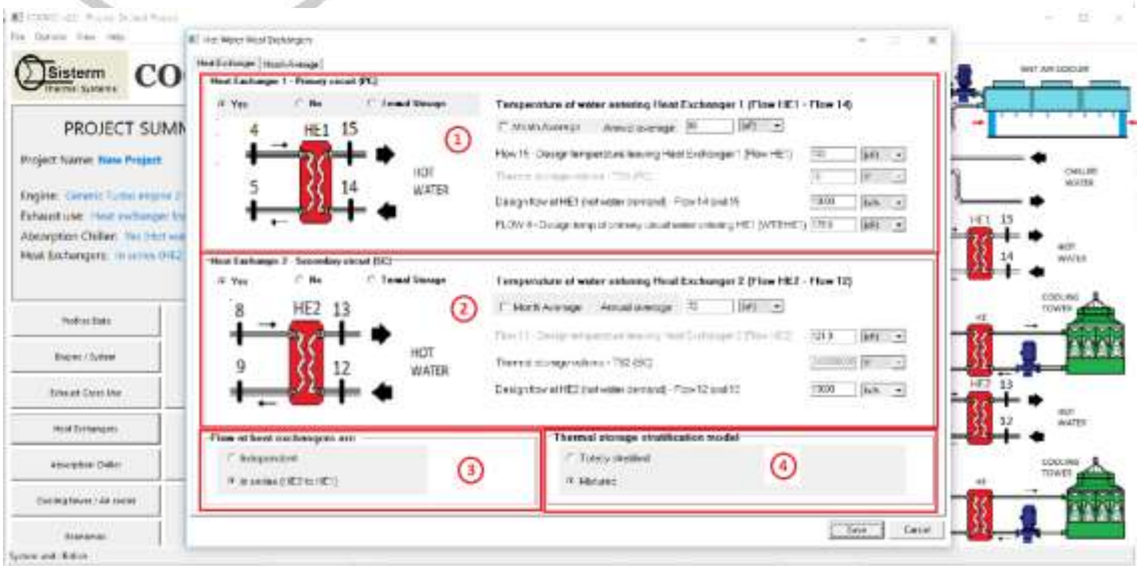
Saturated steam pressure: define the desired steam pressure.

Make-up water temperature: define the HRSG/economizer make-up water temperature.

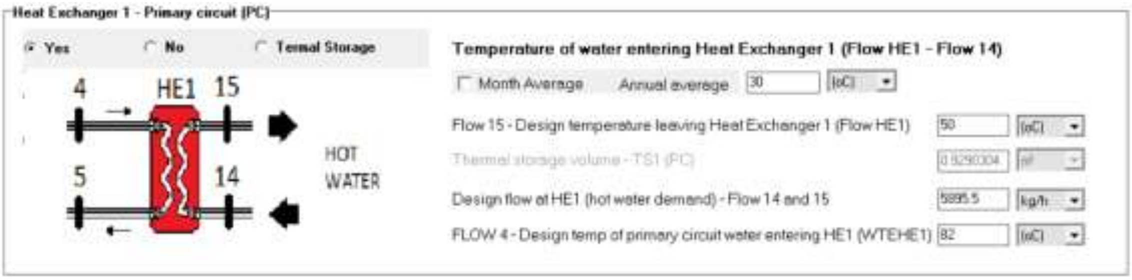
e) HEAT EXCHANGER SCREEN



At the heat exchangers screen the design of the heat exchangers 1 and 2 are defined.



1. For HE1 the following information should be defined:



HE1: Heat Exchanger 1

Checking box:

HE1 EXIST – YES / NO / THERMAL STORAGE

Temperature of water entering heat exchanger 1 (Flow 14): Define the temperature of the process Hot Water entering the HEAT EXCHANGER 1 (HE1). This value is used to design the HE1 and will affect HE1 simulation.

If the month average box is unchecked, then this same temperature will be used in all simulation hours.

If the month average box is checked, then the software will assume different water temperatures entering HE1. These temperatures are defined in the “MAKE-UP / RETURN HOT WATER TEMPERATURE PROFILE SCREEN” a tab screen of the “HEAT EXCHANGER SCREEN”.

For 8 days analysis the COGMCI software uses the first eight data of the HE1 month average value.

For 24 days analysis the COGMCI software uses the HE1 month average data.

Day 1 and 2 – January
Day 3 and 4 – February
.
Day 23 and 24 - December

For 365 days analysis – the HE1 average month value is used at the corresponding month.

Design temperature leaving Heat Exchanger 1 (Flow 15): Define the temperature of the process hot water demand (Flow 15 – HE1 column at the Profiles Screen). This temperature is also used to calculate the hot water demand energy.

Thermal storage volume TS1 (PC) - define the tank storage volume for the engine primary circuit.

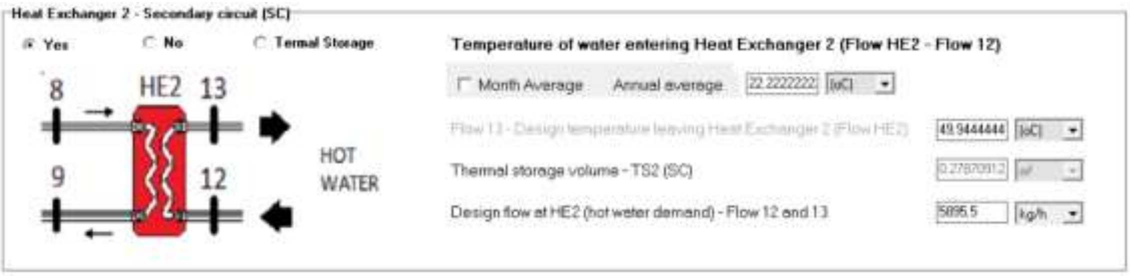
UNDER CONSTRUCTION – NOT YET AVAILABLE

Design flow at HE1: Define the hot water flow used to design the HE1 when utilizing the NTU method. (Flow 14 and 15). This value is used to design the HE1 and will affect HE1 simulation.

Design temperature of primary circuit water entering HE1 (Flow 4): define the temperature of the primary circuit water entering HE1. This data is used at the HE1 design when utilizing the NTU method. This value is used to design the HE1 and will affect HE1 simulation.

Since the primary circuit hot water flow (flow 4) temperature entering HE1 can change in an annual analysis the chilled water demand (absorption chiller energy recovery) is variable. The software gives the user a possibility to define this temperature, allowing for reduced or improved heat exchanger area.

2. For HE2 the following information should be defined:



HE2: Heat Exchanger 2

Checking box:

HE2 EXIST – YES / NO / THERMAL STORAGE

Temperature of water entering heat exchanger 2 (Flow 12): define the temperature of the process hot water entering the HEAT EXCHANGER 2 (HE2). This value is used to design the HE2 and will affect HE2 simulation.
If the month average box is unchecked, then this same temperature will be used in all simulation hours.
If the month average box is checked, then the software will assume different water temperatures entering HE2. These temperatures are defined in the “MAKE-UP / RETURN HOT WATER TEMPERATURE PROFILE SCREEN” a tab screen of the “HEAT EXCHANGER SCREEN”.
For 8 days analysis the COGMCI software uses the first eight data of the HE2 month average value.
For 24 days analysis the COGMCI software uses the HE2 month average data.

Day 1 and 2 – January
Day 3 and 4 – February
.
Day 23 and 24 - December

For 365 days analysis – the HE2 average month value is used at the corresponding month.

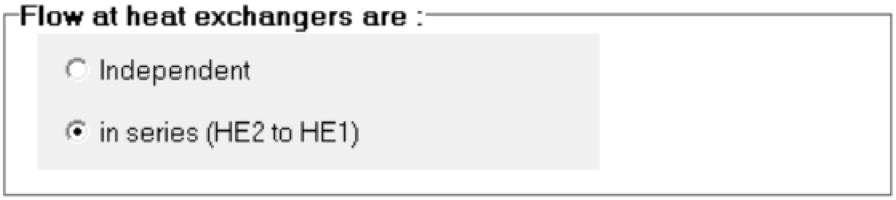
Design temperature leaving Heat Exchanger 2 (flow 13): Define the temperature of the process hot water demand (flow 13 - HE2 column at the Profiles Screen). This temperature is also used to calculate the hot water demand energy.

Thermal storage volume TS2 (SC) - define the tank storage volume for the engine secondary circuit.

UNDER CONSTRUCTION – NOT YET AVAILABLE

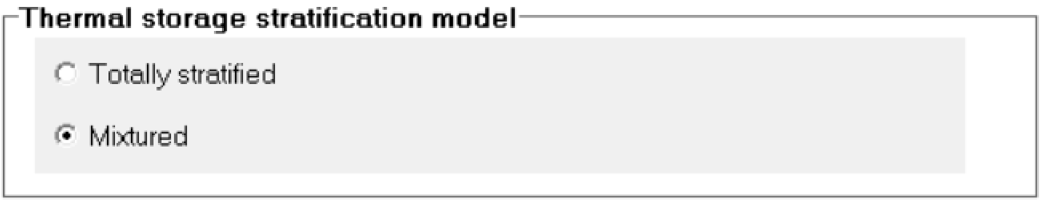
Design flow at HE2: Define the hot water flow used to design HE2 when utilizing the NTU method. (Flow 12 and 13). This value is used to design the HE2 and will affect HE2 simulation.

3. Select the arrangement of HEAT EXCHANGERS 1 and 2



- Independent: Each Heat Exchanger is used for separated HOT WATER processes. At heat exchanger 2 flow 12 is heated using the engine secondary circuit energy, the hot water demand is defined at the HE2 column flow in the Profiles Screen. At heat exchanger 1 flow 14 is heated using the engine primary circuit energy, the hot water demand is defined at the HE1 column flow in the Profiles Screen.
- In Series (HE2 to HE1): The HEAT EXCHANGERS are used for the same HOT WATER demand. Hot water leaves HE2 and enters HE1 (Flow 13 = Flow 14). At this option the HE2 column flow (Profiles Screen) is used.

4. Two methods can be utilized to simulate the performance of the hot water storage tanks:



1) totally stratified: no mixture between the storage tank layers
2) Mixtured: a mixture between the storage tank layers occurs.

5. MAKE-UP / RETURN HOT WATER TEMPERATURE PROFILES

At the second tab of this screen the user can define different water temperatures entering HE1 (flow 14) and HE2 (flow 12).

When using the COGMCI software to develop annual simulation analysis the site weather profiles may influence the make-up water temperature entering the HEAT EXCHANGERS. At this screen the software allows the user to define different make-up / return water temperatures entering HE1 and HE2 (FLOW 12 and FLOW 14). The software uses month average values.

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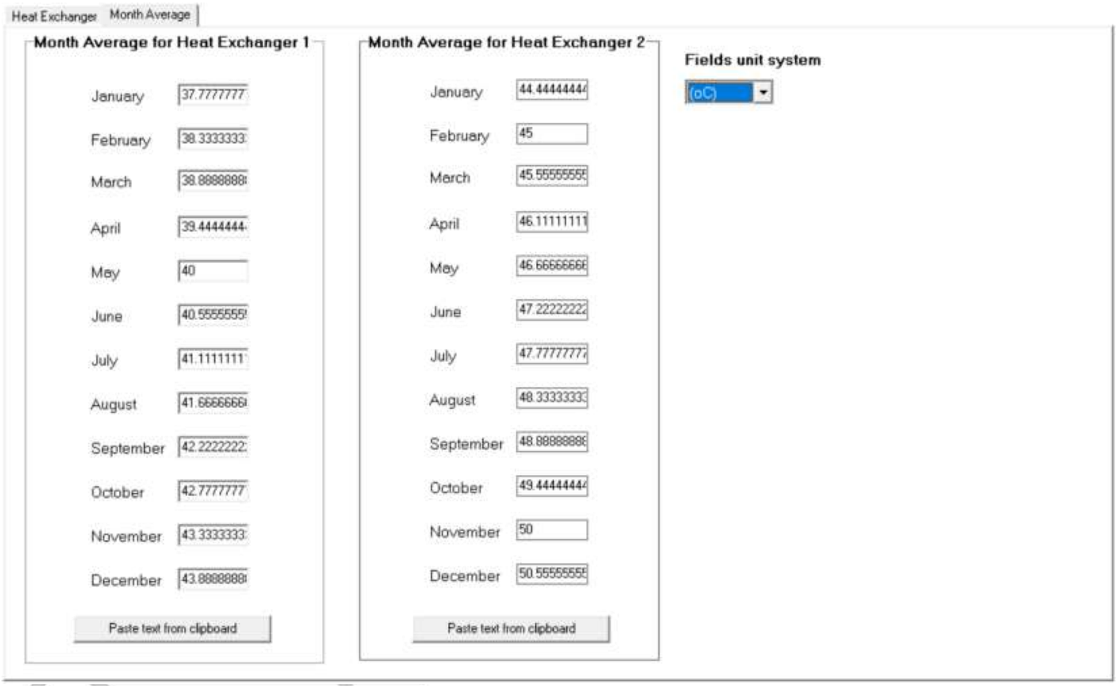
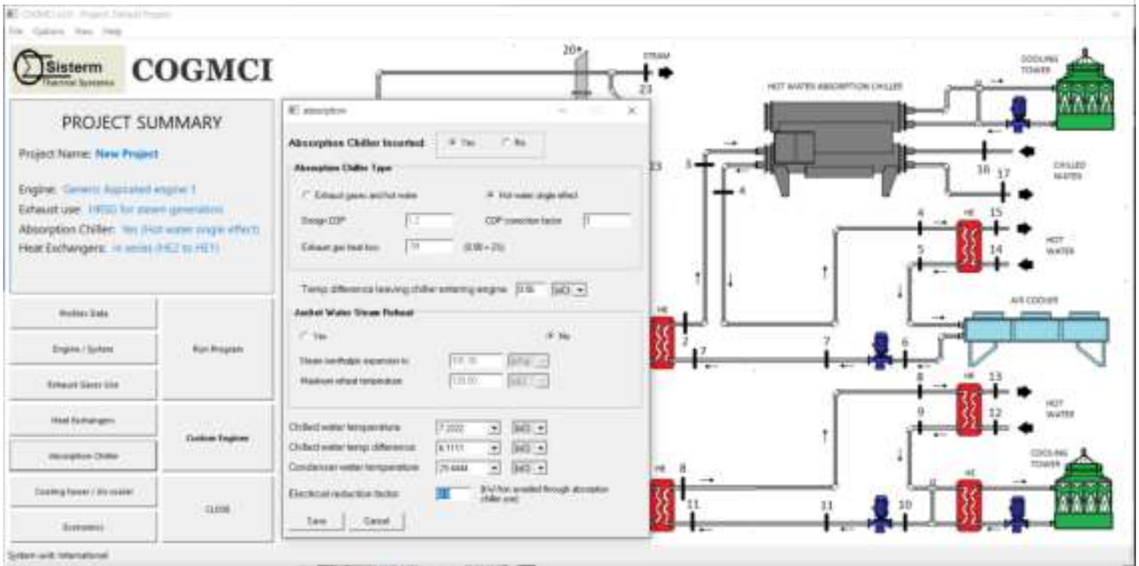


The use of monthly average make-up / return temperatures for HE1 and HE2 can be set at the HEAT EXCHANGER screen.

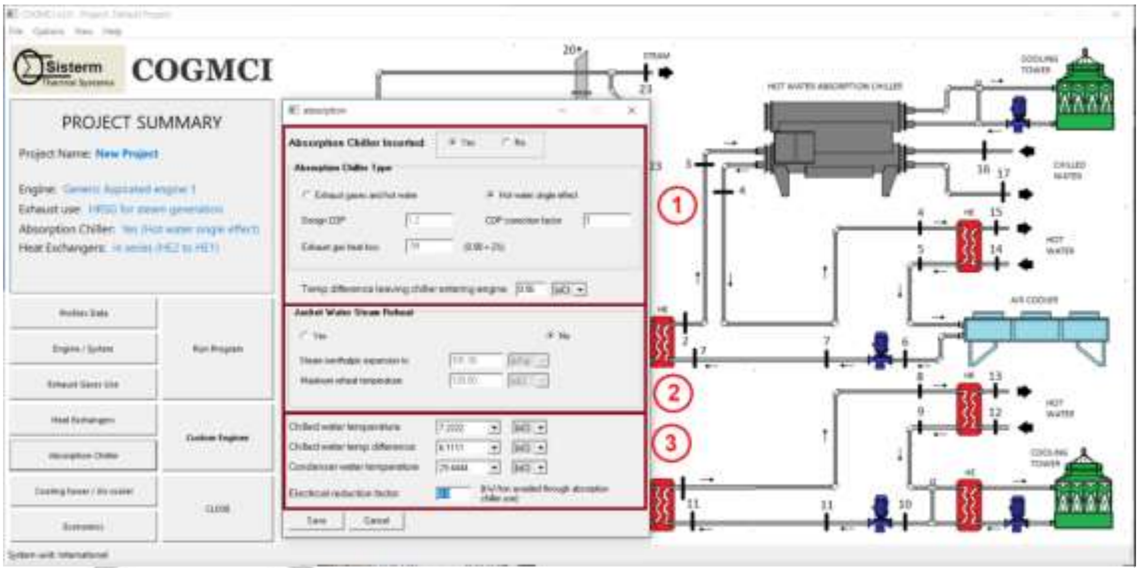
Upload from clipboard using the button bellow each of the profiles.

f) ABSORPTION CHILLER SCREEN

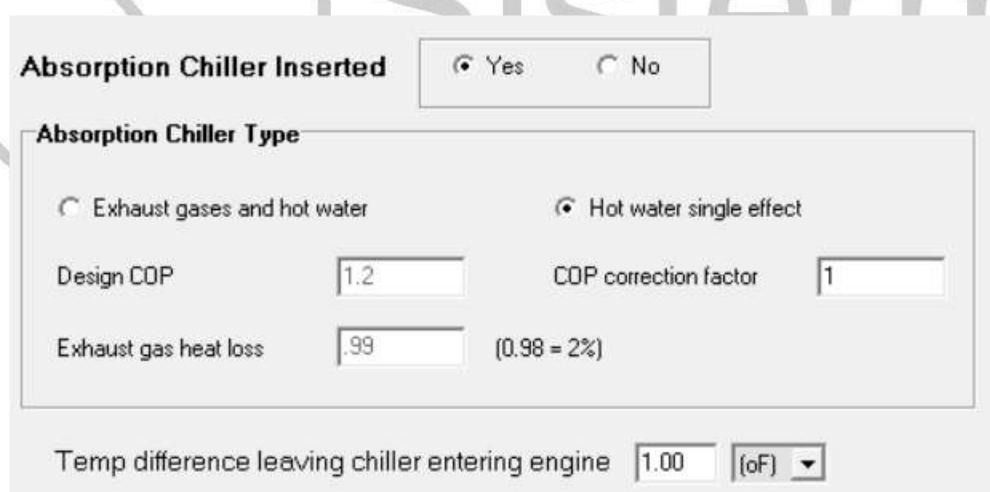


At the absorption chiller screen the user can define some absorption chiller parameters inserted at the cogeneration / trigeneration system.

The screen is defined as bellow:



1. ABSORPTION CHIILER DEFINITIONS



Absorption chiller inserted: Define if there is an absorption chiller in the cogeneration / trigeneration system under evaluation.

Absorption chiller type: Define the absorption chiller type. Two options are available:

I) Exhaust gases and hot water absorption chiller (No Exhaust gas heat recovery system must be selected at **d.1).**

II) Hot water single effect absorption chiller.

Design COP: Defines the exhaust gas and hot water absorption chiller coefficient of performance kW (cooling) /kW (heat). This COP is used to predict the absorption chiller performance.

This field is only used for the exhaust gas and hot water absorption chiller.

COP Correction effect: define a COP correction factor for the hot water absorption chiller. The hot water absorption chiller design and performance is simulated based on an absorption chiller manufacturer performance data. The COP of the absorption can be adjusted utilizing this factor, aiming to enable the user to evaluate the cogeneration / trigeneration performance utilizing their absorption chiller manufacturer COP.

This field is only used for the hot water absorption chiller.

Temp difference leaving the chiller and entering the engine: In this field the user defines the temperature difference between FLOW 4 and FLOW 7. When opting to use some energy for the process hot water on HEAT EXCHANGER 1 (HE1) or to reduce the amount of cooling in the absorption chiller it is necessary to limit the energy used in the absorption chiller. In summary it contribute to define a design temperature difference for the primary circuit hot water in the absorption chiller.

2. JACKET WATER REHEAT

When a HRSG is used a surplus steam production (production higher than demand) can occur in some operating hours. The jacket water steam reheat option allow the use of the excedent steam (flow 23) in a heat exchanger that reheat the jacket water being delivered to the hot water absorption chiller.

No: the jacket water is not reheated;

Steam isentropic expansion to: define the pressure of the steam entering the jacket water reheat heat exchanger.

Maximum Reheat temperature: define the maximum jacket water reheat temperature (flow 3). Depending on the amount of surplus steam the jacket water can be reheated above a desired limit, this field puts a limit on the flow 3 temperature.

3. CHILLED WATER DEFINITIONS
Absorption chiller performance is affected by some design and operation parameters, at this section the user should define some absorption chiller data:

Chilled water temperature: Define the chilled water temperature leaving the chiller.

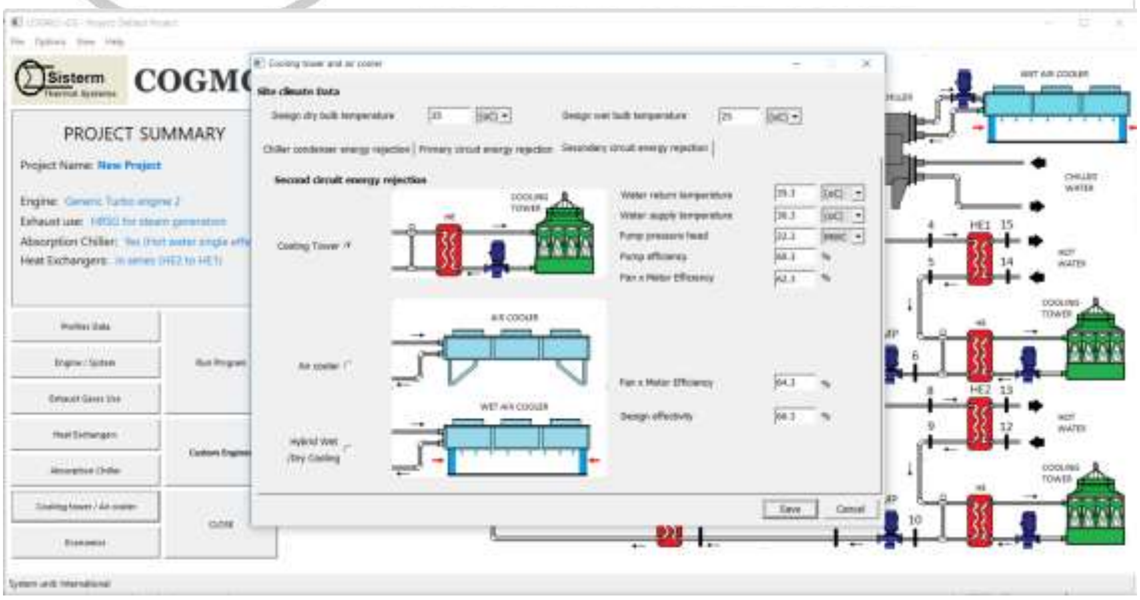
Chilled water temperature difference: define the chilled water temperature difference at the chilled water system.

Condenser water temperature: define the condenser water temperature entering the absorption chiller.

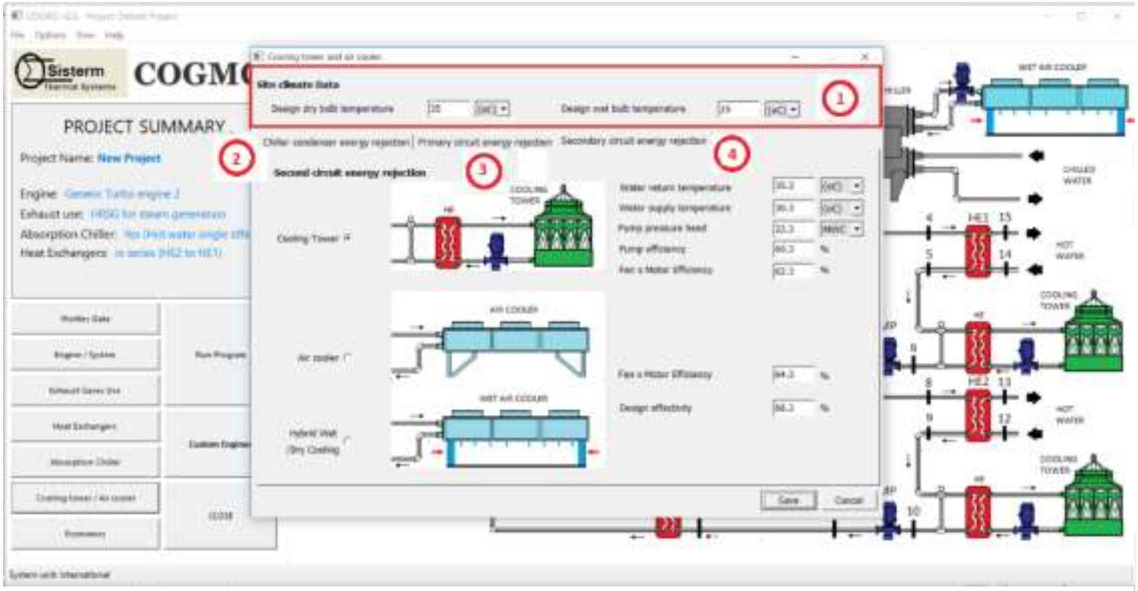
Electrical reduction factor: define the electrical reduction factor due to the avoided electricity consumption at the electrical chiller by the absorption chiller. The absorption chiller use through residual engine energy, reduces the electrical chiller use. In this field the user should define an “Electric reduction factor”. The Electric reduction factor is like the electric chiller COP in kW/RT.

0.8 kW/RT = 4.2 COP 1 kW/RT = 3.5 COP

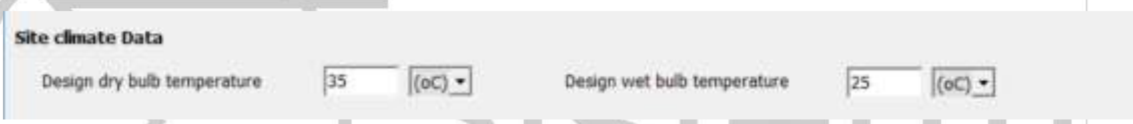
g) COOLING TOWERS AND AIR COOLERS SCREEN



This screen is used to define the energy rejection devices (cooling tower, dry air cooler and wet/dry (hybrid) cooler used in the cogeneration / trigeneration design and simulation analysis. The screen has three different tabs: (i) chiller condenser energy rejection, (ii) primary circuit energy rejection and (iii) secondary circuit energy rejection.

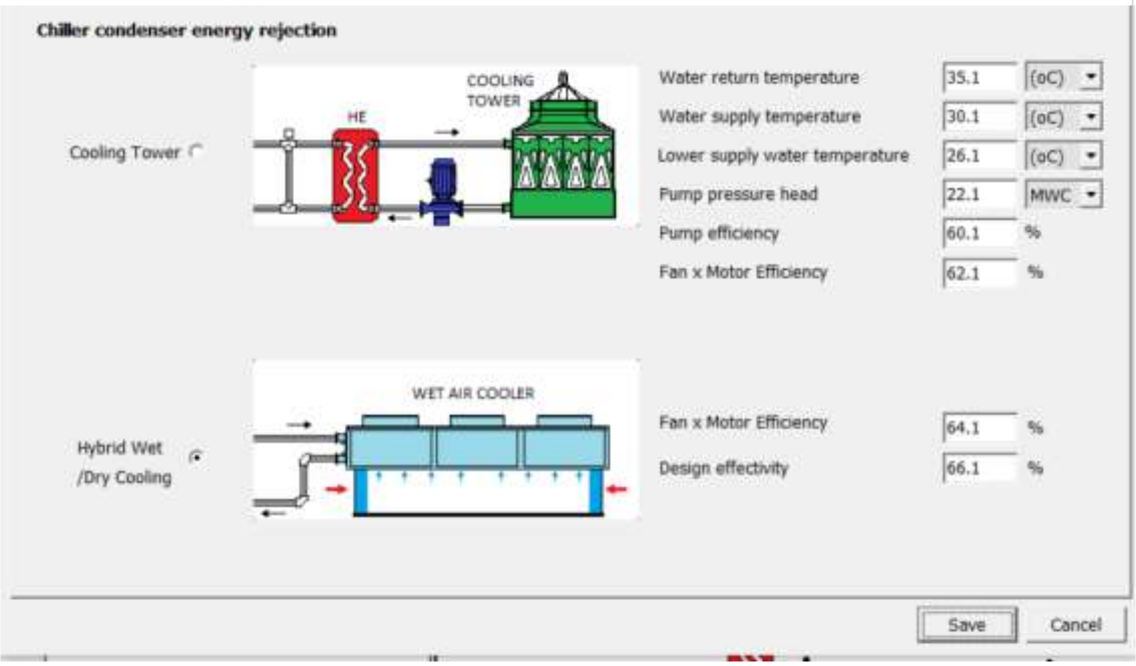


1. SITE CLIMATIC DATA



Design dry bulb temperature
Design wet bulb temperature
Design DBT and WBT is used to design the heat rejection equipment (cooling tower, air cooler or hybrid wet / dry cooler).

2. CHILLER CONDENSER ENERGY REJECTION



For the absorption chiller, two types of energy rejection devices are available:

- COOLING TOWER
- WET/DRY AIR COOLER

Water Return Temperature: define the design water temperature entering the cooling tower or wet/dry air cooler.

Water Supply Temperature: Define the design water temperature leaving the cooling tower or wet/dry air cooler.

Lower Supply Water Temperature: define the lower admissible temperature for the water temperature leaving the cooling tower / wet/dry air cooler. Absorption chillers have better COP and higher capacity when operating with lower water temperature entering the condenser. Cooling tower and wet/dry air coolers are normally selected for maximum energy rejection at critical dry and wet bulb air temperatures. Defining a lower supply water temperature than the design water supply temperature, forces the cooling tower or the wet/dry air cooler to try to reach this temperature, enhancing the absorption chiller COP and capacity. This computational routine is still being implemented – not yet available.

Pump Pressure Head: Define cooling tower pump head pressure.

Pump Efficiency: Define cooling tower pump efficiency.

Fan X Motor Efficiency: define cooling tower fan x electric motor efficiency.

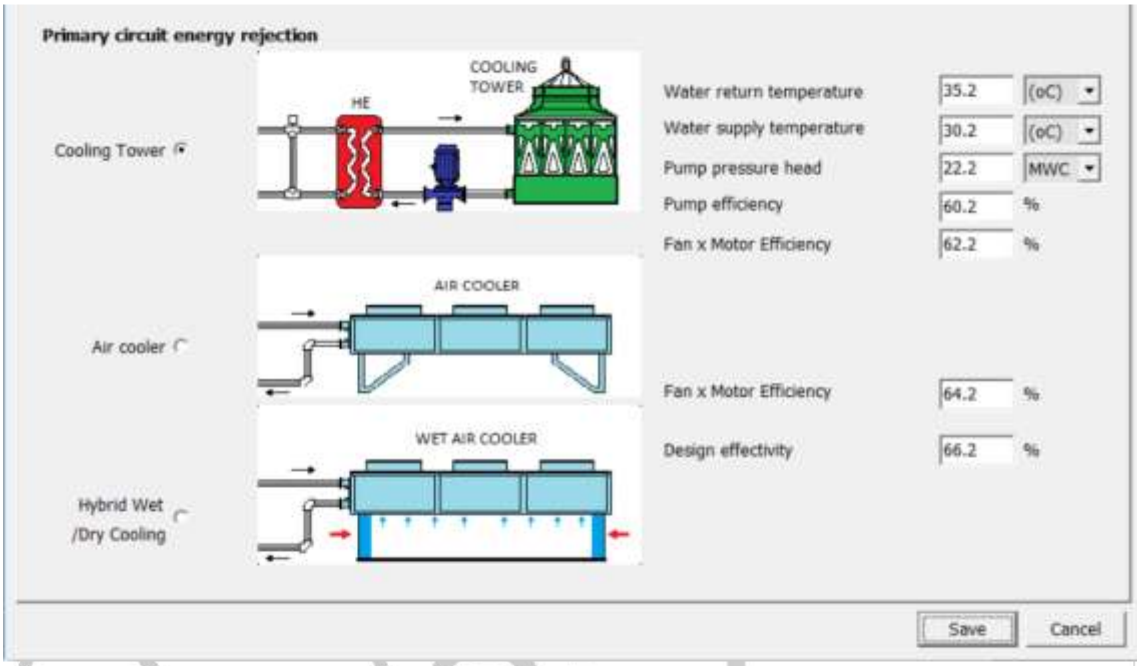
Only used if the cooling tower is selected.

Fan X Motor Efficiency: define wet / dry cooler fan x electric motor efficiency.

Design Effectivity: Define the wet/dry air cooler design effectivity.

Only used if the air cooler or the wet/dry air cooler is selected.

3. PRIMARY CIRCUIT ENERGY REJECTION



For the primary circuit energy, three types of energy rejection devices are available:

- COOLING TOWER
- AIR COOLER
- WET/DRY AIR COOLER

Water Return Temperature: define cooling tower design entering water temperature.

Water Supply Temperature: Define cooling tower design leaving water temperature.

Pump Pressure Head: Define cooling tower pump head pressure.

Pump Efficiency: Define cooling tower pump efficiency.

Fan X Motor Efficiency: define the cooling tower "fan x electric motor" efficiency.

Only used if the cooling tower is selected.

Fan X Motor Efficiency: define the air cooler or wet/dry air cooler "fan x electric motor" efficiency.

Design Effectivity: Define the wet/dry air cooler design effectivity.

Only used if the air cooler or the wet/dry air cooler is selected.

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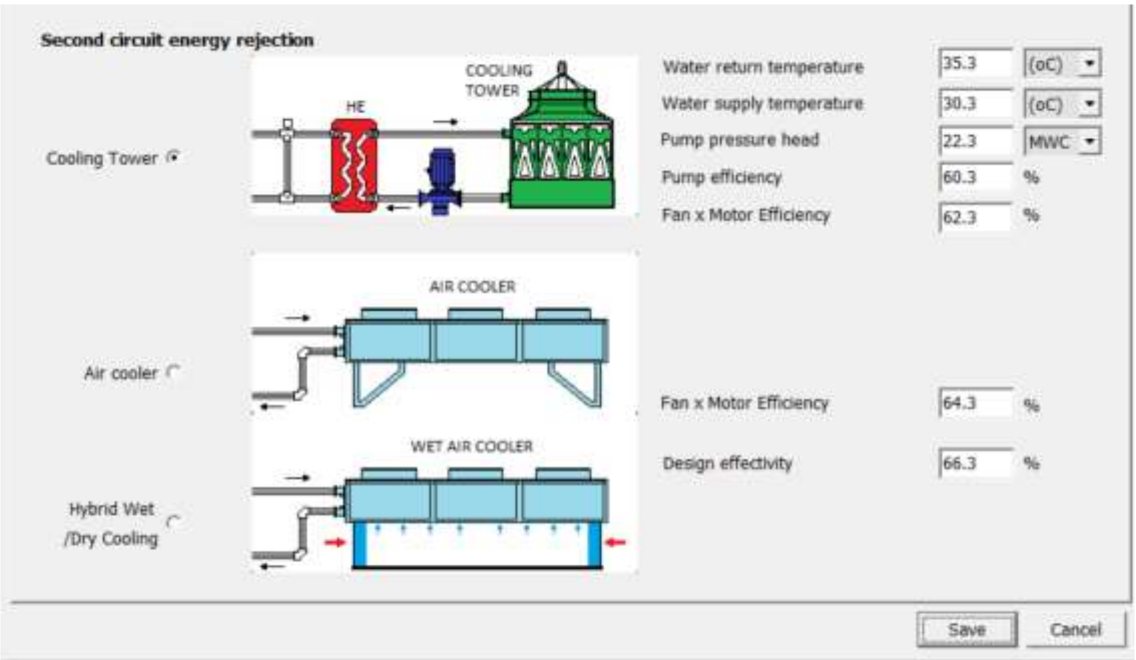
4. SECONDARY CIRCUIT ENERGY REJECTION



For the secondary circuit energy, three types of energy rejection devices are available:

- COOLING TOWER
- AIR COOLER
- WET/DRY AIR COOLER

Water Return Temperature: define cooling tower design entering water temperature.

Water Supply Temperature: define cooling tower design leaving water temperature.

Pump Pressure Head: Define cooling tower pump head pressure.

Pump Efficiency: Define cooling tower pump efficiency.

Fan X Motor Efficiency: define the cooling tower “fan x electric motor” efficiency.

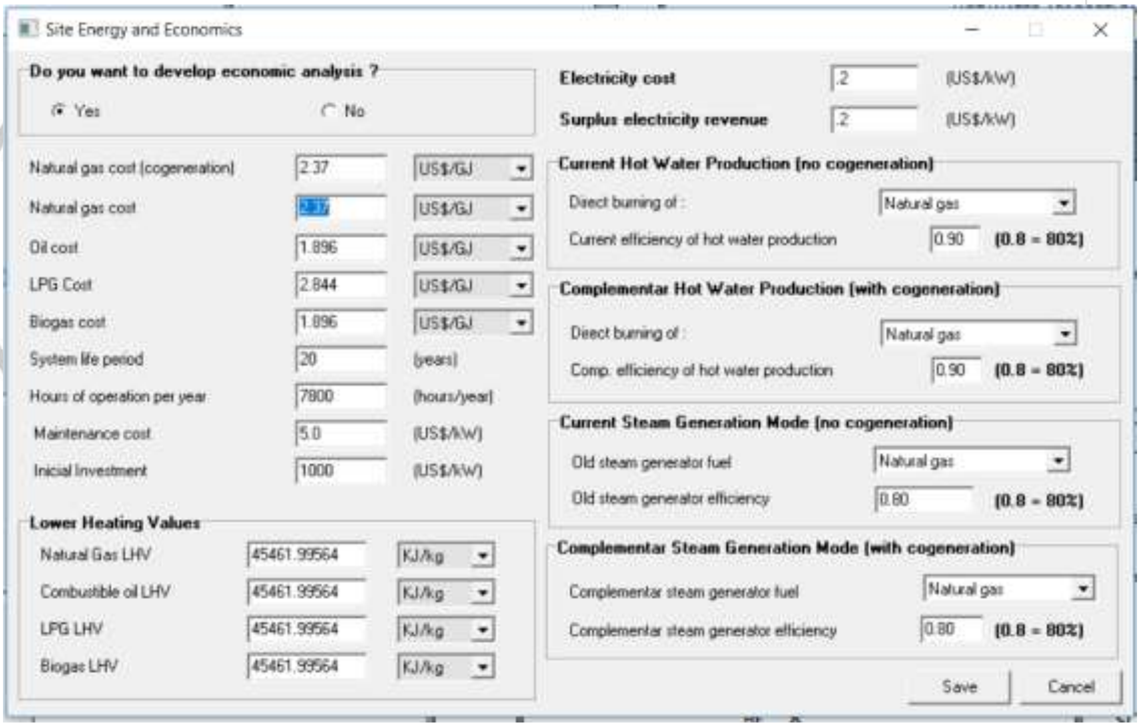
Only used if the cooling tower is selected.

Fan X Motor Efficiency: define the air cooler or wet/dry air cooler "fan x electric motor" efficiency.

Design Effectivity: Define the wet/dry air cooler design effectivity.

Only used if the air cooler or the wet/dry air cooler is selected.

h) ECONOMIC SCREEN



At the economic screen the user should define the economics parameters that are utilized to calculate the NPV and Payback of the cogeneration / trigeneration system under evaluation. The economic analysis is developed as a typical analysis and doesn't take into account particularities of your energy market. Be sure to check your local rules.

Do you want to develop an economic analysis?

Yes: run the economic analysis.

No: no economic analysis.

Natural gas cost (cogeneration): define cogeneration / trigeneration natural gas cost.

Natural gas cost: define natural gas cost for hot water and steam production.

Oil cost: define oil cost.

LPG cost: define liquified petroleum gas cost.

Biogas cost: define biogas cost.

System life period: define the system life period in years.

Hours of operation per year: define the number of hours the cogeneration / trigeneration system is expected to operate (hours per year).

Maintenance cost: define the cogeneration / trigeneration maintenance cost (U$/kW).

Initial investment: define the cogeneration / trigeneration initial investment (U$).

Natural gas LHV: define the natural gas lower heating value.

Combustible oil LHV: define the combustible oil lower heating value.

LPG LHV: define the LPG lower heating value.

Biogas LHV: define the biogas lower heating value.

Electricity cost: define the grid electricity price (U$/kW)

Surplus electricity revenue: define the surplus electricity revenue price (U$/kW)

Current hot water production (no cogeneration): define data of your current hot water production.

Direct burning of: natural gas, combustible oil, LPG or biogas.

Actual efficiency of hot water production.

Complementary hot water production (with cogeneration): define data of your complementary hot water production.

Direct burning of: natural gas, combustible oil, LPG or biogas.

Complementary efficiency of hot water production.

Current steam generation production (no cogeneration): define data of your current steam production.

Direct burning of: natural gas, combustible oil, LPG or biogas.

Actual efficiency of steam production.

Complementary steam generation production (with cogeneration): define data of your complementary hot water production.

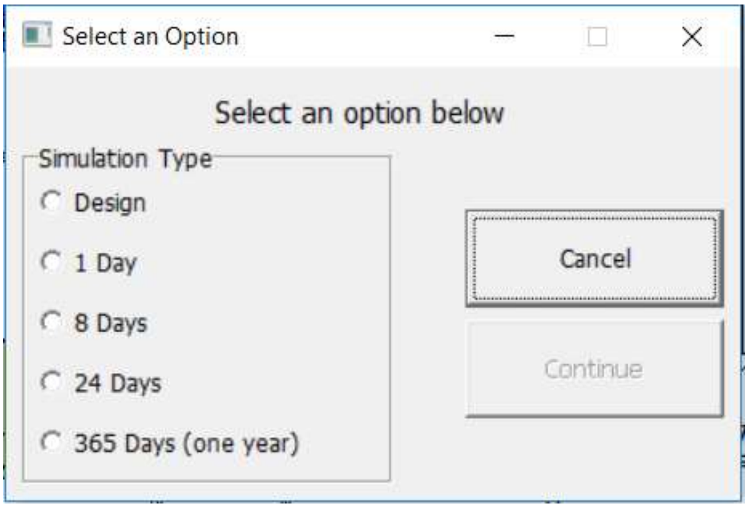
Direct burning of: natural gas, combustible oil, LPG or biogas.

Complementary steam production efficiency.

i) RUN PROGRAM

At this screen the user defines what type of analysis to run:

(i) **design analysis:** the energy balance of your selected engine and selected equipment at design condition (engine full load) is developed. This analysis is very useful to evaluate your design data and how your system operates at full load. We suggest the user to carefully evaluate the design condition and modify design data (if necessary) prior to follow to the simulation analysis.
(ii) **one day analysis:** the design is developed and a 24 hours simulation of the designed system attending the energy demands profiles at the site weather profiles is performed.
(iii) **8 days analysis:** the design is developed and a 192 hours simulation of the designed system attending the energy demands profiles at the site weather profiles is performed.
(iv) **24 days analysis:** the design is developed and a 576 hours simulation of the designed system attending the energy demands profiles at the site weather profiles is performed.
(v) **365 days analysis:** the design is developed and a 8760 hours simulation of the designed system attending the energy demands profiles at the site weather profiles is performed.



j) CUSTOM ENGINES

The CUSTON ENGINES screen allows creating a new engine not yet inserted into the system by inputting the engine performance equations in the COGMCI software.

The engine performance equations are constructed utilizing the engine real operating data provided by your engine supplier. Ask the engine operational data for your engine supplier sales service.

Analyzing the Engine Technical Data: using the engine performance data at full and part load it is possible to build equations (polynomial regression) to be inserted in the COGMCI software and use them to design and simulate an engine cogeneration / trigeneration system.

The engine supplier normally defines the engine performance at some engine loads, as demonstrated in the next figure. At this case the engine supplier defined engine load performance at 50, 75 and 100% load.

0.01 Technical Data (at module)

Data at:				Full load	Part Load	
Fuel gas LHV		kWh/Nm³		9.5		
				100%	75%	50%
Energy input		kW	[2]	1,662	1,291	920
Gas volume		Nm³/h	*)	175	136	97
Mechanical output		kW	[1]	657	493	329
Electrical output		kW el.	[4]	633	473	312
Recoverable thermal output						
~ Intercooler 1st stage		kW		77	32	1
~ Lube oil		kW		84	74	63
~ Jacket water		kW		220	200	177
~ Exhaust gas cooled to 120 °C		kW		434	340	240
Total recoverable thermal output		kW	[5]	815	646	481
Total output generated		kW total		1,448	1,118	792
Heat to be dissipated						
~ Intercooler 2nd stage		kW	[9]	54	42	26
~ Lube oil		kW		~	~	~
~ Surface heat	ca.	kW	[7]	68	~	~
Spec. fuel consumption of engine electric		kWh/kWel.h	[2]	2.62	2.73	2.95
Spec. fuel consumption of engine		kWh/kWh	[2]	2.53	2.62	2.80
Lube oil consumption	ca.	kg/h	[3]	0.20	~	~
Electrical efficiency		%		38.1%	36.6%	33.9%
Thermal efficiency		%		49.0%	50.0%	52.2%
Total efficiency		%	[6]	87.1%	86.6%	86.1%
Hot water circuit:						
Forward temperature		°C		100.0	93.8	87.7
Return temperature		°C		70.0	70.0	70.0
Hot water flow rate		m³/h		23.3	23.3	23.3

The common method to build equations connecting data points is the polynomial regression analysis. Some commercial software can be used. In this example the *Microsoft Excel* is used.

Transfer the data to a spreadsheet, check if the exhaust gas energy needs correction. In this example the exhaust gas energy is given assuming it leaves the HEAT EXCHANGER at 120 °C, it should be corrected as if the exhaust gas would be cooled to the engine test condition (25 °C).

Data Table From Engine Catalogs				
Load (%)		50	75	100
Eletrical Power	kW	400	600	800
Engine Jacket Water Heat	kW	246	309	385
Intercooler LT Heat	kW	21	35	58
Lube Oil Heat	kW			
Exhaust Heat With Temp. After Heat Exchanger	kW	302	409	502
Exhaust Heat Between 120 and 25°C	kW	64	91	118
Exhaust Heat Corrected	kW	366	500	620
Exaust Temperature	ºC	528	508	488
Exhaust Mass Flow, Wet	kg/h	2397	3423	4434
Combustion Mass Air Flow	kg/h	2316	3309	4288
Radiation Heat Engine	kW	15	23	30
Radiation Heat Generator	kW	18	21	26
Fuel Consuption	kW	1069	1493	1922
Electrical Efficiency	%	37,4	40,2	41,6
Thermal Efficiency	%	51,2	48,1	46,1
Total Efficiency	%	88,6	88,3	87,7

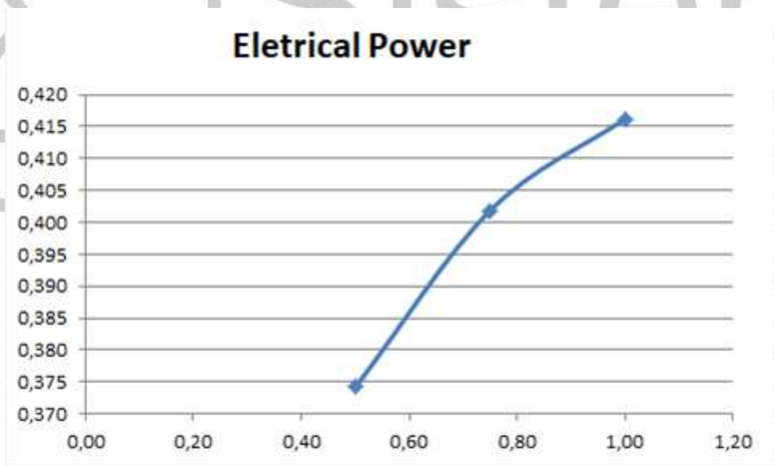
By dividing the data by the fuel consumption, transform the Electrical Power COP, Engine Jacket Water energy, Intercooler LT energy, Lube oil Heat and Exhaust gas energy in percentage:

Data Table From Engine Catalogs						Engine Percentage Data		
Load (%)		50	75	100		0,50	0,75	1,00
Eletrical Power	kW	400	600	800		=D4/D$16	0,402	0,416
Engine Jacket Water Heat	kW	246	309	385		0,230	0,207	0,200
Intercooler LT Heat	kW	21	35	58		0,020	0,023	0,030
Lube Oil Heat	kW							
Exhaust Heat With Temp. After Heat Exchanger	kW	302	409	502		0,283	0,274	0,261
Exhaust Heat Between 120 and 25°C	kW	64	91	118				
Exhaust Heat Corrected	kW	366	500	620		0,342	0,335	0,322
Exaust Temperature	ºC	528	508	488		528	508	488
Exhaust Mass Flow, Wet	kg/h	2397	3423	4434		2397	3423	4434
Combustion Mass Air Flow	kg/h	2316	3309	4288				
Radiation Heat Engine	kW	15	23	30		0,014	0,015	0,016
Radiation Heat Generator	kW	18	21	26		0,017	0,014	0,014
Fuel Consuption	kW	1069	1493	1922	Sum	0,997	0,997	0,998

Note: Fuel consumption in the table is the sum of the other data. Engine suppliers also defines the fuel consumption as energy input.

Data Table From Engine Catalogs		Engine Percentage Data		
Load (%)		0,50	0,75	1,00
Eletrical Power	kW	0,374	0,402	0,416
Engine Jacket Water Heat	kW	0,230	0,207	0,200
Intercooler LT Heat	kW	0,020	0,023	0,030
Lube Oil Heat	kW			
Exhaust Heat With Temp. After Heat Exchanger	kW	0,283	0,274	0,261
Exhaust Heat Between 120 and 25°C	kW			
Exhaust Heat Corrected	kW	0,342	0,335	0,322
Exaust Temperature	ºC	528	508	488
Exhaust Mass Flow, Wet	kg/h	2397	3423	4434
Combustion Mass Air Flow	kg/h			
Radiation Heat Engine	kW	0,014	0,015	0,016
Radiation Heat Generator	kW	0,017	0,014	0,014
Fuel Consuption	kW	0,997	0,997	0,998

By creating a dispersion graph with the “Load percentage” on the X-axis and adding the trend line, a polynomial formula that represents the engine electric power is created:



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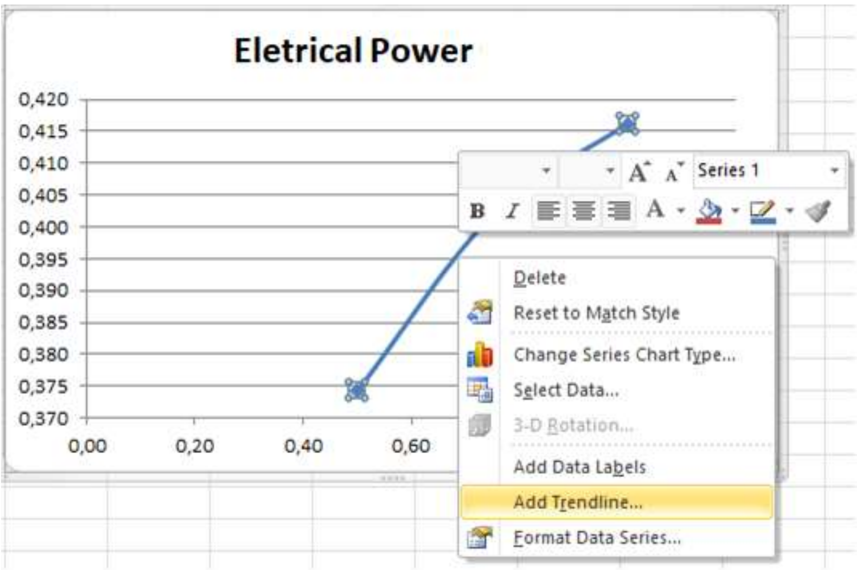
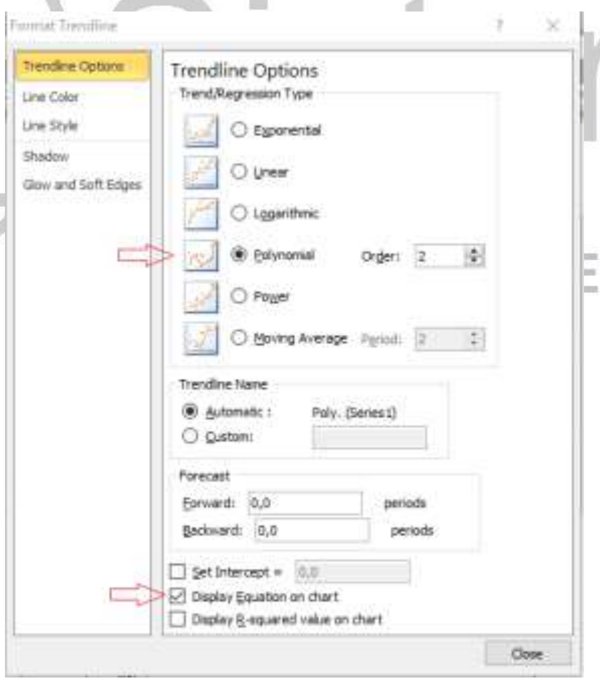
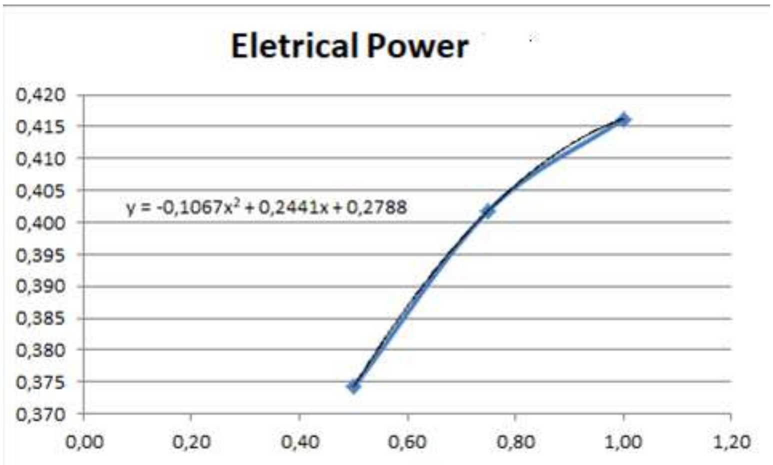


Excel offers various types of approaches, select the polynomial approach and select to show the equation on the chart:





Verify the formula on the spread sheet, some approximation (small errors) is expected:

Data Table From Engine Catalogs		Engine Percentage Data			Tabela de Verificação de formulas			
Load (%)		0,50	0,75	1,00	Formulas	0,50	0,75	1,00
Eletrical Power	kW	0,374	0,402	0,416	$y = -0,1067x^2 + 0,2441x + 0,2788$	0,374	0,402	0,416
Engine Jacket Water Heat	kW	0,230	0,207	0,200	$y = 0,132x^2 - 0,2576x + 0,3259$	0,230	0,207	0,200
Intercooler LT Heat	kW	0,020	0,023	0,030	$y = 0,0235x^2 - 0,0142x + 0,0209$	0,020	0,023	0,030
Lube Oil Heat	kW							
Exhaust Heat With Temp. After Heat Exchanger	kW	0,283	0,274	0,261				
Exhaust Heat Between 120 and 25°C	kW							
Exhaust Heat Corrected	kW	0,342	0,335	0,322	$y = -0,0413x^2 + 0,0227x + 0,341$	0,342	0,335	0,322
Exaust Temperature	°C	528	508	488	$y = -80x + 568$	528	508	488
Exhaust Mass Flow, Wet	kg/h	2397	3423	4434	$y = -120x^2 + 4254x + 300$	2397	3423	4434
Combustion Mass Air Flow	kg/h							
Radiation Heat Engine	kW	0,014	0,015	0,016	$y = -0,0094x^2 + 0,0172x + 0,0078$	0,014	0,015	0,016
Radiation Heat Generator	kW	0,017	0,014	0,014	$y = 0,0179x^2 - 0,0334x + 0,0291$	0,017	0,014	0,014
Fuel Consuption	kW	0,997	0,997	0,998	Sum	0,997	0,997	0,998

On the CUSTON ENGINE SCREEN, equations are inputted in the designed areas and are described as follows:

$$Eqt = A0 + A1.x + A2.x^2 + A3.x^3 + A4.x^4$$

- A0 – constant
- A1 – X constant
- A2 – X^2 constant
- A3 – X^3 constant
- A4 – X^4 constant

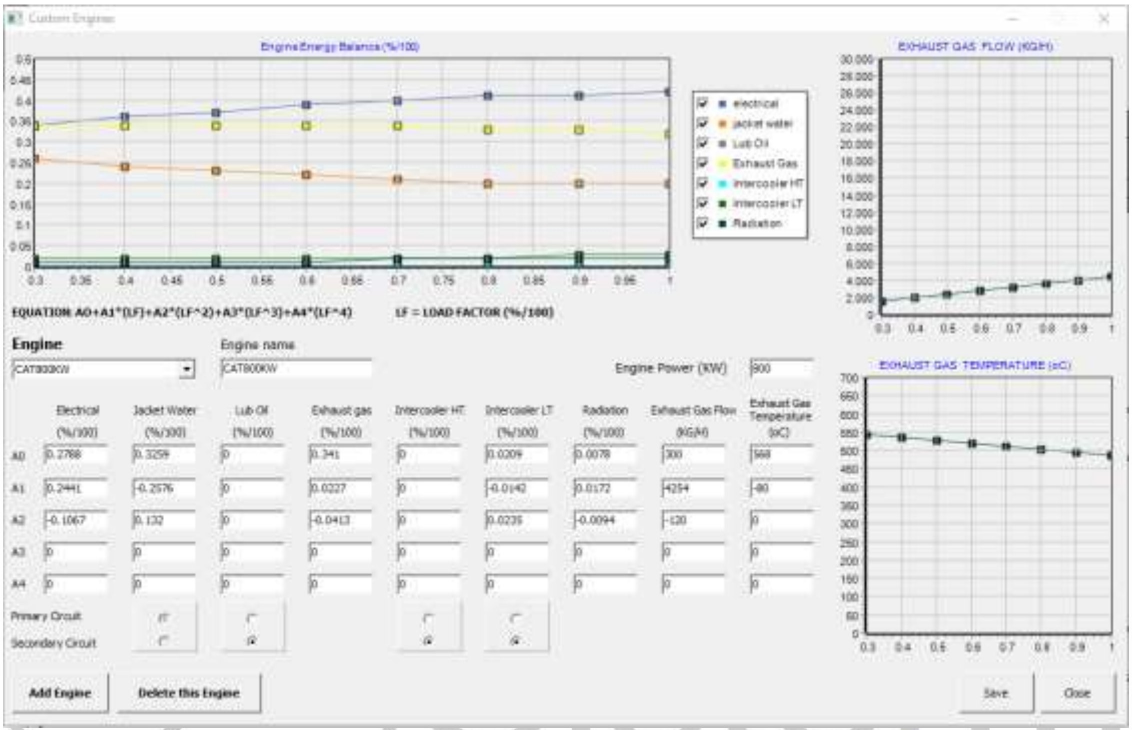
Insert the A0, A1, A2, A3 and A4 values at each correspondent field.

Define a name for the engine in the field “ENGINE NAME”.

If the engine doesn’t have any recoverable energy in one of the listed options (for example in the low temperature intercooler), then just fill the fields with 0.

Engine part load used to build the engine performance curves, must be in the decimal format, it means 50% load is 0.5.

Use the ADD ENGINE BUTTON to save the engine to the Custom ENGINE models to use it in your project. The saved engine can be selected in the ENGINE / SYSTEM SCREEN.



The final screen shows the energy power balance chart of the created engine, the exhaust gas flow and temperature. It's possible to select if the Lube oil, HT intercooler and LT intercooler are in the primary or secondary circuit;

k) CLOSE

The close button is used to exit the COGMCI software.

l) ADDITIONAL REFERENCES DOCUMENTS

a) COGMCI ANALYSIS
b) COGMCI CONFIGURAIONS
c) COGMCI WEATHER FILE CONVERTER
d) COGMCI EXAMPLES
e) COGMCI FIRST PROJECT
f) COGMCI RESULTS REPORT

m) COGMCI ADDITIONAL INFORMATION

a) The main screen figure was created with a defined pixel number. Lower pixel monitors cannot display the whole figure.

COGMCI is a software developed by Sisterm Thermal Systems – Campinas – SP - Brazil
www.sisterm.com.br sisterm@sisterm.com.br Phone: +55 (19) 3579-1505

b) Microsoft Excel is used to display the results. The developer recommends using the software COGMCI at a computer with Microsoft Excel.

c) Some examples (cmi and cmidat files) are available in the software COGMCI examples directory. Try to build your own cases modifying the existing examples. The developer recommends creating a directory for your cases outside the software main directory.

d) Engine load is limited to 50%.

e) Building your new cases using an existing cmi file can avoid problems with unused inputs that are checked by some computational routine. That means that all the fields in the input screens needs to be filled with acceptable values.

f) up to 20 custom engines can be created in the COGMCI professional version.

december / 2019

Sisterm

COGMCI SOFTWARE